Lund University Master of Science in

International Development and Management

May 2020

LEVERAGING DIGITAL TECHNOLOGIES FOR TRANSITIONS TO CLEAN AND SAFE WATER

A Case Study of Kibera Informal Settlement in Nairobi, Kenya

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Abstract

Inadequate water infrastructural development and high costs of water are few of the many challenges that affect water access in Kibera. Consequently, many alternatives to piped water grew out of necessity to meet the needs of residents. The aim of this thesis is to examine the conditions that have led to poor water provision in Kibera and how transitions to improved water access can be achieved by looking at technologies such as M-maji that seek to improve water access. This thesis seeks to answer, one, how can Kibera achieve a transition towards improved water access? And two, how do users of M-maji perceive this technology for their water needs? The findings of the thesis were analysed using theoretical constructs from transition theory and political ecology. A qualitative case study was carried out in which 26 semi-structured interviews were conducted. Findings from the data indicate that governance failure contributed to the challenges of water access in Kibera, socio-political dynamics that prevented extension of services to residents, and disincentives for households to connect to infrastructure such as high connection fees. Additionally, integration of household technologies like M-maji can contribute to improved water access and ultimately, that different technologies can coexist to achieve transitions to improved water access.

Key words: Water, Kibera, access, transitions, sociotechnical systems, malfunction and disrepair, governance failure, coexistence, mediating technologies, privatisation, archipelagos

Word count: 14,972

Acknowledgements

Writing this thesis was quite challenging, especially at the preliminary stages of designing this study and collecting data. To this regard, I would like to thank Umande Trust for giving me the opportunity to conduct this research, my research assistant, Kelvin for taking me through Kibera to meet respondents, and to the respondents and key informants who took time out of their busy schedules to speak with me.

I would also like to thank my family, friends and fellow LUMIDers for their support throughout this period.

To my supervisor Axel Fredholm, thank you for your support throughout the thesis course and for our one-one sessions which were vital to the success of this thesis.

Lastly, a special thanks to my mother for supporting my studies in Sweden, I am indebted to you.

I cannot thank you all enough!

Contents

Abbreviations

CBO	Community Based Organisation
CDC	Centers for Disease Control and Prevention
GOK	Government of Kenya
ICT	Information and Communications Technology
ISD	Informal Settlements Department
JMP	Joint Monitoring Programme for Water Supply, Sanitation and Hygiene
KES	Kenya shillings
LIAs	Low-income areas
NCWSC	Nairobi City Water and Sewerage Company
NGOs	Non-Governmental Organisations
SMS	Short message service
UNDP	United Nations Development Programme
USSD	Unstructured Supplementary Service Data
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WSUP	Water and Sanitation for the Urban Poor

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1 Introduction

An estimated 2.1 billion people lack access to clean water and more than double this number live without improved sanitary facilities (WHO, 2017). Kibera, the largest urban informal settlement in Africa and one of the most densely populated in the world, grapples with this water and sanitation crisis. Due to its status as an informal settlement Kibera is underserved by public services such as water and sewerage connections, and waste management services. This has led to unhygienic and unsanitary ways of disposing both waste and human excreta (Kimani-Murage & Ngindu, 2007) which lead to ground water contamination and consequently water-borne diseases (ibid). Low infrastructural development forced Kibera residents to seek alternative ways to meet their water needs, majority of which is provided by small-scale private vendors (water vendors). They source their water either from the Nairobi City Water and Sewerage Company (NCWSC), boreholes or a variety of other sources (UNDP, 2004). Many of the vendors are known to operate illegally often using poor quality pipes to connect to the main water network (ibid). These pipes are prone to bursts and leaks that exacerbate the risk of water contamination. Not to mention the presence of cartels who control the water supply in Kibera selling water of unreliable quality to the residents at exorbitant prices (WSUP, 2018).

These are some of the factors that make up the water regime of Kibera. Although NGOs and government partnerships have provided basic services, they are not to the scale required for the large population living in this area. Rapid urbanisation coupled with poor economic development has led to an increased number of people living in informal settlements in Kenya (Mutisya & Yarime, 2011). In 2014, 56 percent of the urban population in Kenya lived in informal settlements. With urban population growth projected to reach nearly 46 percent of the country's total population by 2030 (NCPD, 2018), it is becoming more difficult to connect informal settlements to public services. To fill this gap, many NGOs and community-based organisations have come up with different initiatives to meet the needs of residents of informal settlements (Meredith & MacDonald, 2017) many of which are technological innovations.

Several technologies have been deployed to improve the living standards of informal settlements many of which are ICT based. Mobile-based querying, consumption tracking and payment platforms have flooded the market. Such innovations include Majivoice, Jisomee Mita, and Token Water Initiative, large-scale projects supported by government agencies. However, small-scale technologies have made their way into the urban water regime (Bell, 2015). An example is M-maji by Umande Trust, a mobile-based solution in Kibera that

provided water vendors a platform to advertise their services and provided customers real time information of the availability, cost, and nearest location to a water vendor. Although the application only operated for two years, it had an impact and implications on its users.

1.1 Aim and research questions

Therefore, the aim of this thesis is to examine the conditions that have led to inadequate water access in Kibera and how transitions to improved water access can be achieved by looking at technologies that seek to improve water access to Kibera residents. By taking the case of M-maji, this thesis seeks to understand the perceptions of Kibera residents towards technologies that purport to improve their quality of life. This research draws on the theoretical constructs of transition theory and political ecology to examine the research questions in detail. The study will address the following research questions:

1. How can the water regime in Kibera achieve a transition towards improved water access?
    a) What factors cause inadequate access to clean and safe water in Kibera?
2. How do users of M-maji perceive this technology for their water needs?

1.2 De-limitation

It is important to note that this thesis focuses on potable water, hence separates the water regime from the sanitation regime. Although sanitation and hygiene are directly affected by water and vice versa, M-maji was linked to improving access to clean and safe water which aligns with the water supply regime that this thesis discusses.

1.3 Background

Safe drinking water is considered a basic human right. The Constitution of Kenya: Bill of Rights- Article 43 (b) and (d) on economic and social rights declares that every person has the right to accessible and adequate housing, reasonable standards of sanitation; and to clean and safe water in adequate quantities respectively (KLRC, 2019). The Sustainable Development Goals address the need to improve access to clean drinking water and hygiene for all. This is captured in goal 4 which advocates for the equal rights to economic as well as basic services for all. Goal 6 particularly addresses the issue of equitable access to clean water, sanitation and hygiene: “to ensure availability and sustainable management of water and sanitation for all” with target 6.2 paying special attention to the needs of women, girls and those in vulnerable situations (United Nations, n.d.).

In 2017, 6.3 percent of the Kenyan urban population used surface water for their drinking needs while 4.7 percent used unimproved sources of water. An estimated 19.3 percent used unimproved sanitary facilities, 1.9 percent practiced open defecation and 28.7 percent of the urban population lacked access to handwashing facilities (JMP, n.d.).

Poor households and communities are the most affected populations as these services are too expensive for them to afford. Contaminated water, poor sanitation and hygiene are associated with water-borne diseases that make up the burden of disease that contributes to high mortality rates in children under-5 years in sub-Saharan Africa (Skolnik, 2016). Of these, diarrhoeal diseases are the most common and often the deadliest when left untreated. In 2015, Kenya recorded 72,000 deaths of under-5 children relating to diarrhoeal diseases (WHO, 2016).

Water access in Kibera- case study site

The UN Habitat estimates that the total population of Kibera ranges from 500,000 to 700,000 inhabitants (UN Habitat, n.d.). It is densely populated with residents living in semi-permanent structures typically measuring 10 by 10 metres (Wamuchiru, 2015). Kibera also sits on public land thus residents have no secure land tenure (Mutisya & Yarime, 2011), this makes it difficult for residents to invest in water and sanitation infrastructure for fear of government resettlement (van Welie, et al., 2018).

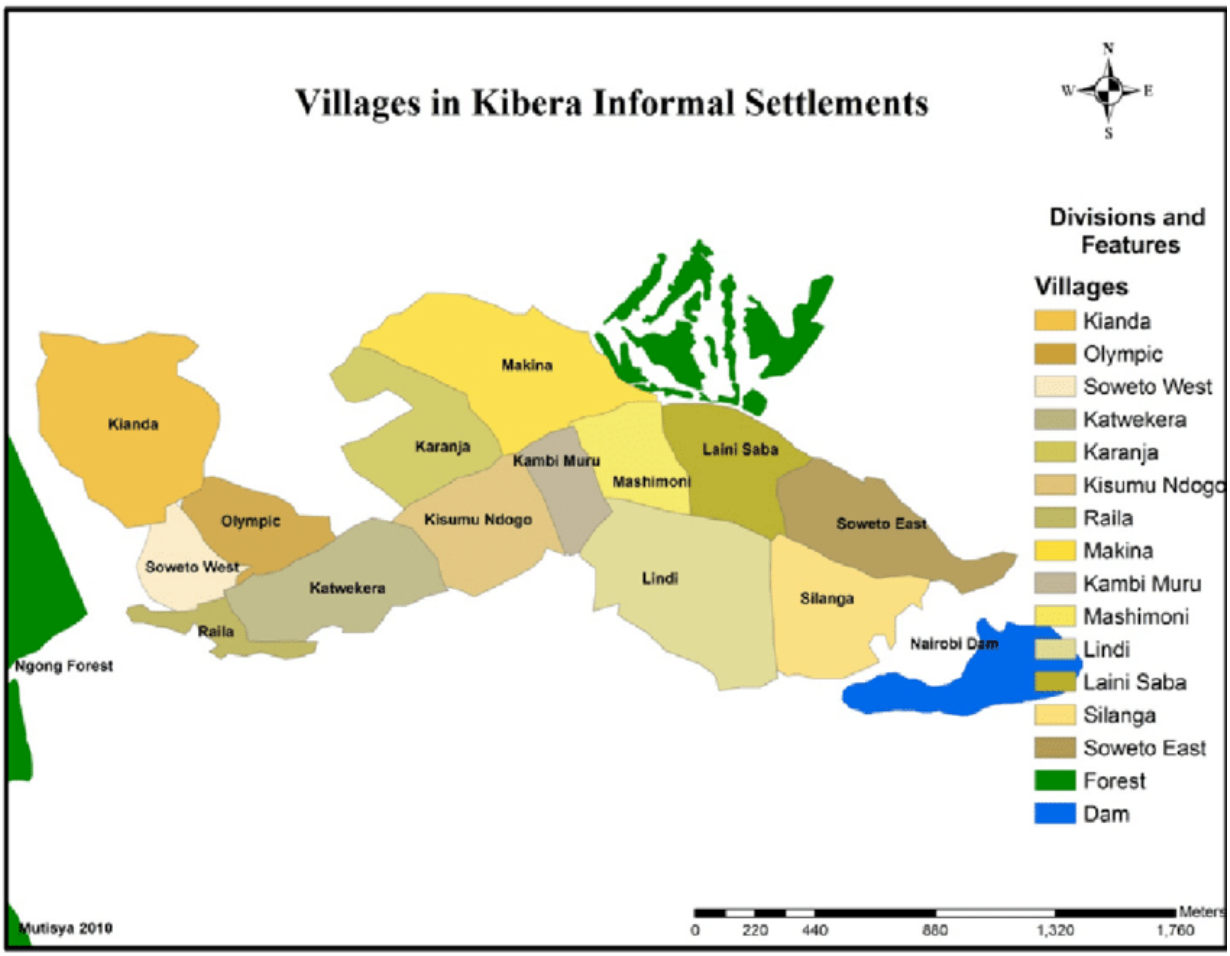

Figure 1: *Map of Kibera informal settlement (Mutisya & Yarime, 2011, p. 203).*

In 1963 the Kenyan government gazetted Kibera as an illegal settlement (Mutisya & Yarime, 2011). Subsequent public policies ignored the issues in the settlement, particularly excluding the informal settlements from city planning and budgeting processes (Amnesty International, 2009). This was further exacerbated by the 2002 Water Act which moved provision of water services away from the government and into private hands making water more expensive in Kibera than in the formal areas of the city (Mutisya & Yarime, 2011). Consequently, residents turned to a variety of alternative sources to meet their water needs. These included, shallow wells, rivers, water vendors, bottled water, water trucks and illegal connections to networked water (Bakker, 2010). With the living conditions ever so deplorable, NGOs, religious organisations, and other community-based organisations (CBOs) partnered with communities to provide water services that city officials neglected (Mutisya & Yarime, 2011; Wamuchiru, 2015). It was only until the recognition of informal settlements in government policies many years later that water and sewerage connections in these settlements became a priority (Guma,

et al., 2019). This was further reinforced by the Constitution of Kenya 2010 that recognised the right to basic services such as water (KLRC, 2019).

In 2009, Nairobi's main water service provider, the Nairobi City Water and Sewerage Company (NCWSC) created an Informal Settlements Department (ISD) within the company to directly handle provision of water and sewerage services to all informal settlements in Nairobi (WSUP, 2018). The main purpose for its establishment was to extend services to informal settlements that were largely ignored and to reduce high amounts of non-revenue water,[1] one of the major challenges that plague water provision in the settlements, and subsequently increase revenue to the company (WSUP, 2018).

According to NCWSC less than 60 percent of Nairobi residents were legally connected to the city's water network and only 40 percent receive a 24-hour supply of water. The rest are forced to find alternative means of accessing water (WSUP, 2018). Consequently, illegal vendors (cartels) who are not registered with the utility company have taken advantage of the situation in informal settlements (Amnesty International, 2009; von Heland, et al., 2015). In Kibera the water cartels collude with rogue utility officials to create artificial shortages, hiking the prices up for rapid profits (M-maji, n.d.). The ordinary price of water in Kibera varies from 2-5 KES per 20 litre jerrycan, almost 12.5 times what metered customers pay for (von Heland, et al., 2015). In times of shortages, these water prices can shoot up to 20 times the cost of metered water (Amnesty International, 2009).

Rise of innovations- scale and impact

Information and communication technologies are increasingly becoming popular in urban development in Africa (Guma, 2019). More so, with the use of telecommunications such as mobile and wireless services to boost water service delivery in cities. Mobile payments, mobile based querying, billing, vending, dispensing, metering and consumption tracking are some of the technologies being deployed by water service providers in Kenya for better service provision (Guma, 2019). The Integrated Urban Development Master Plan for 2014-2030, outlines the critical importance of ICT for efficient, effective and transparent urban service provision in Nairobi. Mobile payment methods such as Mpesa are the most common way to pay for water in the city. 46.6 million Kenyans have active mobile subscriptions with approximately 24 million Kenyans actively transacting with Mpesa (Tanui, 2018).

[1] Water that is produced but is lost or unaccounted for (Kingdom, et al., 2016).

The NCWSC is increasingly using digital technologies to improve management and service delivery to its customers and hopes to use these innovations to tap into underserved populations in the city (Guma, et al., 2019). Jisomee Mita and Majivoice are two examples of such technologies. The former is a mobile based application that enables water customers to send their own meter readings, query, receive current water bills and pay using mobile money (World Bank, 2015). The latter is an ICT based initiative of the Water Services Regulatory Board (WASREB) that enables water customers to voice their complaints, concerns, feedback and comments through SMS or internet and receive timely feedback on these issues from the water company (WASREB, n.d.).

2 Literature Review

2.1 Privatisation of water

Privatisation of water in developing countries[2] was a process of neo-liberal ideas promoted by the Bretton Woods Institutions through the structural adjustment policies imposed on these countries. The World Bank supported the commodification[3] of utilities such as water by providing private companies with water-related loans (Paul, 2016). Privatisation was considered a solution to the limitations of government services with the assumption that private companies are expected to be more efficient and provide cost-effective results (Oosterveer & Spaargaren, 2010). Suleiman (2016) describes the commodification of water by defining the term "economic good" to mean that "the pricing and provision of water should be based on cost recovery principles, but not on profit-making motivations" (Suleiman, 2016, p. 191).

Swyngedouw (2005) in his analysis of privatisation and dispossession to water, provides a historical account of water management particularly in Europe whose water utilities were publicly managed for some time until the governments transitioned to a new mode of water governance rooted in neo-liberal policies (Swyngedouw, 2005). Similarly, the political economic configurations have since evolved to "institutional arrangements that permit a more business- or market-oriented management that is more in tune with profit-making strategies." (Swyngedouw, 2005, p. 86). Through this pressure to recover full costs of sanitation systems, private companies are forced to seek rents only from high income areas or fully paid services leaving the poor and marginal areas under the responsibility of under-funded local authorities and Community Based Organisations (CBOs) (Oosterveer & Spaargaren, 2010). Thus, this privatisation of the commons as Swyngedouw puts it, has led to 'accumulation by dispossession'[4](Swyngedouw, 2005; see Harvey, 2003). This shift of water from a public good to a commodity has serious implications on "the social and political meaning and the cultural valuation of water" as Swyngedouw, et al. (2002, p. 20) explain.

[2] Developing countries here refers to low- and lower middle-income countries with a GNI per capita lower than $3,995 as per the World Bank's definition. See https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

[3] Commodification here refers "to turning water from a public good into a marketable commodity subject to the principles governing a market economy (regardless of the nature of the ownership of both water and the water companies) and privatisation refers to changing ownership of water infrastructure and/or the management of water services from the public sector to the private sector" (Swyngedouw, et.al, 2002, p.10).

[4] A term coined by David Harvey, it describes the "ways capitalism uses force and theft to rob the world of value—both human beings and nature—in its insatiable quest for profit" (Bailey, 2019).

Social and political power in privatisation of water is encompassed in the quest for money and capital. Political involvement reduces the power of the citizen and turns citizens into water customers rather than citizens entitled to the access of water (Swyngedouw, 2005). In a study by Guma, et al. (2019), Jisomee Mita, a digital water application in Soweto Kayole, Nairobi was promoted as a self-accountability, self- control system and user driven application which citizens could use to read their own water meters and send the information to the water utility company. In reality, it was a top-down, market-based system that promoted cost-efficiency to the water utility company by reducing the number of staff and outsourcing the work to the citizens.

In the human rights discourse, authors like Baer and Gerlak (2015), discuss how the human right to water and sanitation (HRtWS) is open to interpretation by international frameworks that support and implement this right. On one hand, it can be interpreted as the fulfilment of basic needs while another interpretation focuses on the freedoms and entitlements of citizens such as "freedom from arbitrary disconnection and contamination of water sources." (Baer & Gerlak, 2015, p.1529). According to Baer and Gerlak (2015), the human right to water does not regulate how public and private companies provide water. It does not provide guidance to these entities, hence, can be easily marketized as a commodity. Taking the first interpretation of the human right to water as the fulfilment of basic needs, neo-liberal policies encourage market-oriented solutions to the access to clean water.

Suleiman (2016) challenges the rights-based approach to water by approaching the matter through an ethical lens; looking at people not as water consumers but as water citizens (Priscoli, 2004). The view of water users as water buyers and consumers instead of citizens, and water as a private commodity instead of a communal and public good resulted in serious social and environmental consequences (Suleiman, 2016). Bond (2010) proposes moving away from the rights language towards a 'commons' strategy[5]. By holding water communally, there is better participation in the use and access to it. Suleiman highlights the need to examine what is ethical and moral and points out that water access to low-income communities has nothing to do with affordability. If affordability were the concern, then illegal water vendors would not be able to sell water to low-income urban residents who end up paying more than affluent residents (Bond, 2010; Suleiman, 2016).

[5] The commons are the access to cultural and natural resources held communally and not privately. https://en.wikipedia.org/wiki/Commons

2.2 Splintered urbanism in developing cities

Many developing cities[6] consist of highly polarised social structures dating back to discriminatory colonial era policies that were carried on by post-colonial governments. This is seen in the heterogeneity of social policies in these cities (Gandy, 2008). In Jakarta, the original water supply systems were intentionally restricted to the 'European urban population' (Bakker, et al., 2008). As a result, different service levels co-exist in the same geographical area (Furlong, 2014; van Welie, et al., 2018). In Nairobi, the main water company offers post-paid metering to high and middle-income areas, as well as tanker truck services in case of water shortages, while low-income areas receive other solutions that cater to their ability to pay for water. These include water kiosks, public standpipes, communal water taps, prepaid water dispensers, tanker trucks, borehole vendors and pushcart vendors (Hailu, et al., 2011).

In Mumbai, Gandy (2008) paints a picture of the stark difference in the geographies of the city. The high-income areas are very wealthy while the low-income areas are very poor. These inequalities are reflected in water service provision. Many parts of the city receive water a few times a week, but a large proportion remains disconnected to the mains. Consequently, 'water mafias' or cartels take advantage of this situation by raising the prices tenfold for communities. Moreover, corrupt city officials collude with private water vendors "who seek to engage in rent-seeking activities by limiting access to piped water supplies for marginal communities" (Gandy, 2008, p.117).

Jaglin (2008) explains this splintering urbanism by looking at the case of Cape Town. The municipal authorities in charge of water provision in the city homogenised their services with the aim to provide equitable services to all. This resulted in investment in water infrastructure and the application of a free water allowance of up to 4.2 kl per month[7] and a progressive tariff to all households that consume above the allowance. However, Jaglin shows how the municipal authorities failed to provide these equitable services. Subsequently, it ended up benefitting the working class more than the poorest households.

Barnes (2009) and Bond (2010) examine how the differences of water metering in Johannesburg furthered the inequalities of water provision in the city. The service model in the

[6] 'Developing cities' here refers to cities in low and lower middle-income economies (van Welie, et al., 2018).
[7] 4.2kl (4200litres) of water per month was insufficient for households. In Johannesburg this allocation was 6kl/month. Johannesburg Water "had based its calculations on a minimum of 25 litres per person per day (the minimum required for human functioning). However, the World Health Organization's (WHO's) current recommendation is 100 litres per person per day as the optimal allocation for health and well-being" (Barnes, 2009, p. 160)

high-income areas differed to the low-income areas. Households in high-income areas were connected to post-paid water meters, meaning they would pay for their water at the end of the month. They also got ample notice before the utility company, Johannesburg Waters would disconnect their meters. This was unlike in the poor areas where households were connected to prepaid water meters and would have to pay before their usage. Moreover, poorer households had their water disconnected as soon as they depleted their credit.

As developing cities rapidly grow, the gap between the urban poor and rich continues to widen. This is seen through different service offerings which can perpetuate inequalities in hybrid systems. The work of authors like Graham and Marvin argue that "policies of economic liberalisation led to widespread network "unbundling" and the "splintering" of the urban experience" (Furlong, 2014, p. 140). Furlong also notes that the thesis on 'splintering urbanism' has limited applicability to the urban experiences in the South (Coutard, 2008 cited in Furlong, 2014). According to Bakker infrastructures in the South could not splinter because they exist in 'archipelagos' and not 'networks' and were not universalised to begin with (Bakker, 2003; Furlong, 2014). According to Jaglin (2008), large homogenous infrastructures fail to represent the current realities of urban residents and fails to "offer realistic visions for sustainability transitions" (van Welie, et al., 2018, p. 260).

2.3 Smart urbanism as a solution?

For a long time, due to the profit-making agenda, private water companies failed to invest in long-term and capital-intensive water infrastructure (Swyngedouw, et al., 2002) in informal settlements. However, over the years, strategic partnerships and technical support from international agencies and organisations have emerged to improve urban development through deployment of technologies that target water provision in low-income areas (Guma, 2019).

Studies have shown that most residents in urban informal settlements are concerned about three important water issues: access, cost and quality (Mutisya & Yarime, 2011; Wamuchiru, 2015). Therefore, governments in their quest to provide clean water to all, are embracing the use of technology for better performance and cost savings. In the findings by Foster, et al., (2012) residents of Kiamumbi in the outskirts of Nairobi readily adopted the use of mobile money for their monthly water utility payments. This was attributed to time and cost savings of making the usual trips to the banks. This new mode of payment benefitted the water service providers as well as customers as traditional modes of transacting typically posed high transaction costs for water customers and utilities.

A study by Heland, et al. (2015) shows that by leveraging the potential of ICT through sensor networks the quality and supply of water can be improved. These sensors work to detect leaks and bursts in the piped connections. Residents are trained to fix pipes and through a mobile application receive automatic notifications for system maintenance. Furlong (2010) supports this argument that the use of simple small technologies (referred to as mediating technologies) can lead to network efficiency and performance. Bell (2015) in her analysis also suggests the use of household devices that can improve water efficiency such as low flow shower heads and other simple technologies like smart water metering.

Although technologies can be useful, Bell (2015) notes the importance of relationships that are formed between technologies and infrastructure. Individuals construct meanings around technology and infrastructure that shape their everyday practices. For innovations like Jisomee Mita in Kenya, the project had its own drawbacks. Lack of participation and accountability on the water utility's side made it difficult for the citizens to trust the system (Guma, et al., 2019).

This literature review illustrates the potential issues that privatisation and commodification of water have contributed to developing countries. By emphasising profits over water rights, water companies have created an inequitable urban waterscape that benefits wealthier areas than poorer ones. Consequently, technological solutions are sought to improve water access in poor areas of the city. Although many studies have been conducted in this field, few have used the theoretical constructs used to analyse this paper and none have been done regarding M-maji. This thesis therefore aims to provide empirical evidence of this technology and advance theory that will contribute to the wider discussion on technologies for water access in Kibera.

3 Theoretical Framework

This study uses a combination of theories and concepts from science and technology studies and political ecology to explain how technologies function in a hybrid and disaggregated system that constitutes the water sector in Kibera. This section starts by introducing theory of sociotechnical transitions, theoretical concepts of these systems and political ecology to explain inequalities that stem from these disaggregated systems. In the end of this section, theories and concepts will be combined into a theoretical framework used to analyse the findings from the study.

3.1 Transition theory: socio-technical systems

The theory of sociotechnical systems falls within the larger literature on transition studies and science and technology studies (Furlong, 2014). Geels and Schot (2010, p.11) describe transitions as "shifts from one socio-technical system to another" which operate "at the level of societal domains or functions" such as energy, transport, agriculture, and water. System changes are labelled 'socio-technical' because they entail new technologies, changes in markets, user practices, policy, and cultural meanings (Geels, 2010).

Sociotechnical transitions take place in three analytical levels (also known as the multi-level perspective): niches, sociotechnical regimes and a sociotechnical landscape (Geels, 2002; 2010; Geels & Schot, 2010). Radical innovations occur at the niche level (Geels, 2002). Social networks here are small and unstable, entrepreneurs and innovators are willing to take a chance while actors must put in more work to uphold the niche. Rules and regulations at this level are characterised by uncertainty and fluidity (Geels & Schot, 2010) unlike sociotechnical regimes which are locked-in and more stable (Geels, 2010). A regime can be defined as the "dominant constellation of structures, culture, and practices in a certain societal system" (Loorbach & Shiroyama, 2016, p.7).

Sociotechnical regimes have larger social networks, regulations, artefacts, markets and infrastructure capsuled in stable configurations and articulated rules (Geels & Schot, 2010). These rules and configurations of these regimes "account for the stability and lock-in of socio-technical systems" (Geels & Schot, 2010, p.20). The sociotechnical landscape is an external structure which contains a set of heterogeneous factors such as economic growth, emigration, cultural and normative values, political coalitions, oil prices and environmental shocks (Geels, 2002). It is depicted as an exogenous environment (Geels & Schot, 2010) because actors cannot

influence these factors in the short run. Thus transitions defined as regime shifts take place "through interacting processes within and between these levels" (Geels, 2010, p. 495).

However, Geels and Schot (2010) explain that transitions do not come about easily because of lock-in mechanisms, for instance government subsidies and policies that favour a specific technology, or if the users of a technology adapt their lifestyles to the technical system. Additionally, these set of rules in the sociotechnical systems enables organisations and industries to create relationships between buyers, suppliers and users, and may form professional associations to maintain these rules hence resulting in lock-in mechanisms.

3.1.1 Understanding transitions in a developing context

Much of the literature related to sociotechnical systems and sustainable transitions is based on analysis from industrialised countries (van Welie, et al., 2018). This literature grew from the experience of the global North's infrastructural development that offered a universal solution, 'one size fits all model' that does not reflect the diversity and hybrid nature of infrastructural development in developing economies (Furlong, 2014; Jaglin, 2008). Instead, Furlong explains that water supply in the South[8] has had a history of "multiple systems in varying degrees of coexistence" (Furlong, 2014, p.139). Bakker describes these systems as 'archipelagos'- "spatially separated but linked 'islands' of networked supply in the urban fabric" (Bakker, 2003, p. 337). Because water supply systems in the South do not operate homogenously, they overlap with alternative service delivery mechanisms (Bakker, 2003).

Service delivery systems in developing countries face a myriad of challenges including but not limited to: expensive water infrastructure that requires long-term maintenance, spatial distribution and physical layout of the systems that pose difficulties in densely populated areas such as informal settlements, weak institutional settings such as a lack of secure land tenure, government unwillingness to extend services to low-income areas and poor management of water supply (Bakker, 2003). Consequently, different services are offered according to the socio-economic status of residents in these cities creating these archipelagos (Bakker, 2003; Jaglin, 2008). Thus, sociotechnical systems in a developing context are considered to be systems of 'malfunction and disrepair' (Furlong, 2014).

[8] The terms North and South "are not direct reference to the Northern and Southern Hemispheres but applied to differentiate nations in terms of socio-economic capabilities and related characteristics. Global North are higher-income nations (with a GNI per capita>$3956), while Global South are lower-income nations (GNI per capita<$3.955)" (van Welie, et al., 2018, p. 260).

In the multi-level perspective (MLP) literature, transitions follow specific paths for technological substitution. Geels and Schot (2010) describe four transition pathways: transformation, reconfiguration, technological substitution, and de-alignment and realignment. Stability and reproduction are the main elements of transitions. Transitions occur when pressures on the landscape create tensions at the regime level producing windows of opportunity for regime shifts (Geels & Schot, 2010; Geels, 2010). In the de-alignment and realignment pathway, the regime experiences rapid landscape pressure. If this change is sudden and divergent it can cause problems in the regime making regime actors lose faith. This leads to "de-alignment and erosion of the regime" (Geels & Schot, 2010, p.63). In this path, there is no stable niche innovation and that creates space for multiple niche innovations that co-exist and compete for resources and attention (Geels & Schot, 2010). Eventually, a prolonged co-existence characterised by uncertainty and competition for resources ultimately leads to one niche-innovation gaining momentum and becoming the dominant followed by "re-alignment and re-institutionalisation in a new socio-technical regime" (Geels & Schot, 2010, p.63).

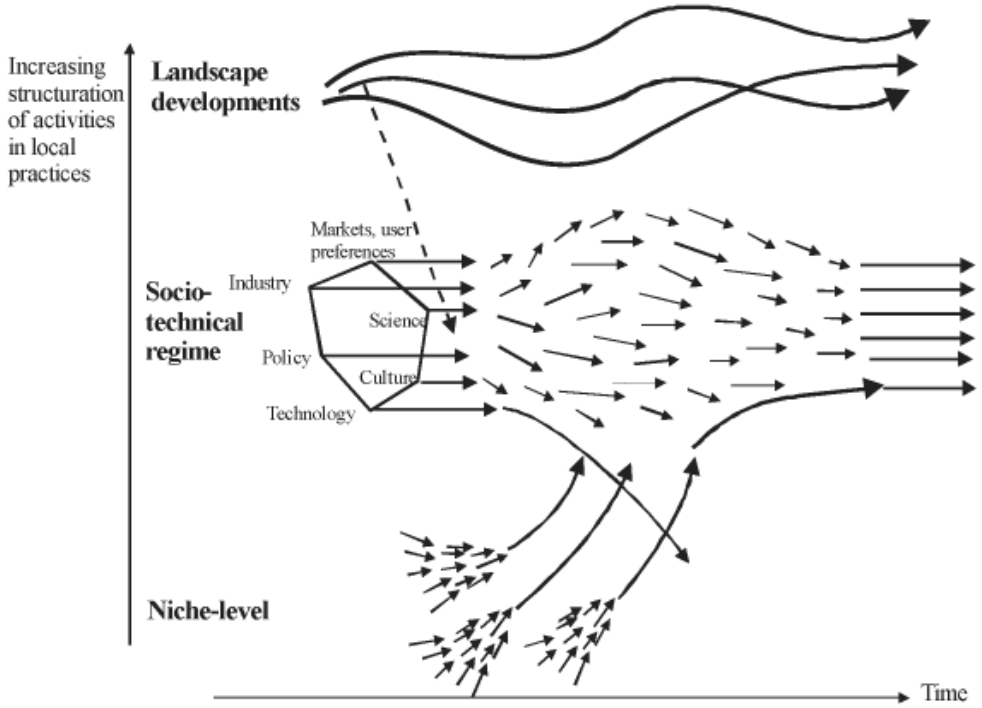

Figure 2*: De-alignment and re-alignment pathway in MLP (Geels & Schot, 2010, p.64)*

In order to understand transitions in a developing context we must recognise that MLP and much of the transition literature focuses on the North's developmental experience (Furlong, 2014). Thus, a key limitation of MLP in analysing sociotechnical transitions in developing countries is that it assumes a "universal system as the end point, i.e. one system is replaced by

another" (Furlong, 2014, p. 140). Furlong explains that when disrepair is normal and an everyday experience for users, it creates its own 'momentum'. Momentum a concept developed by Hughes, describes "how the links between society (including users and a variety of institutions) and technology evolve to create a stabilised sociotechnical system that is resistant to change" (Furlong, 2014, p.142). It also describes how people adapt their lifestyles to technical systems (Geels & Schot, 2010). Thus, when services like water are unreliable, users may seek different tactics to improve reliability through clandestine connections, storage (Furlong, 2014) or underground systems such drilled boreholes (Guma, 2019).

Therefore, it is difficult for sociotechnical transitions to occur in the global South where malfunction and disrepair has created a lock-in mechanism that has stabilised the regime. However, Furlong does acknowledge that transitions can occur in network performance. As such, improvement of water supply systems is encouraged instead of its replacement (Furlong, 2014). In this instance, integration of technologies into physical infrastructure is sort out rather than innovations (ibid). Hence co-existence is advocated as opposed to 'the universal infrastructure ideal'.

3.2 Political Ecology

Political interests form a large part of sociotechnical transitions which serve as "context, arena, obstacle, enabler, arbiter, and manager of repercussions". (Meadowcroft, 2011 p.71). Politics also plays an important role in the conditions that usually stabilise existing regimes such as favourable subsidies and regulations (Geels, 2010).

The urbanisation process historically has led to the accumulation of socioenvironmental processes in which environmental transformation has occurred (Swyngedouw, et al., 2002). These processes or socioecological change result in the "continuous production of "natures", of new urban social and physical environmental conditions", for example, water reservoirs and dams. And that these processes "occur in the realms of power in which social actors strive to defend and create their own environments in a context of class, ethnic, racialised and/or gender conflicts and power struggles" (Swyngedouw & Heynen, 2003, p.900).

Swyngedouw and Heynen (2003) explain how these processes of urbanisation in capitalist systems led to the uneven resource mobilisation and income disparities that many cities in the South face. Because of underlying economic, political and social processes, urban change tends to be highly uneven. Cities with marginalised populations endure negative environmental

change while affluent areas enjoy an increase in the quality of environmental resources. (Swyngedouw & Heynen, 2003).

Political ecology is used to understand the conditions that enable these complexities in sociotechnical systems in the South and why these issues persist by looking at the power disparities in the water sector. Swyngedouw and Heynen (2003) suggest that questions of who gains and who pays need to be seriously considered in terms of power relations. By interrogating these power dynamics among actors and agents there can be a means to enhance a more equitable distribution of social power and more inclusive mode of environmental production (Swyngedouw, et al., 2002). Therefore, the aim of urban political ecology is to expose processes that lead to uneven urban environments (Swyngedouw & Heynen, 2003).

Moreover, Bakker (2010) argues that better water governance can address these socioecological issues that produce uneven environments by contesting the privatisation of water, and by reframing our "understanding of the involvement of governments, communities, and private actors in water supply" (Bakker, 2010, p.8). Hence, the next section introduces the concept of governance failure to discuss the persistent failures of water provision in developing cities.

3.2.1 Governance failure

Water is a politically contested resource (Swyngedouw & Heynen, 2003; Mollinga, 2008). We see how power plays out in the control of water which is the subject matter of water management (Mollinga, 2008). Any human intervention that alters the water cycle, affects the time or spatial characteristics of water availability and or its quality is a form of water control (Mollinga, 2008).

Political ecology is opposed to environmental injustices reproduced through socionatural inequalities (Loftus, 2012). Many political ecology authors link environmental injustice to privatisation and commodification of water (Swyngedouw, et al., 2002; Loftus, 2012; Swyngedouw, 2005). Some go a step further to discuss the material properties of water, such as the questions of quality in relation to water access (Rusca et al., 2017) and the role of power in determining the quality of water access in different social groups.

Overall, these complexities can be understood by interrogating the political factors that lead to unevenness through the lens of governance failure. It is also important to note the consequence of market failure and state failure in water provision in addition to governance failure. However, this thesis looks at governance failure because of the role that government, private actors and citizens play in the urban water supply system. The failure of institutions to achieve

an integrated water network, may have created room for informal modes of water provision that coexist with government and private networks (Bakker, 2010). Despite water infrastructure being in private or public hands, these arrangements do not predict the efficiency of water utility companies. Instead distributional concerns such as tariffs rates, connections to poor households determine efficiency (Bakker, et al., 2008).

Although governance failure is associated with economic theories, it plays a major role in understanding water governance. The United Nations Development Programme (UNDP) defines government failure as the "political, economic and social processes and institutions by which governments, civil society, and the private sector make decisions about how best to use, develop and manage water resources" (UNDP, 2004, p. 10). It also includes participation by citizens in decision making processes pertaining to these resources. Therefore, governance failure occurs when the dimensions of water management and decision making do not effectively consider the needs of poor citizens which creates disincentives for water utility companies to connect poor households to networked infrastructure and for poor households to connect to the network (Bakker, et al., 2008). These dimensions of water management include administration, delivery (technical services), financial and economic management, and political oversight (UNCHS, 2003, cited in Bakker, et al., 2008). Below are some examples of governance failure.

The decision-making process for water management may fail to address the needs of poor households because of
1. Absence of consumer entitlements to basic services (e.g., lack of universal service requirement on the part of utility)
2. Political disenfranchisement (e.g., lack of ''voice'' on the part of poor households)
3. Culture of governance (e.g., elite-focused, top-down)
4. Economic disincentives for connecting poor households
Individual households may be subject to institutions, incentives, or other factors, which undermine their capability to connect to the water supply system
1. Tenure system (lack of clear property rights)
2. Lack of skills (e.g., literacy) facilitating interaction with service provider
3. Cultural beliefs (e.g., appropriate water treatment protocols)
4. Tariff structure (e.g., high connection fees)

Table 1: *Examples of governance failure adapted from Bakker et al. (2008, p.1895)*

Therefore, the concept of governance failure adds a richness to the analysis of sociotechnical systems of malfunction and disrepair. It enables the reader to understand the particulars behind the failure to provide uniform water infrastructure and services to cities and the reasons for persistent failure that has become part and parcel of the sociotechnical regime in developing countries. With this understanding, this thesis interrogates the concept of governance, co-existence and how these can improve water systems that can lead to sociotechnical transitions in urban informal settlements.

4 Methodology

4.1 Research design

This study uses a qualitative approach to examine the research questions in detail. This approach was favoured over quantitative methods because it allows the researcher to study things in their natural element, addressing a problem, its meaning to individuals and groups and includes the voice of the participants and reflexivity of the researcher to describe and interpret the problem (Creswell, 2013).

A single case study approach was selected as it enables an in-depth investigation into a contemporary phenomenon (the "case") within its real-world context (Yin, 2014). The intent of a case study is to describe in detail a unique case or one that has unusual interest. It can also be used to describe a specific issue, problem or concern (Creswell, 2013). Case study research is bounded by time and place or multiple bounded cases that requires in-depth data collection using multiple sources of information (Creswell, 2013; Yin, 2014). For this reason, the unique strength of a case study is "its ability to deal with a full variety of evidence" (Yin, 2014, p. 12).

Although there is no exact format to writing a case study (Creswell, 2013), a linear-analytic approach is used to structure this thesis. According to Yin (2014) this starts with a problem or issue being studied, review of prior literature, choice of methods, data collected, data analysis, presentation of the findings and lastly conclusions and their implications for the problem being studied.

4.2 Site selection

The study site was selected based on the location of the users of M-maji in Kibera. The project was initially piloted in five villages namely: Gatwekera, Kambi Muru, Kisumu Ndogo, Makina, and Mashimoni (see figure 1). However, a few years have passed since the project ended in 2015. Therefore, former users of the application have since either moved to different villages or moved entirely out of Kibera. With the help of a research assistant, I identified participants for the study in three locations: Gatwekera, Soweto West and Olympic. I conducted the interviews during the beginning of the school year, in January when most people are back to work. Additionally, over the Christmas break many Kenyans travel from the cities to their rural homes. Some potential respondents whom my research assistant identified had yet to come back from their rural homes. This made it difficult to reach some respondents.

4.3 Data collection methods

Data was gathered in the form of semi-structured interviews with M-maji users and water vendors; key informant interviews with Umande Trust staff, stakeholders from government agencies working in the water sector and other specialists in the sector, field observations and desk review of M-maji project documents and reports. This process took about six weeks between January and February 2020. A set of predetermined questions (interview guide) was prepared for different stakeholders to manage the conversations. Semi-structured interviews were selected because they are "well suited to exploring understandings and perceptions" (Hammett, et al., 2014, p. 141). This type of interview leads to open discussions that allow for a flow of conversation (Hammett, et al., 2014), and for unexpected information to come up that can be explored further. The use of key informant interviews was also a way to corroborate and compare findings from the data (Yin, 2014).

All interviews with M-maji users and vendors were handwritten and those with key informants were recorded. Under the advice of my research assistant, I did not record the interviews with the respondents because of scepticism held for researchers, even as a local researcher. Kibera is a highly researched area where many development initiatives have been implemented. The presence of researchers may irritate or annoy residents. Hammett, et al. (2014) note the importance of researchers to be cognizant of the unintended outcomes of development work and research that may have lifelong negative impacts. It was important that I kept this in mind and ensured to manage the expectations of respondents. Additionally, the use of field notes also had an impact on the quotations of the respondents (as seen later in the discussion). The interviews were conducted in a mix of Swahili and English. I translated the conversations to English in real time because I understand and speak Swahili.

4.4 Sampling

Purposive sampling (Creswell, 2013) was employed to pick out the respondents, including two key informants from Umande Trust. In order to gather rich information on M-maji, it was important that respondents selected had direct knowledge and experience with the technology. This posed difficulties in finding M-maji users, years after the project ended. Snowball sampling (ibid) was used to pick the rest of the key informants who were referred due to their knowledge of the water sector and context of the case. My research assistant was a water specialist at Umande Trust and part of the project team that introduced M-maji to the community. He therefore knew all the M-maji users and vendors and their locations which helped in identifying respondents. As such we walked around hoping to find the participants at

their homes or places of work. If unavailable, we left a message with a colleague, neighbour or through a text message, and would return later to interview them. In total, 26 interviews were conducted, 19 semi-structured interviews with M-maji respondents and 7 key informant interviews.

4.5 Limitations

One of the main limitations with single case studies is the ability to generalise from these studies. Yin (2014) explains that case studies can be used to generalise theoretical propositions and not to entire populations. Instead, they can provide in depth information that can be compared with other cases. Ragin and Amoroso (2019, p. 104) also add that case studies provide "especially rich raw material for advancing theoretical ideas". This thesis seeks to advance theoretical thinking of technologies and water access in urban informal settlements, but the findings cannot be used for generalisations.

Due to the time and resource constraints, I had very few days to conduct interviews with respondents. As such, the interviews were short, possibly reducing the amount of information that respondents could have shared. Moreover, I interviewed respondents at their places of work, at their homes or while they fetched water. This also posed a challenge regarding the number of questions and amount of time that respondents could offer to the study. Although this was the case, it gave me a better understanding of the respondents lived experience by interacting with them in their locale.

Additionally, interview data is subjective. Some responses can be partial, inaccurate or biased (Hammett, et al., 2014). One of the potential biases was using the services of a research assistant who is well-known to the respondents. This may have influenced the selection of respondents and the outcome of the material. As well, M-maji is no longer in use and finding new information proved to be difficult. Some respondents could not remember the initiative. To mitigate this challenge, I politely asked for clarifications where necessary, and in some cases, my research assistant helped to rephrase questions that may have been difficult to answer. I also made sure to ask key respondents for permission to follow up if I would need further clarification.

4.6 Reflexivity and ethical considerations

During the research process, I ensured that I was aware of my own biases that could have been formulated through prior reading of the issue at hand as well as my positionality. As a local researcher of a different socioeconomic background, I was aware that this may create a power

dynamic between me and the respondents. For this reason, I acquired the help of a research assistant who lived in Kibera and is well known to the participants. Therefore, by conducting interviews in the community with the assistant, I was acquainted with the participants and this facilitated an easier interview process and field observation. To remedy the positionality of the research assistant (McLennan, et al., 2014), I spoke to the respondents separately, where I had difficulties, my research assistant stepped in.

Yin (2014) cautions researchers from substantiating preconceived positions in case study's and encourages researchers to open their minds to contrary evidence. Following this advice, I maintained an open mind and allowed for participants to give their opinions and thoughts without inflecting them. Guest, et al. (2013) suggest researchers should be aware of their own biases and avoid collecting data on their own points of view, but rather on the social reality of the people. This inspired the methodology of this research.

In terms of ethical considerations, the thesis followed the guidelines provided by the LUMID department (adapted from the Swedish Research Council). To this degree, the study did not address any sensitive questions or involve vulnerable groups. All research participants were informed of the purpose and aim of the thesis. They were each requested to give verbal or written consent to participate in the study. Depending on the response of the participants, interviews were either recorded or handwritten and typed up as field notes. All participants were assured of utmost use and integrity of their data. That includes use of their data for the purposes of this thesis only and the destruction of recordings at the end of the study period.

4.7 Data analysis

All recorded interviews were either manually transcribed, or with Otter, a transcription software. A transcription software is an assistive technology and is not intended to replace the transcription process. Although I used a software to transcribe some of the interviews, I reviewed each of them for any errors. The handwritten interviews and field notes were typed up and uploaded to NVIVO 12. This was the qualitative data analysis software used to code the data. Data analysis involved a detailed description of the case and identification of themes or issues uncovered from interviews, reports and project documents (Creswell, 2013). When analysing case studies, Yin (2014) proposes finding meaningful patterns that emerge from the data. A mix of approaches were used for the creation of codes. Some of the findings were categorised into pre-set codes based on my previous knowledge of the research topic and the theoretical framework, while other codes were formulated based on information from the

respondents. This also involved auto-coding through Boolean searches for information that had reoccurred in the data (Yin, 2014). These processes were done iteratively to create groups of codes which were analysed into broader themes.

5 Background to M-Maji in Kibera

The following section describes the case, beginning with how it was developed, how the application worked, the aim and purpose of M-maji and lastly its challenges. The case is presented after the methodology section in line with Creswell's statement regarding data analysis involving a detailed description of the case (see 4.7). It takes its own chapter due to the amount of information presented. It is also presented here for the reader to grasp the forthcoming analysis of the field data.

5.1 How it all began

In 2010, student teams from Stanford University and the University of Nairobi developed a mobile application that looked to solve the issue of water inaccessibility in informal settlements called M-maji ("mobile water"). Using human-centred design, the teams engaged the end users in the design and development of the solution[9]. M-maji aimed to offer underserved Kenyans in informal settlements with better information about water quality, availability and pricing. The theory behind this solution was based on the mobile penetration rate in Kenya[10]. Kenyans may lack access to clean water, but they do not lack access to mobile phones. The project was officially launched in 2012. The mobile application was developed by a Kenyan technology firm Wezatele. The application was free to use and could be operated with any mobile device as it used a combination of USSD, mobile web and SMS technology (Sunday, 2012).

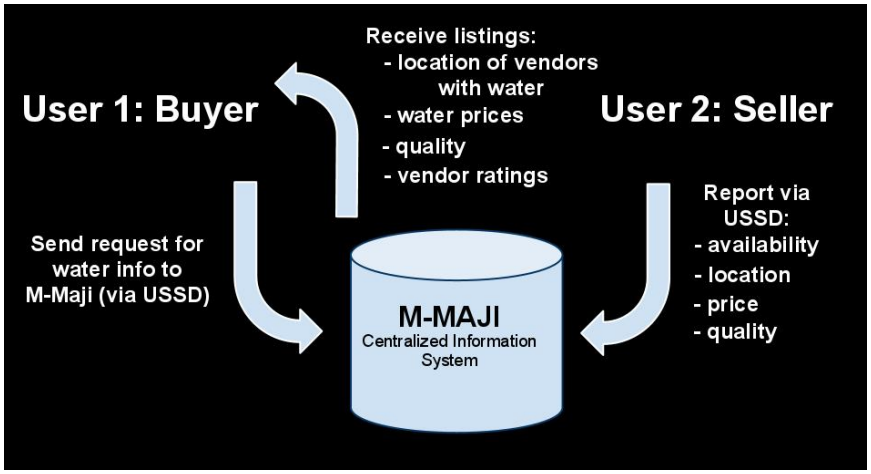

Figure 3: *System view of M-maji* (M-maji, n.d.)

[9] M-maji document-Can Mobile Phones Improve Clean Water Access in Developing Country Slums?
[10] Kenya's mobile penetration surpassed the 100 percent mark in 2018. For more, see https://www.businessdailyafrica.com/corporate/companies/Mobile-penetration-crosses-100pc-mark/4003102-4901572-tx39qy/index.html

5.2 How M-maji worked

Seller (water vendor)

To create an M-maji account, water vendors registered their kiosk name, phone numbers, location and water purification methods to use the service. At the beginning of each day water vendors would update or upload a water advertisement consisting of the price, location, quality of water, and their purification method if any, through the M-maji USSD code (see figure 5 and 6). These adverts were stored in the centralised information system as shown in figure 3 and were set to expire at midnight of that day. All advertisements were broadcasted free of charge to the whole of Kibera.

Buyer (water user)

The buyer would dial the USSD short code to obtain the information advertised by water vendors. The location of water vendors, water prices, quality and vendor ratings would appear on the screen. Buyers could also send a blank SMS to the USSD code with the name of the village they were looking for water in and information of available water vendors would appear on the screen[11]. In the likelihood that water was not available in that particular village, information from the nearest village was displayed[12]

Additionally, if a vendor misreported water information, that is, the availability, price, location and quality, a buyer could send a complaint through the application using the USSD as shown in figure 4. The database kept track of complaints and alerted water buyers on negative feedback through vendor ratings. On the other hand, M-maji staff carried out random water quality tests once a month to confirm the absence of faecal matter in the water. Water vendors who failed these tests were immediately removed from the list of trusted suppliers (Umande Trust, 2014).

[11] M-maji document- Can Mobile Phones Improve Clean Water Access in Developing Country Slums?
[12] M-maji project summary document

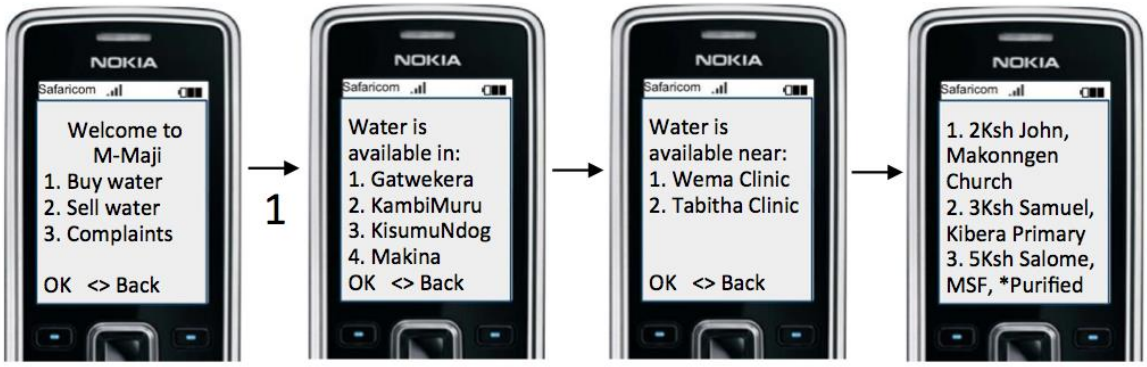

Figure 4: *Step by step process of M-maji* (M-maji, n.d.)

5.3 Project aim and purpose

M-maji was a novel approach aimed at tackling the information gap that arose from the supply and demand of water in informal settlements. Informal settlements are characterised by erratic water supply usually triggered by cartels, leakages and rationing. By providing communities with information on location, price and quality of water, M-maji reduced the residents' burden of finding clean water. As well, the hope of M-maji was to put "downward pressure on water prices, making clean water affordable and accessible to larger segments of Kibera's population" (M-maji, n.d.).

Figure 5: *M-maji advertisement*

Figure 6: *M-maji advertisement*

5.4 Challenges of M-maji

The key challenges of M-maji were firstly, the USSD codes given at the start of the project (*167# and *355#) did not function as intended. As a result, the project did not pick up for the first year. Umande Trust then re-launched M-maji in 2013 with new codes (see figure 6) to reassure residents of the project and its potential benefits (M-Maji Video 2, 2013). Secondly, it was difficult to get water vendors and customers to adapt to a new water system other than the ones they were used to. Third, residents held high expectations and expected incentives from the project such as water tanks and resources to improve piped connections. Lastly, financial sustainability of the project was a challenge. Stanford University supported the communication costs of Safaricom, Wezatele and other partners. The project received small grants from the Freeman Spogli Institute's Global Underdevelopment Action Fund and the Centre for Innovation in Global Health (Beges-Thysen, 2012). Although M-maji was free to use for Safaricom subscribers, it was dependent on subsidies from Stanford University.

The technology had its challenges, but it also had the potential to scale up. According to one of the project documents, there was demand for the application by non-Kibera residents. Secondly, there was potential to establish partnerships with other organisations and agencies to determine the water quality at household levels and thirdly to link the application to Majivoice.

6 Findings and Discussion

The following section presents the findings and theoretical discussions on the state of water access in Kibera, perceptions of M-maji and the use of technologies to improve access to water in informal settlements. To preserve anonymity of respondents, interview references are made in the order of water user, water vendor or key informant and the interview number. Some of the findings from respondents and key informants fall within a wider discussion that goes beyond household technologies such as M-maji. Those themes are primarily discussed in section 6.1 and 6.3 and the findings directly related to M-maji are discussed in section 6.2. Although, it is important to note that these themes are interlinked and appear throughout the discussion.

6.1 Inadequate access to clean and safe water in LIAs

6.1.1 Water service provision in Kibera

The provision of water services in Kibera is faced with a myriad of challenges as a NCWSC official notes, "the inability of customers to pay, uncertainty of land ownership…vandalism, lack of space, the high cost of water because they have to buy from cartels and all that" (Key informant 7). Although the Government of Kenya (GOK) has improved the policies to connect households to better services, residents of Kibera still face many of the challenges mentioned above. In regimes of malfunction and disrepair, Furlong (2014) explains that such challenges form lock-in mechanisms which stabilise the regime making it difficult for transitions to occur.

From the respondents interviewed, all the water users did not have piped water connections to their houses or compounds. Only the water vendors at the time M-maji operated had piped connections to their water kiosks. Users bought their water from fixed point vendors (standpipes and water kiosks) which they believe are supplied water by the NCWSC. To increase water access, the company provides water to Kibera through sub-concessions to private water vendors and CBO run water kiosks for resale to customers (Hailu, et al., 2011). Because land tenure is a major barrier to improved water connections, the use of small-scale water providers offers increased coverage to residents and acts as a source of income.

However, the presence of private water vendors is contested. On one hand they offer increased coverage to residents thereby reducing water search costs, and on the other hand, they charge more to earn profits. Moreover, illegal water vendors tend to drive up the cost of water during

shortages. The NCWSC charges water vendors 20 KES[13] per m^3 for water (0.40 cents per 20 litre jerrycan) which vendors sell at 100 KES per m^3 (2 KES per 20 litre jerrycan) on the lower end. During shortages, this price can go as high as 20 KES per 20 litre jerrycan. Residents of formal settlements pay a flat rate of 204 KES for their first $6m^3$ of water, then 53 KES per m^3 for water use between 7 to $60m^3$ (NCWSC, n.d.-b)[14]. Hence, the minimum cost of water in Kibera is twice the cost of water in formal areas. A key informant from Umande Trust echoed the same sentiment, "somebody who has a running meter pays less than somebody in Kibera. I think those are some of the poverty penalties that we have in this country when it comes to accessing water" (Key Informant 3). Although it is cheaper to pay for metered water, high connection fees and transaction costs discourage households from connecting to the main network which costs between 2,500- 15,000 KES (depending on the distance from the main pipe) excluding a meter deposit of 2,500 KES.

In line with Bakker, et al. (2008) these examples reflect governance failure, whereby households are incapable of connecting to the main water supply network due to these high costs. As well as their inability to pay which disincentivises water companies from connecting supply networks to LIAs. According to Bakker (2010), failure to achieve these homogenous services to all residents within a city contributes to the different service modes that serve citizens left out of the networked service. These form 'archipelagos', which coexist with other systems as Furlong (2014) notes. Due to these different services, poor households are likely to pay a poverty penalty, considerably higher costs for water of dubious quality than networked households. Bakker, et al. corroborate that poor households in many large developing cities spend a higher share of their income on water than wealthier households do. However, the NCWSC rolled out a social connection policy to increase network coverage in informal settlements and reduce non-revenue water. Although the question currently may not be the ability to pay but the willingness to pay which is a challenge for the NCWSC (further discussed in section 6.3).

Another issue highlighted was incomplete service provision by NCWSC to water vendors. When vendors connect legally to the network, the utility company only connects them up to a certain point and leaves it to the water vendor to connect to their kiosk, as described by one informant,

[13] The exchange currency used was 1 KES= 0.096 SEK
[14] $1m^3$ is equivalent to 1000 litres of water

> …when it comes to connection, the Nairobi water should take the responsibility of connecting the water up to the water vendor to be connecting and disconnecting because by the time they are doing the connection or they are doing repairs that water ends up now being contaminated.
>
> (Key Informant 2)

This may eventually lead to the use of low-quality plastic pipes (so called spaghetti connections) that cannot withstand the pressure of water. When leaks occur and repairs are needed these water pipes may get contaminated posing health risks to water customers. This may also explain why vendors at the beginning of M-maji expected incentives such as water tanks and resources to improve their water connections. In line with Bakker (2003) failure to extend services to marginalised areas in cities is highly correlated to socioeconomic status of residents. Swyngedouw and Heynen (2003) note that such uneven urban processes lead to disparities in water provision. This type of incomplete service provision to water vendors indicates governance failure on the part of the company that may perpetuate these systems of malfunction and disrepair.

6.1.2 Corruption and crime

In Kibera many water vendors are known to run their operations by connecting illegally to the network. A 24-inch water pipe passes through Kibera, which informal vendors tap and sell to households through 'spaghetti' connections and electricity conduit pipes. These pipes are prone to bursts and leaks which contribute to high amounts of non-revenue water, one of the major challenges for NCWSC in informal settlements. A key informant mentioned that,

> In the slums, a number of the people are not legally connected, even if they are legally connected, it reaches a point where they don't pay for the water they are using, so there is an issue of corruption.
>
> (Key informant 2)

Furlong (2014) mentions that when services are highly unreliable, users opt out of the system, for instance through illegal connections. Due to low service connection, residents in Kibera may seek reliability by using such strategies to gain access to water. As well, frequent water shortages (see 6.1.3) may discourage residents from paying for water. Moreover, the water supply in Kibera is controlled by a few individuals, so called cartels as mentioned by a NCWSC official,

> Water and sanitation are actually controlled by private individuals and illegal groups, we are calling them cartels. These lead to exploitation of residential highly priced services and also unaccounted for water is actually very high because of the illegal connections. Water is there but we cannot be able to measure because they just want to take water for free.
>
> (Key informant 7)

Swyngedouw, et al. (2002) explain that power geometries among social actors determine who has access to and control over water. Like Mollinga (2008) states, any human intervention in the flow of water is a form of water control. Absence of government control and regulation in informal settlements can create a power vacuum that gives carte blanche to cartels and illegal groups to exploit poor households. Consequently, the presence of cartels in water networks implies poor governance on the part of the state and water company. This poses a challenge to the NCWSC as this may not only affect water supply to residents in both formal and informal areas but also affect the company's revenue stream.

Similarly, informal vendors and cartels collude with corrupt company officials who deliberately siphon water to resell it at higher prices. Due to the commodification of water, water access has been turned into a business idea as stated by one key informant,

> …those cartels are the same people living in those informal settlements, and they have generated the problem of water access into a business idea to an extent that sometimes even when the Nairobi Water is providing enough water they deliberately close the pipes to the communal water points so that they can vend the water and therefore that is a challenge.
>
> (Key informant 5)

One M-maji vendor mentioned that the presence of cartels in the area forced her out of the business. She explained that some water vendors (linked to cartels) would disconnect her water supply while others who had not registered with M-maji would also attempt to sabotage other M-maji vendors. Guma (2019) notes that illegal groups use such strategies to assert their social power as a form of control and governance. Thus, poor connectivity and neglect of existing networks can cause political manipulation of residents of informal settlements as Gandy (2008) illustrates.

Nonetheless, the NCWSC has provisions to penalise illegal connections. In their customer charter, the customer is responsible for reporting bursts, leaks and illegal connections or practices that could impact service provision negatively. However, a poor culture of governance as described by Bakker, et al. (2008) whereby rampant corruption, incompetence, poor or lack of enforcement of policies and regulations, can be linked to corrupt officials, and community members themselves who engage in criminal activities. As well, political disenfranchisement (Bakker, et al., 2008) of households may discourage them from voicing their concerns and using these channels to improve service delivery (see Table 1).

6.1.3 Intermittent supply of water

In many networked systems, water may flow intermittently, sometimes a few hours per day or per week (Bakker, 2003). A NCWSC official admitted that they are unable to provide adequate water to all the residents of Nairobi. However, in Kibera, water rationing is aggravated by high amounts of non-revenue water. To reduce this loss, the water company rations the water in the settlement. This was a challenge cited by many respondents. One water vendor mentioned that during shortages customers would visit his water kiosk and find water unavailable. Other vendors linked water disruption to the NCWSC when they temporarily shut the connection to clean their main water tanks. This disruption of services cost water users time as they were forced to queue for water during shortages. It also inconvenienced the water vendors because they were unable to gain revenue during these shortages. However, for some water kiosks like Tosha Bio-centre in Gatwekera, there was a constant supply of water.

Intermittent supply of water can also be linked to its quality. To ensure water quality, a continuous flow of water is required to avoid negative pressures that may cause infiltration of microbes and contamination of water (Furlong, 2014; Bakker, et al., 2008), which may further reduce access to water (Bakker, 2003). Affluent households can use other alternative means for their drinking water such as bottled water, but less affluent households may need to treat their water even if the water company has already treated it. M-maji users and vendors were advised to treat their water and clean their tanks regularly.

Although water supply may need to be improved in informal settlements and Nairobi as a whole, the fact that Kenya is a water scarce country burdens the supply of water as mentioned by one of the key informants,

> Kenya is a water scarce country; our per capita water availability was 647m^3 per person per year in 1999. Today, with the population increase, far much less…in 2008, Nairobi

> county was getting 477,000m^3 per day the demand then was 680,000m^3. So that gap means that the availability, we would never get 100%. Today, Nairobi because of the additions that have come up, Nairobi is getting about 580,000m^3 of water per day but the demand is 780…we have no magic plate because we are trying to expand the water.
>
> (Key informant 5)

The NCWSC aimed to meet this demand by June 2019 as stated in their strategic plan 2014/15-2018/19 (NCWSC, n.d.-a) but the current water supply in the city is still short of the target that the utility company set. According to Bakker, et al. (2008) and Furlong (2014), unreliable services such as intermittency force people to make water storage an essential bridge to service gaps. Furlong recommends the use of simple and well-known technologies in enabling sociotechnical change to bump supply to homes, such as rainwater harvesting technologies. This may be a challenge for residents as stated below,

> But then you find that in Kibera somebody cannot store maybe 200 litres of water because of that space that they occupy. You find that the highest amount they can store maybe is 80 litres. I'm talking about four jerrycans.
>
> (Key informant 3)

Furthermore, Bakker, et al. (2008) describe that the need for storage options adds transaction costs that poor households cannot afford to incur. This indicates governance failure whereby households cannot connect to the piped network. Water vendors on the other hand can harvest rainwater and treat it with chlorine. One of the officials from the NCWSC explained this further,

> In my view, I believe something can be done to ensure that the intermediate supply of most water utilities is handled by micro-rationing, where you say this area will get this water today. And you ensure they get. And then of course, you teach people how to store. If you stored water to await your rationing day, there will be something to sustain you…And when it's raining, a lot of water goes to waste…Earlier you could not harvest rainwater without the county giving you a license for that. But those are laws that should actually be repealed and removed…
>
> (Key informant 7)

As stated by Furlong (2014) readily accessible household technologies are sought as opposed to new technological innovations. This indicates that transitions are less about innovation and

more about integration into the existing system. Improving the supply schedule, where every part of the city receives water on their given dates for a certain number of hours can allow people to store water. Moreover, it may allow users to plan their water consumption. But for areas like Kibera where space is a premium, technologies for rain harvesting may need to be improved, instead of looking to innovations that would displace the whole system.

6.2 Adoption of niche technologies- M-maji

6.2.1 Daily experience of using M-maji

All water users interviewed shared their experience of buying and fetching water through M-maji. The users explained that it took about five to fifteen minutes to fetch water in total depending on the distance to the nearest water vendor. When they used M-maji, they would send a SMS inquiring information on water availability, cost, and quality, then wait for a response. Once they got the response, they would carry their jerrycans to the vendor and fetch the water they needed or could afford for that day. Notably, some users maintained the same water points after the project ended. Below are narrations from three water users on their experiences with M-maji:

User 3 explained that it took her only five minutes to fetch water because the public tap is very close to her house. Her only issue was the waiting time or queues at the taps during water shortages. When she used M-maji, she would send a SMS inquiring information on water availability, cost and quality and wait for a response. Once she got the response she knew where to fetch the water which she would then pay for at the vendor.

User 2 travels approximately 5km to and from the water vendor. She makes four trips carrying one 20 litre jerrycan at a time because she is elderly. She cannot carry two even if she would like to. She owns a school for early child development and buys the water for the school as well. For this, she makes five trips just to buy the water for the school on top of her own needs. When she used M-maji, she would call or text the water vendor who would have the water delivered to her. However, she now must walk to the water vendor to fetch water and that takes time unlike when she used the application.

User 7 sent a text message to the USSD code to inquire information from water vendors. Once he received the information he would then go and fetch water and pay for it at the vendor. It took him about five minutes in total because the water vendor was close to his house. However, he explained that there were times when he would find a queue at the vendor which took him longer than usual to fetch water.

These examples reveal that residents of Kibera may be accustomed to disrepair and malfunction as their norm. As stated by Furlong (2014), such disruption of water services creates habits and customs of its own, as such people adapt their lives to this technical system that creates its own momentum. Lack of universal infrastructure caused by a culture of governance that undermines the needs of the poor and places a priority on profits (Bakker et al., 2008) indicates how residents in Kibera adapt to systems that are available to them and these become 'their lived normality' (Furlong, 2014). According to Star, these customs are resistant to change and bound in a wider social order (Star, 1999 cited in Furlong, 2014). However, in line with Furlong's argument on integration, modest changes to such regimes can occur using mediating technologies. For this reason, M-maji may have easily been adopted into this regime not because it was a large technological innovation but because it was a simple, easy to use technology that users welcomed.

6.2.2 Information is king

The main objective of M-maji was to bridge an information gap that would eventually lead to reduced water search costs, increase clean water uptake, and encourage vendor accountability. A former water specialist at Umande Trust explained that,

> The social impact was just to give people access to that information instead of you just coming from your house and going around the village looking for water. You did not have to with the new technology that was there…
>
> (Key Informant 2)

The purpose of providing citizens with information is to empower them to make informed decisions (Ssozi-Mugarura, et al., 2015). The high proliferation of ICTs has provided a platform for information sharing that allows citizens to make choices. Water users viewed a list of different water vendors in their area and chose which ones to buy water from. In times of scarcity, the information was useful for cost and time management. For water vendors this was a platform to increase their visibility and compete with other vendors in the area. It also provided free marketing for water vendors, a cost-effective solution to gaining customers.

Additionally, M-maji had a complaint mechanism where water users could report poor services from water vendors. If vendors charged high prices, provided inaccurate information about water availability or the quality of water, users could make a formal complaint through the application and the project officers would intervene. As well, the application provided a rating system for water vendors which users could see when they were looking up information on the

application. One of the project's aims was to drive the prices of water down in the area through information sharing. By giving water users a voice, water vendors could be held accountable for misinformation and poor water quality. This was intended to prevent vendors from hiking their prices and providing customers with safe and clean water.

According to Bakker, et al. (2008) governance failure occurs when poor households are politically disenfranchised and have no 'voice' or say in matters either because they have no information or no avenues to voice their concerns. In this way, information can be used as a 'power tool' whereby certain people take control of water and decide who benefits and who loses as Swyngedouw and Heynen (2003) explain. In most cases, the elite may control and benefit from water leaving out poorer households. Without proper information, water users may be forced to deal with a system of malfunction and disrepair, stripped of their voice to make choices and demand for better services.

Nonetheless, Furlong (2014) states that systems that have stabilised routines and habits have collective customs that are normalised. In Kibera, illegal water vendors are probably accustomed to hiking prices during water shortages to gain more profits. In line with Furlong, assuming the right information will induce behavioural change may neglect these complexities. Hence, the aim of M-maji to drive prices of water down through information sharing would have proven to be difficult.

6.2.3 Convenience

One of the benefits of M-maji was the convenience of the application. It was easy for the respondents to use. Additionally, it allowed users to plan their time and money well in advance before they purchased water. Hailu, et al. (2011) describe this as time poverty. In this case, it refers to the distance between a household and a water source. One user noted how it helped her access the nearest water vendor and saved her time in looking for water. Before, she would spend approximately 45 minutes looking for water because she had to walk downhill to search for a water vendor, make a few trips, depending on the amount of water she needed, carrying two 20 litre jerrycans per trip (User 1). Thus, the application contributed to reducing the time poverty of users. A key informant noted the same,

> …it was for them now to save time. Once they know where they are going to get water they can now time themselves for example if walking from here to the next water source can take 10 minutes so maybe in the next 10 minutes you should have planned what to do next after going to the water point.

(Key informant 2)

In Furlong's view, convenience is important in understanding how sociotechnical systems develop to meet the needs of users. It is not only about accessible services but also the interactions with sociotechnical systems that enable users to manage their time (Furlong, 2014). In fact, some water vendors delivered water to their customers. One of the users explained how convenient it was to have water delivered to her house. Currently, she takes a longer time to fetch water unlike when she used the application. She further described how important the service was for the sick or elderly who needed to purchase water for their households. Not to mention, the convenience of a delivery service enabled users to avoid the queues at the water vendor. In line with these findings, Furlong (2010) suggests that convenience in a sociotechnical system can be achieved through mediating technologies. Although the study by Furlong uses the example of mediating technologies to boost performance of networked infrastructure, applications such as M-maji can act as mediating technologies because they are simple small technologies that can easily integrate into regimes like Kibera.

6.2.4 Quality and health

The aim of the project was to increase the uptake of clean water as mentioned by a key informant, "the project was to address the issue of health whereby now we were advising our people to have access to safe and clean water, not just clean water but also safe for drinking" (Key informant 2). Ground water in poorer areas tends to be more polluted due to proximity to industrial sites, open sewage drains and high population density (Bakker, et al., 2008). In Kibera, frequent leaks and bursts provide an avenue for contaminants to enter the water distribution network and, consequently lead to water related illnesses which usually affect children under five the most (Heland, et al., 2015). One user reiterated this by saying that "the water in Kibera passes through filthy places, even the health officers do not approve it" (User 8). Bakker (2003) explains that local states in the South typically failed to extend services to socio-economically marginalised areas of cities. According to Swyngedouw and Heynen (2003), poorer areas receive the brunt of negative environmental consequences while affluent areas receive higher quality of environmental resources. In line with these statements, disparities in water quality in poorer areas suggests governance failure on the part of the government and NCWSC that may undermine the health of citizens in Kibera.

Despite this, majority of the users trusted the quality of the water. All the water vendors indicated that they received piped water to their individual water kiosks or standpipes from the

NCWSC, of which was stored in tanks. The NCWSC treats the water before it is distributed to the network. One user remarked that the water she bought from the M-maji vendors was clean. As mentioned above by a key informant, water users and vendors were advised to treat their drinking water. Most users treated their drinking water with chlorine solutions or boiled it. However, two users explained they did not treat the water because it was piped directly by the NCWSC and was already treated. Another user was advised against adding any other water treatment solutions to it as it would be too excessive. From these discussions, users mentioned they did not have any health-related issues from consumption of the water they bought. Although one user mentioned that when she was not boiling the water, she and her children would get stomach cramps and diarrhoea, but when she started boiling the water, she did not have the same problems.

The water vendors were also asked about the hygiene of their water tanks. Tank cleaning varied across all vendors. Some cleaned their tanks monthly, others twice a month and even went a step ahead to treat the water in the tanks again with chlorine. One vendor stated that he cleaned the tank every year and that the surrounding population did not have any health-related issue from the water at his kiosk. Because the water is treated by the NCWSC some vendors did not see the need to treat the water again. Looking back at Bakker, et al. (2008) examples of governance failure, individuals may be incapable of connecting to the water supply network due to their cultural beliefs such as water treatment protocols. This may not be the case as described by many respondents. Because the water was supplied by the NCWSC, many perceived it be safe for consumption, regardless of its susceptibility to contamination. Nevertheless, using information as a tool to encourage water treatment may have contributed to safeguarding the health of M-maji respondents.

6.2.5 Overall perceptions of M-maji/new technologies

All the respondents interviewed expressed their satisfaction with the application's technology. Out of the 19 respondents 15 stated they would use the application again if it was returned. There were mixed reactions, some hard yes's, and few hard no's but most respondents were nonchalant about using M-maji again or other mediating technologies. Although majority of the users saw the benefits of the application, some felt that M-maji did not have any impact to their lives or businesses. When asked to elaborate, one of the users mentioned that there were no other alternatives, no other technologies for them to compare to. One particular vendor's water kiosk was located down a slope which hindered his business. Nevertheless, some

respondents were excited for the prospects of the project's return, while others had not thought much about the application and would not mind using it again.

One water vendor remarked that he would only use M-maji on condition that the application runs for a longer period. As earlier mentioned, the project was only operational for two years. He explained that if the project is to be revived for a short period it would not make sense for him to use it again. Even if M-maji were to be revived, the project would be redundant due to an influx of water vendors as cited by one vendor. Another vendor stated that M-maji was very good, the only problem is that when technologies are introduced to Kibera, they do not last. They are not maintained and after some time they lose meaning. This was also mentioned by a user who said that the project ended abruptly. There was no communication from the project team. The project was not inherited by Umande Trust to continue with implementation and therefore faded out of Kibera.

> One, it was somebody's project just for study, but we were being promised that once they carry out the studies, they will come back and work on their findings. So maybe they are still working on it… But the project was not scaled up because after some time they left Umande and started working with the CDC because of the issue of the water quality…
>
> (Key informant 2)

In findings by Guma (2019), M-maji was highly lauded by residents for the realtime information it provided for clean water access. It reduced water search costs, provided users and vendors with information on quality and held water vendors accountable for the information they advertised. Nevertheless, it failed because the project team could not develop partnerships with telecommunication providers such as Safaricom or Airtel (Guma, 2019). As mentioned, the project did not receive enough funding to sustain it for a longer period. There was also the possibility of forming partnerships with organisations to safeguard quality of water sold to residents (such as with the CDC) and link the application to Majivoice.

Geels and Schot (2010) explain that at the niche level technologies are not well developed, social networks are small and unstable. Building these social networks can contribute to development of niche technologies. They argue that network building for niche technologies requires collaboration with incumbent actors who have many resources and competence. However, they suggest that it is better to work with outsiders who think 'out of the box' than to work with incumbent actors who "have too many vested interests and will try to hinder or

encapsulate radical innovations" (Geels & Schot, 2010, p.90) and this may favour lock-in mechanisms hindering any transitions in the regime.

In this sense, M-maji may not have completely failed as a technology because it was well developed in its early stage with resources from Stanford University and moved to the regime where it was accepted by users in the market. However, it may have failed to develop these relationships that would have been vital to its expansion, evolution and sustainability.

6.3 Expansion of services to informal settlements

The use of digital technologies can be useful to residents of informal settlements. For majority of M-maji users, the application made their lives easier. However, when niche technologies are not well developed, regimes experience de-alignment and re-alignment with multiple niche innovations blossoming and coexisting (Geels & Schot, 2010). Although Geels and Schot mention that one niche innovation becomes dominant, this may not be the case in sociotechnical systems of malfunction and disrepair. Instead, these multiple niche innovations may coexist. In Kibera, several technologies have been deployed to improve access to clean water. These innovations are developed more so as household technologies that mediate access to clean water and not necessarily as innovations that can displace this sociotechnical regime (Furlong, 2014).

However, improving universal and equitable access to water may be difficult in such sociotechnical systems. Instead Furlong (2014) explains that transitions can occur in network performance- improving the networked system through multiple efficient avenues. For the NCWSC this implies improving networked connections by bridging these archipelagos through an innovation approach comprising prepaid water meters and token dispensers.

Through this approach, the NCWSC can provide water to residents at a cost of 50 cents per 20 litres of water compared to 2-5 KES from water vendors. In the long run it may be more affordable to get an individual connection or use the utilities prepaid dispensers. Thus, to increase household connections, the NCWSC and WSUP together with the World Bank rolled out the social connection policy. This policy subsidises "first-time water connections that are aimed at benefiting the poor, which are only intended for households." (World Bank, n.d.). Through a microloan from the World Bank, households pay a commitment fee and a balance over time to get a prepaid water meter connection. Normally this may be beyond the reach of poor households due to the high connection fee for first time connections. The project was piloted in Kayole Soweto, a low-income settlement in Nairobi.

> The targets were those who are willing to pay but cannot afford…the subsidy covered half of the loan including interest and costs of materials. The balance is repaid through affordable amounts passed to the customers' monthly bill for a maximum 36 months and that has really helped. This is the kind of money they are paying as a commitment. And then we have villages that were actually doing that commitment fee, they pay 1648 KES as a one off and then they pre-qualify. This policy is actually suited for low income settlements with *clear land ownership* because others do not have. (emphasis added)
>
> (Key informant 7)

Residents of Kibera grapple with secure land tenure. This makes it difficult to connect water and sewerage services to the settlement. Bakker, et al. (2008) explain that land tenure status and regulations are out of the hands of water utility companies and fall within the government's authority. Even with pro-poor policies that encourage improved water and sanitation services to Kibera, insecure land tenure indicates governance failure as poor households may not be able to connect to water networks, likewise this may disincentive the water company from extending these services to poor households.

Secondly, the water company in collaboration with SUSTEQ[15] installed prepaid water dispensers in informal settlements to alleviate the issue of non-revenue water. Consumers buy water credits that are loaded onto a chip which they use to access water from the water dispenser. The consumer buys credit of 50 KES and becomes the owner of the chip. There is also enough credit left over to buy water. When the credit is depleted, the consumer can reload at the face of the water dispenser, through mobile money or at an authorised operator. The company aimed to install 1200 dispensers in informal settlements, unfortunately only succeeding to install 150 as explained below,

> Then we have the prepaid communal water dispenser, this is an innovation providing water at affordable prices. The project aims at installing 1200 from 2016. We may not have done well. Because so far, we have done about 150 and you can see by 2018 we had done 125. Why? It's because where to place it, someone says this place you cannot go in and install it because they will still demolish it anyway.
>
> (Key informant 7)

[15] Susteq is a Dutch company that provides solutions to water companies and NGOs for reliable water supply. For more see http://www.susteq.nl/about/

In line with this quotation, introduction of new technologies in a sociotechnical regime that may be accustomed to unreliable services may interrupt the livelihoods of water vendors and rattle some cartels. This is an example of how habits and customs have stabilising effects on sociotechnical regimes and become resistant to change as Furlong (2014) describes. Any changes to these habits may cause resistance of the technology as mentioned by two key informants below,

> …two issues are emerging, one there is a bit of resistance from the water vendors. Reason is that the prepaid meters is eating into their profits. There is that reduction on their income because they were charging water the way they wanted. Two, there is also some sort of interference from the company officials, from the corrupt company officials that you can call them, the cartels, because they have been profiting in this.
>
> (Key informant 3)

Regarding the ATM dispensers, Kibera residents resisted the technology's introduction as explained by a NCWSC official,

> Kibera people, somehow resisted this because they were used to free water with good pressure because of the mains, the 24 inch that passes through them where there is water and they had punctured them illegally.
>
> (Key informant 7)

As Furlong explains, in systems of malfunction and disrepair people may become accustomed to disorder and cope with their daily conditions. When these habits and customs are stabilised in the regime, there may be more incentive to resist. In the beginning phase of the M-maji project, it was difficult for the water vendors and users to adapt to the technology because they were already used to a different system. Phasing out water vendors by increasing piped water or prepaid water dispensers may be one option to increase access to clean water in informal settlements, however it comes with its challenges as mentioned below,

> It will not be easy to negotiate with the citizens of the informal settlements so that they refuse to buy from the vendors. Because once the market is not there then the vendors will become powerless but as long as these people are buying from there, they will have the motivation to close the pipes…
>
> (Key informant 5)

Instead, Furlong (2014) suggests improvements in service provision, supply schedule and the use of mediating technologies to regulate consumption. In the governance literature, Bakker, et al. (2008) suggest water utilities to adopt strong regulatory frameworks to cover both networked and non-networked water supplies. Whether or not the these 'archipelagos' are managed by private or public entities, improving water service provision in Kibera is key, and this can be done through the coexistence of simple technologies that can be regulated and managed well.

7 Conclusion

Kibera has had a history of uneven water service provision that correlates to the socioeconomic status of residents. Due to these inequalities multiple alternative service modes emerged to serve those disconnected from the water network, forming 'archipelagos.' These service modes do not operate homogenously, and are instead characterised by old and dilapidated infrastructure, corruption, illegal water connections, water shortages and weak institutional arrangements. Hence, these sociotechnical systems are described as systems of 'malfunction and disrepair'. In such systems, it is difficult for sustainable transitions to occur, that is, shifting from a disconnected water regime to a networked one. However, complexities of service provision in informal settlements makes it difficult to achieve a system displacement, rather coexistence of multiple service modes through network performance is encouraged for regime change.

The concept of governance failure from political ecology has been used to interrogate the conditions that led to poor water infrastructure and services in Kibera. The findings indicate that governance failure contributes to the socio-political issues inherent in water provision. These are the government and institutional processes and decisions that prevented extension of services to LIAs, as well as the social factors that prevent poor households from connecting to networked infrastructure. We also see how small-scale technologies can impact how communities interact with sociotechnical systems of malfunction and disrepair. Reduction in water search costs, increased clean water uptake and vendor accountability indicate that technologies like M-maji can improve how people access water in Kibera.

Overall, this thesis suggests that transitions can occur in developing cities through modest changes or improvements in water service provision, by integration of mediating technologies into the existing network, co-existence with other technologies, and better water governance. Contrary to Geels and Schot (2010), collaboration with incumbent actors may be a means to achieve better access to clean and low-cost water. The innovation approach by NCWSC shows that transitions can occur when incumbents develop technologies to improve service delivery and performance in sociotechnical regimes of disrepair.

This thesis sought to advance theory on water services and integration of technologies in Kibera that can be compared to other cases in urban informal settlements. Nevertheless, this thesis does not capture all aspects around water access and M-maji. In my findings, partnerships and network building were vital to the success of M-maji in the water regime (see 6.2.5). However,

due to limited data from the fieldwork, these concepts were not expounded. Hence, they can be advanced through further research. As well, there are many other technologies that exist in Kibera like those implemented by NCWSC. It would be important to examine the pros and cons of the innovation approach in Mathare (Soweto Kayole) and what its implications could be for Kibera residents. Additionally, this thesis can benefit from a gendered analysis of technology for water access. In the global South much of the water related duties are assigned to women. By taking a feminist approach, further studies can examine inherent gender norms in technology use and their effects on women's access to clean water.

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Appendix I: List of interview respondents

	Interview	Role	Type of interview
M-Maji respondents	1	User	Field interviews (face to face)
	2	User	
	3	User	
	4	User	
	5	User	
	6	User	
	7	User	
	8	User	
	9	User	
	10	User	
	1	Vendor	
	2	Vendor	
	3	Vendor	
	4	Vendor	
	5	Vendor	
	6	Vendor	
	7	Vendor	
	8	Vendor	
	9	Vendor	
Key informants	1	Regional P.A WASH	Face to face interviews
	2	Fmr. Water Specialist, Umande Trust	
	3	Community Partnerships, Umande Trust	
	4	Technical Services Director, Human Needs Project Kibera	Email interview
	5	Executive Director, Network for Water and Sanitation (NETWAS)	Face to face interviews
	6	Principal Consultant, ETC Consulting	
	7	Customer Relations Coordinator, NCWSC	
	Total: 26		

Appendix II: Images of water infrastructure in Kibera

Image 1: Water pipes mounted to walls along the river

Image 2: Water pipes passing through sewage and waste

Image 3: A resident using a prepaid water dispenser (WSUP, 2018)