

Assessing Deployment of Science, Technology & Innovation in Catalysing Sustainable Water Services Provision in Nairobi City County, Kenya: Case of Soweto Kayole Jisomee Mita

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Abstract:- More than 40% of Kenya's population depend on unimproved water sources and water and sanitation challenges are prominent in the informal settlements characterised by poor infrastructure of piped water. Deploying science technology and innovation (STI) interventions can help residents of Nairobi City County and Nairobi City Water and Sewerage Company (NCWSC) with more efficient, innovative, and profitable water services provision. The study assessed the successes and challenges of deployment of STI in catalysing sustainable water services provision, water services infrastructure development, utilization and management and recommendations for possible adoption and uptake of the emerging innovations and technologies for improved and efficient management of water services provision. The researcher used a descriptive survey design and analysis, relying on a qualitative approach to capture detailed information about the perceptions and dominant narratives on the role and impact of deployment of STI in accelerating progress toward meeting SDG 6. 320 residents were interviewed including 10 landlords, seven staff from NCWSC and two World Bank (WB) staff. Also interviewed were local water vendors, operators and community representatives. Descriptive statistics and correlational analysis used to analyse the data and descriptive statistics used to interpret the findings. Inferential statistics used to establish the level of deployment of STI in catalysing sustainable water services provision while addressing issues on water services development, utilization and management. Main finding is that factual evidence in which STI infrastructure plans and deployments aligned to organizational and institutional visions do not always sometimes conform to situations and realities on the ground especially by the final beneficiaries. The initiative has proved feasible for the informal settlement and can be enhanced by deployment of STI enabled digital tools for existing public structures and institutions; institutional strengthening, financial and STI pro poor innovations and community engagement and subsequently improved transparency and accountability.

Keywords:- Innovative Financing; Emerging Technologies and Innovations; Sustainable Water Services.

I. INTRODUCTION

Water security pose an eminent dynamic and complex challenge for the continent with a growing population, a changing and more volatile climate leading to floods and water shortages in different parts of the continent, demographic changes, urbanization, water quality, diminishing supplies of water from aquifers, and potential for conflict over water resources (UN Water, 2020). In 2017, the United Nations estimated that globally 2.2 billion persons are without safely managed drinking water, including 785 million without even basic drinking water, and 4.2 billion without safely managed sanitation (sdgs.un.org). The Africa Water Vision for 2025 is in tandem with the African Vision for 2063, the United Nations (UN) Sustainable Development Goals (SDGs) and Kenya Vision 2030 and the current president big four agenda. Goal number 6 of the UN's SDGs has the following eight targets including provision of drinking water (6.1), sanitation and hygiene services (6.2), treatment and reuse of wastewater and ambient water quality (6.3), water-use efficiency and scarcity (6.4), transboundary cooperation (6.5), protecting and restoring water-related ecosystems (6.6), international cooperation and capacity building (6.a), and participation in water and sanitation management (6.b) (UN Water, 2018).

Given the current progress of the implementation of SDG 6 in Africa, it is unclear whether the SDG 6 water security targets will be achieved by 2030 (Network of African Science Academies, 2014). The Africa Water Vision 2025 also offers a context within which water security and sustainable management of water resources could be achieved. Science and technology and innovation are the major drivers for Africa and global prosperity and has assisted to realize the ever-increasing demands in the water sector. Africa's Agenda 2063 has recognized STI as a tool and enablers necessary for achieving the development goals. Also, the Agenda 2063 has emphasized that, for sustained

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growth, economic transformation, and competitiveness to be achieved in Africa, there must be continuous investment in new technologies and innovation in several sectors including clean energy, water, health, education, agriculture. Africa is well-placed to leapfrog to new ways of operating when it comes to technology and innovation. The Science, Technology and Innovation Strategy for Africa (STISA-2024) aimed at achieving the AU vision calls for increasing efficiency while eliminating duplications when designing and implementing STI policies nationally and regionally (African Union Commission, 2014).

Ever increasing rate of urbanisation is exacerbating water management challenges in Nairobi city and across most of the cities in the regions (WWAP/UN-Water, 2018). Accounting for urban water, combining data from hydraulic and hydrological modelling, measurements from fields and remote sensing, can improve understanding of the urban water cycle and can help to address complex and dynamic urban water challenges. Some of the knowledge gaps the study will focus on are water provision strategies in the informal settlements, inadequate or total lack of data, limited management skills of the utility staff, and unreliability of supply of water to the urban informal settlement segment.

The study context is centered around assessment of the level and extent of deployment of STI in catalysing sustainable water services provision, water services infrastructure development, utilization and management in Nairobi City County. Water provision at the NCWSC is shrouded by numerous inefficiencies which hamper effective services delivery, coupled with chronic lack of data to measure performance output and set the sector on the right growth trajectory, with limited management skills and non-adoption of contemporary management tools and knowledge contributing to continued inefficiencies in the sector and reliance on voluntary water users associations resulting in high unreliability of services and consequently promoting overexploitation of the residents from expensive water vendors or travel long distances to collect water. Deployment of emerging STI, processes and knowledge that can help to make Nairobi and Kenya at large water sector more efficient, innovative, and profitable is foreseen to be vital in the near future. Major innovative investments is required in the current platforms for science, policy and enterprise to involve/ engage, with a portfolio of long, medium & short-term programmes stimulating and promoting business incubation and investment, and aiding both national and county governments to meet environmental and climate targets, as well as social objectives. However, identifying how to invest and maximize the impacts of STI in water services start with understanding the present use of STI in the water sector, current institutional and decision-support frameworks and financial mechanisms associated with STI use in the context of water services provision, assessing STI actions already underway, and identifying promising future STI initiatives for achieving water services provision in Nairobi City. With STI actions varying from location to location, specific analysis of STI interventions in Soweto Kayole deemed crucial for better governance, access to water services, collaborations, effective regulations and

enhancement of more proactive and focus interventions and cooperation and partnership. Presently, of the over 4.8 million residents of Nairobi City County, slightly over fifty per cent have direct access to piped water. The rest obtain water from kiosks, vendors and illegal connections. Of the existing customers, about 40 per cent receive water on the 24-hour basis.

The study expected to contribute to the development of knowledge on suitable strategies for deployment of STI in the sustainable management of water services provision and water security while ensuring access to the populace. This might enhance the attainment of the Kenyan Vision 2030, NWMP 2030, 2030 Sustainable Development Goal 6 (SDG 6) and 2063 Agenda for Africa. The findings of this research might also be used to make recommendations to the relevant water sector institutions such as NCWSC, WASREB, WRA, WSTF, AWWDA, NWHSA, and MoWSI and other policy makers and relevant stakeholders on the appropriate measures that can be instituted to promote adoption and uptake the emerging STI interventions in the management, framework conceptualization and policy formulation of the water sector in Kenya and beyond.

For the realization of the identified gaps/ problems in this study, the researcher established the status of water services provision; evaluated the current and emerging innovations and technologies applicable in the urban water services provision; investigated emerging innovations and technologies infrastructure for water services development, utilization and management established and promoted by the water sector institutions; evaluated the current impacts on adoption and uptake of emerging innovations and technologies in improving sustainable management of water services and access; and finally, established the strategies in place for mainstreaming best bet practices in STI interventions into national water sector development policies and frameworks.

II. METHODOLOGY

The study used a descriptive survey design, where questionnaires were administered to gather data. The design relied on a qualitative approach by seeking to capture factual and detailed information about the views and perceptions and the dominant narratives on the role and impact of deployment of STI and how these innovations have changed the way the local residents receive water services, their living standards and work. The study employed descriptive analysis to establish opinions and knowledge about the deployment of STI in catalysing sustainable water services provision.

The researcher targeted a sample size of 327 respondents from Soweto Kayole drawn from a total sample population of 2217 connected Jisomee Mita beneficiaries focusing on the local water vendors, users, operators and community representatives and also from NCWSC, WASREB, AWWDA, WSTF. Others were Safaricom (M-PESA) who are a mobile service provider, Water and Sanitation Services Improvement Project (WASSIP), Kenya Informal Settlements Improvement Project (KISIP). A

descriptive study of 10% or above of the accessible population is sufficient to proceed with the study (Mugenda and Mugenda, 2003) which complied with our study which was at 14.75%, while Cochran (1977) assumes that a sample of 30% is adequate for a research work to proceed.

The researcher interviewed 327 respondents (14.75%) from the locality in Soweto Kayole. At the project sites, the researcher interviewed actors directly interacting with the Jisomee Mita such as local water vendors, users, operators and community representatives. The researcher also obtained quantitative data on water supply, distribution of the Jisomee Mita gadgets, and issuance of tokens as well as cost recovery, from the project sites (Operators) and also from NCWSC. Thus, both quantitative and qualitative methods were

explored but it is good to indicate that this was mainly a qualitative study hence not offering very good grounds for statistical analysis even though the study provided an array of clear indications of how deployment of STI in the water sector helps in catalyzing sustainable water services provision in Soweto Kayole. The researcher investigated correlation / relation in three broad categories: Science Technology and Innovations functionality; entrepreneurial model related functionality; and Socio-political functionality by means of administration of questionnaires and interviews to the key actors and stakeholders in the water services provision. This was then summarized in the table below with a final synthesis of the research and interlinks of findings from the five specific objectives of the study.

Research Objectives	Research Questions	Approach Deployed to Realize the Objectives	Research Tools & Instruments
To assess the status of water services provision	What was the status of water services provision?	Empirical studies; Data Collection & Analysis through administration of Questionnaires, Interviews, KII & FGDs	Survey Questionnaire, KII guide, FGD guide, Field Observations, Field Photography, IBM SPSS
To identify the current and potential emerging technology and innovations applicable in the urban water services.	What are some of current & potential emerging technology and innovations applicable in the urban water services?	Empirical studies; Data Collection & Analysis through administration of Questionnaires, Interviews, KII & FGDs	Survey Questionnaire, KII guide, FGD guide, Field Observations, Field Photography, IBM SPSS
To investigate STI infrastructure for water services development, utilization and management established and promoted by water sector institutions.	What were some of the STI infrastructure for water services development, utilization & management established & promoted by the water sector institutions?	Empirical studies; Data Collection & Analysis through administration of Questionnaires, Interviews, KII & FGDs	Survey Questionnaire, KII guide, FGD guide, Field Observations, Field Photography, IBM SPSS
To identify the current impacts on adoption and uptake of STI in improving sustainable management of water services and access.	What were the current impacts on adoption and uptake of STI in improving sustainable management of water services and access?	Empirical studies; Data Collection & Analysis through administration of Questionnaires, Interviews, KII & FGDs	Survey Questionnaire, KII guide, FGD guide, Field Observations, Field Photography, IBM SPSS
To assess the strategies in place for mainstreaming best bet practices in STI interventions into national water sector development policies and frameworks.	What were some of the strategies in place for mainstreaming best bet practices in STI interventions into national water sector development policies and frameworks?	Empirical studies; Data Collection & Analysis through administration of Questionnaires, Interviews, KII & FGDs	Survey Questionnaire, KII guide, FGD guide, Field Observations, Field Photography, IBM SPSS

Table 2.1: Research Approach Framework

III. RESULTS & DISCUSSIONS

Introduction of JM in Soweto Kayole has presented some new paradigm shift in the general perception of the residents in water services provision. There are a number of both internal and external misalignments discovered as presented below:

- Assessment of the dimensions and elements of water service provision such as perceptions of water users, convenience, affordability, availability, accessibility, quality and quantity amongst other in the study location

revealed that local residents lack confidence on the quality of water in the pipes reiterating that they have to further boil the water for drinking as the quality is doubtful or use it only for laundry; inadequate design, piping material and pipe networks as both portable water and sewerage could be mixing on the conveyance process. To make it more worrying, some residents were more confident with the quality of borehole water to that of piped water as they believe borehole water was safer than the piped water, since “the pipes pass through the sewer lines”.

- The physical installation of JM system involves connection of pipes and meter that constitute the main technology and innovation otherwise JM approach would not be able to fulfill its intended fundamental functions and operations as one of the key salient observation made was the relatively low level of functionality of the JM installations. At some of the sites visited where the JM was installed, some were found malfunctioning, meters found to be faulty, disconnected, fully vandalized or partly vandalized.
- Tenants are exploited by the business concept functionality adopted by the water utility in collaboration

with the landlords. The landlords charge between US\$ 3.13 and US\$ 4.91 on top of the monthly rent, even if water only is available for 8-10 hours per week, or sometimes less. The monthly income for the landlord or landlady to cover the water and sewerage charges amount to between US\$ 37.89 and US\$ 78.64 in the plots visited. However, according to the company’s sales records, landlords pay NCWSC on average between US\$ 8.94 and US\$ 17.87 per month for water and sewerage services hence the JM entrepreneurial model currently produces a considerable over-pricing for the end consumers.

Plot Number	Number of JM systems installed	No of rented houses within a plot	Amount of water bill paid by tenants to landlords per month (US\$)	Total amount paid by tenants to landlords (US\$)
1	1	12	4.47	53.64
2	1	16	4.91	78.56
3	1	10	4.74	47.4
4	1	13	4.74	61.62
5	1	20	3.13	62.6
6	1	9	4.47	40.23
7	1	15	4.02	60.3
8	1	13	4.47	58.11
9	1	8	4.74	37.92
10	1	12	4.91	58.92

Table 3.1: Water Users Prices in 10 Mapped Plots in Soweto Kayole (Obunga, P. et al., 2021)

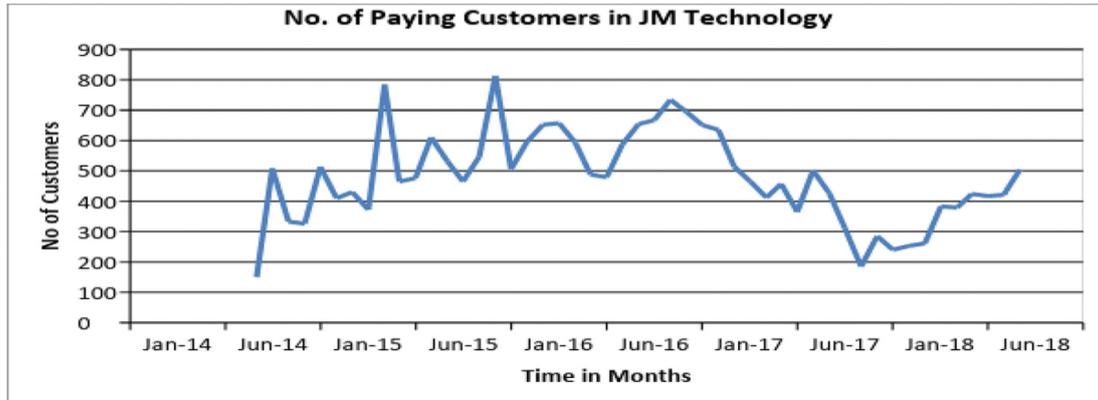


Fig. 3.1: Number of paying customers on JM connections, per month, 2014–2018. Source: NCWSC

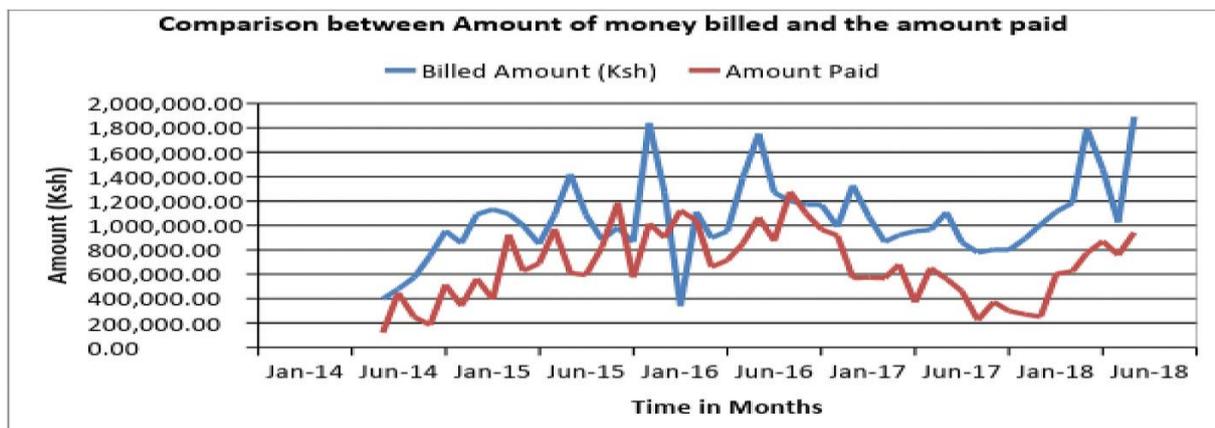


Fig. 3.2: Billing and payments collected through JM per month, 2014–2018. Source: NCWSC

- The JM technologies and innovations took into consideration the political economy of low-income areas and informal settlements even though socio-political misalignment of the JM system noted as the mandate of NCWSC terminates at the issuance and installation of meters and thereafter revenue collection while not considering protection of water consumers from exploitation by the landlords as the law prohibit WASREB and NCWSC to control and set fixed water prices.
- Internal misalignment of technology and innovation approach, strategy and routine methodology adopted by JM system comes into conflict with already established and dominant routines, approaches and technologies by NCWSC, AWWDA and WASREB. Making concrete comparison or reference to the strategy or approach adopted by the JM system, the researcher observed instances of internal misalignment within the JM ecosystem, of which the most striking one is that of water rationing by the water utility.

Figure 3.3 below shows a conceptual framework or scheme about the JM in Soweto Kayole depicts reality on the ground as can be seen, the informal water sector is not included. The landlord holds the connection and pays per actual consumption but charges her/his tenants as a monthly fixed charge. The JM, in reality, favours the landlords who are the rich segment, instead of the poor end water consumers.

Despite the water challenges being faced in the urban informal settlements, through deployment of STI, solutions are within reach as technology and innovation can play a vital role in creating sustainable solutions for both water provision / supply and security. STI should be coupled with partnerships, financing and business models for effective implementation as depicted in figure 3.4 and figure 3.5 below.

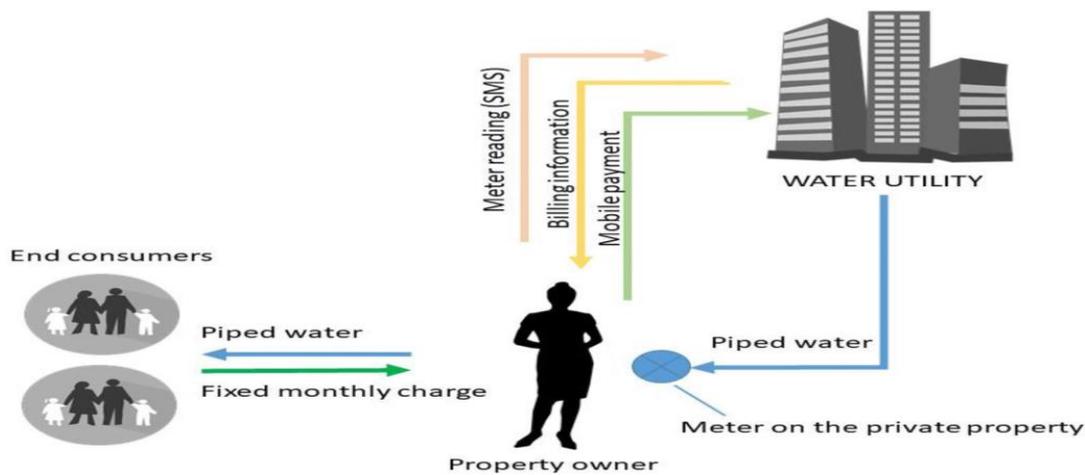


Figure 3.3: JM Architecture

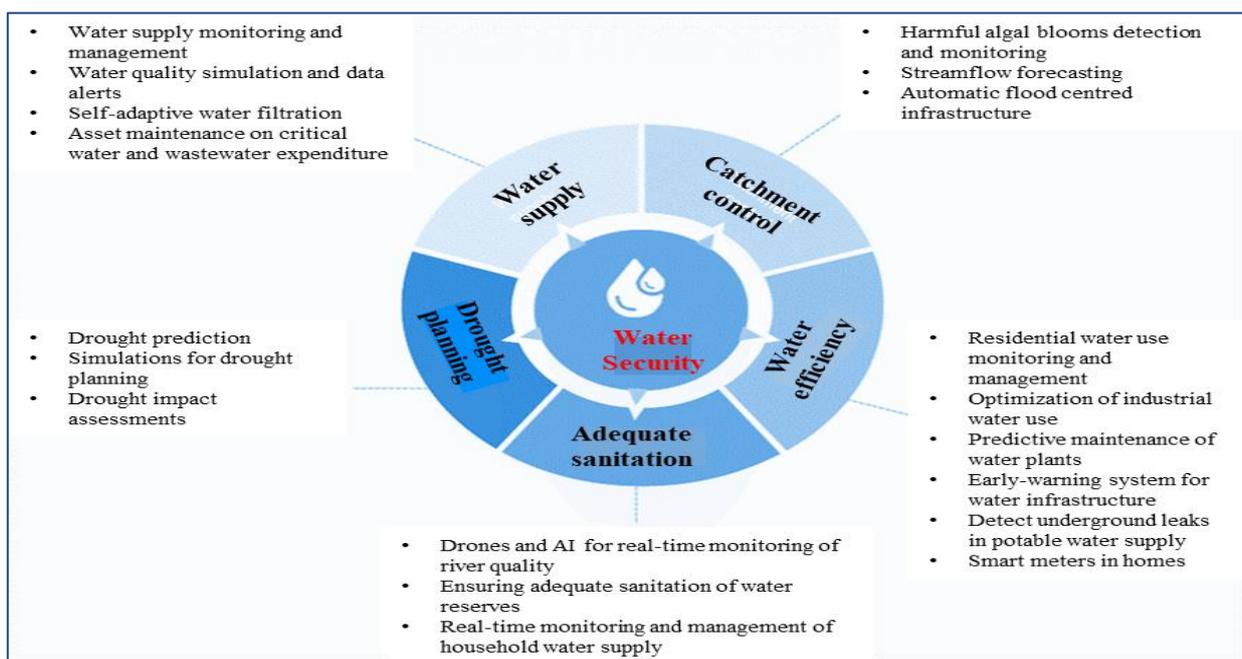


Figure 3.4: Role of STI in promoting water services and sustainable management

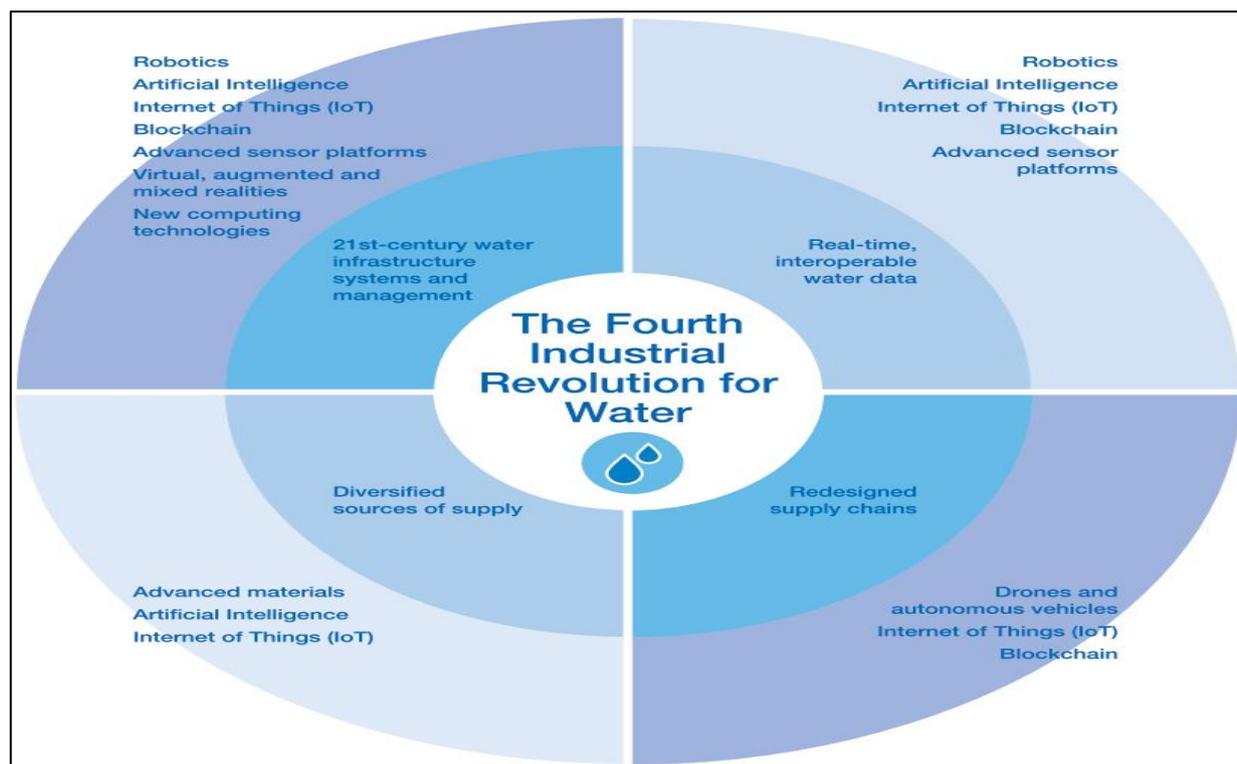


Figure 3.5: 4IR innovations for water and sanitation. Source: World Economic Forum, 2018.

Critical interface misalignment			Internal misalignment
Technology/ Innovation	Entrepreneurial model	Socio-political	
12.5% of the 80 JM installations visited were found to be non-functional [10]	The progressive tariff can push larger consumers with many tenants into a higher price bracket	Most connections serve properties with small plots and influential landlords	The overall shortfall of raw water provision in Nairobi City County forces NCWSC to ration water supply within the 9 zones in Soweto Kayole, hence counteracting and reducing the benefits from the investments made in JM distribution Through the National Government, the Nairobi Metropolitan Services [NMS] managed to sink a number of boreholes which the residents fetch for free for their domestic use. Lack of effective coordination at the NCWSC resulted to the destruction of newly installed water infrastructure during construction works in the area.
Non-durable meters, high maintenance need and unavailable spare parts reported by some users	The entrepreneurial model of billed consumption favours the landlords who cover costs using flat rate	Formal land ownership required for connection but landlords/ ladies are often not reachable and non-responsive leading to low commitment	
Software maintenance and data backup system are costly and not available in the country	The low accessibility (8–10 h per week) makes it difficult to out-compete the private vendors/ cartels	Impossible to regulate end-consumer price since this is re-selling on private property	
Due to water rationing, there is water supply in the JM system on average 8–10 h per week	Parallel meter readings also done by NCWSC reinforces distrust between users and the utility	JM technology is resisted by local water “cartels” who try to discredit the system	
More containers required by the tenants due to irregular & unreliable water supply	Pricing and how the metering works are not clear to customers	Utility staff prone to attack when visiting the site due to poor security and distrust	
Water quality is disputed due to illegal connections, inadequate plumbing and disruption of the networked infrastructure by road construction	Non-willingness to pay by some landlords remains a problem	A history of distrust between the local users and the regime actors makes the relationship tense;	
		water is free notion making some users sort to non-payment and illegal connections	

Table 3.2: Summary of all misalignments observed in JM Project (Obunga, P. et al., 2021)

IV. CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

A. Conclusion

The study deduced that water services provision has to some extent improved as a result of adoption of the JM project which is a hybrid infrastructure combining a new piped water networks with digital technologies with functionalities such as self-meter reading and mobile-phone-based billing, payment, and querying systems in Soweto-Kayole informal settlement in Nairobi City. The success of the project is attributed to the NCWSC as the implementing institution and WB as the financier together with other stakeholders. JM is a STI system that epitomizes the complex, localized power dynamics and infrastructural work resulting from attempts to incorporate a peripheral community into a centralized system operated by NCWSC, built by AWWDA and regulated by WASREB. The study portrayed that JM has a unique planning features which have been deemed appropriate in a number of ways by its users and the multiple intermediary actors, reflecting their socio-economic and political as usual dynamics and urban rhythm.

B. Recommendations

JM system and similar innovations with functionalities such as of billing and customer care system would need to be explicit on how it meets the criteria for fit for purpose; offer the best price-performance ratio of the alternatives considered; fit in with the overall strategy of the utility that is implementing the social connection policy; and delivered within a specified timeframe. Measured against these metrics, then, a business case for expansion and scale-up of JM to other informal settlements in Nairobi City County can be laid out as already envisioned by NCWSC. Further, below are some key recommendations based on the research findings:

Infrastructure development and community engagement for pro-poor: To increase access to reliable, affordable and sustainable water supply and sanitation services to the low-income localities, NCWSC need to undertake network intensification activities such as expansion of piped water supply and sewerage network through the extension of primary and secondary distribution pipes. This should be done through all-inclusive participatory approach including the involvement of communities' in decision making and planning. The local residents who are final beneficiaries should be consulted before project implementation in order to ensure ownership. Many community members, such as youth groups participated in the construction of the water and sewer networks.

Financial, STI enabled pro-poor innovations and locally-available technology: Various financing mechanisms aimed at supporting efforts to supply improved and affordable water and sewerage services to the low-income localities should be explored, piloted and expanded. An innovative financing arrangement by commercial banks should leverage additional resources and ensure sustainability and effective use of resources. The innovative financing arrangement for JM by the WB provide two distinct potential

benefits to the urban water sector and leverages additional financing from other players, such as commercial financiers and, it contributes to sustainability and effective use of resources including locally available mobile phones based systems.

Financial reality of the low-income communities': The study strongly portrayed the willingness of low-income residents to subscribe and make remittance for improved water services if it is delivered to them consistently, reliably and affordably. However, one of the key barriers for households in accessing a piped network is the initial connection costs. Implementing WSS projects in the low-income areas requires that NCWSC to understand the target communities' financial realities and expenditure patterns. Socio-economic assessments and studies that capture household incomes, expenditure, validated data, should guide NCWSC to design a scheme that suits the fluctuating incomes of self-employed and informal sector earners. The financing of JM technology oriented and innovations have made WSS services affordable to low-income households through access to subsidized micro-loans and staggered payment of consumption bills. The low-income households come together to borrow the money needed for the initial cost of installing a metered stand pipe within their residential compound; and can get access to credit facilities to offset the initial costs of connection and, through a flexible payment scheme, repay the loans together with the monthly water bill over an agreed period.

Robust and sustainable investment planning and pro-poor policy approach: A corporate policy supporting extension of services to low income settlements is requisite for the success of the emerging technologies and innovations projects. A policy approach ensures scalability and provides a channel for internal budgetary allocation or external financing. To target the slum urban poor, the geographical targeting approach is applicable and highly recommended for the Soweto Kayole and other informal settlements with similar characteristics. A part from this financing from WB, utilization of the Water Services Trust Fund 'Maji Data' would be useful to supplement and be used for expansion purposes. As mentioned earlier, a local presence of the water service provider is crucial at the settlement level. This innovative approach combines a Social Connections policy with OBA, provided through the Global Partnership on Output-Based Aid, to enable low-income households to access subsidized micro-loans from commercial banks. The performance risks are taken by NCWSC that is eligible for a partial OBA subsidy of about 50% on delivery of outputs to refinance a part of the loan and keep the debt repayment affordable for poor households.

Mainstreaming and strengthening of the existing public structures and institutions: Use of existing institutional structures is required within the devolved water service delivery framework which allocates the responsibility of provision of water and sanitation services including storm water management as the function of county governments. Within WSPs, a dedicated department and team need to support the utility's activity in low-income areas.

Strengthening of the team/department focusing on the low-income areas is essential to ensure the right skill mix with regards to the advancement in technology and innovation.

C. Suggestions for Further Research

This research study scope was limited to the JM innovations in Soweto Kayole while there are other technologies and innovation in the water services provision. There is still need to conduct more comprehensive research on the STI initiatives similar to JM and assess their applicability, replicability, scale up and viability so that all the informal settlements in Nairobi City County can get access to safe drinking water. It is important to undertake more in-depth studies on the emerging technologies and innovations deployed in catalyzing sustainable water services provision especially tailored to suit the unserved and underserved in the informal urban settlements.

ACKNOWLEDGEMENT

We are glad and grateful to the following: Nairobi City Water and Sewerage Company (NCWSC), Soweto Kayole Community, World Bank (WB), The Water Services Regulatory Board (WASREB), Athi Water Works Development Agency (AWWDA), National Commission for Science Technology and Innovation (NACOSTI) and The University of Nairobi (UoN) for providing the necessary information, guidance and creating conducive and enabling environment during the research study period and productive discussion.

Authors Contributions

Patrick Ouma (P.O.O) conceived the idea and researched the project. Prof. Ezekiel Nyangeri (E.N.N) and Dr. Simpson Osano (S.N.O) supervised and co-wrote the manuscript. P.O.O conducted field data gathering, synthesized and analysed all the related data and wrote the original draft. E.N.N and S.N.O reviewed, edited and were the research supervisors. All authors discussed the results and contributed to the preparation of the manuscript.

Conflict of Interest

The authors declare no conflict of interest

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