Water Practice & Technology

IWA PUBLISHING

Water Practice & Technology Vol 00 No 0, 1 doi: 10.2166/wpt.2024.223

Misalignments in prepaid water technology: findings from urban poor settings of Kampala, Uganda

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ABSTRACT

Progressive urban water utilities in developing countries have, since the mid-2000s deployed prepaid dispensers (PPDs) to provide reliable and equitably priced water services to slum residents. This paper reports on a study that evaluates the performance of the PPDs first deployed in the slums of Kampala in 2006 by the National Water and Sewerage Corporation (NWSC), Uganda's main urban water utility. By February 2020, over 1,400 PPDs were installed in 20 slums, serving residents through over 33,000 access tokens. Data were collected in 2019/2020 through 275 household questionnaires, 17 key informant interviews, and 8 focus group discussions. The main finding was that although the PPD technology has achieved a relatively high diffusion rate, water drawn therefrom was an average of a paltry 7 litres per capita per day, meaning that many slum residents still rely on other water sources of doubtful quality. Key misalignments include misappropriation by local middlemen, who inflate the prices; high levels of technical malfunctions; and the utility's overreliance on international development financing for asset maintenance and expansion. NWSC should mainstream the pro-poor service department and build the necessary capabilities to ensure better technical functionality of the PPDs, including setting up smart partnerships where necessary.

Key words: prepaid dispensers, slums, technological innovation, user experiences, water services

HIGHLIGHTS

- The study brings out the end-user voices which have not been coming out in previous studies.
- The study captures the trajectory of implementing prepaid metering over a 15-year period.
- The study blends management perspectives with user experiences in the implementation of this prepayment technology.
- The study provides evidence of whether the prepaid metering technology is achieving its intended objectives.

INTRODUCTION

Sub-Saharan countries are experiencing an escalation of 'slum' populations in urban poor settings (Musoke *et al.* 2018). For this paper, a slum is a high-density, low-income urban informal settlement characterized by poor housing with most residents defined by poverty, low income, miserable living conditions devoid of standard social amenities such as reliable piped water supply, road network, sanitation, and drainage (Renzaho *et al.* 2020). Other common features include poor solid waste management; poor housing conditions; unsafe food; poor vector and vermin control; and inadequate personal and general hygiene (Musoke *et al.* 2018; Ahabwe *et al.* 2021).

Urban water utilities experience challenges in extending water services to these low-income urban settlements. The main barriers may broadly be categorized as (Kayaga *et al.* 2020): (i) economic and financial constraints, including the high cost of investment capital; (ii) physical/technical barriers – for example, unplanned physical layouts and difficult terrain that require unconventional service delivery technologies; (iii) structural/legal constraints, whereby slum settlements are declared illegal and/or are not prioritized under official definitions of city boundaries, planning approaches and property rights; and (iv) institutional barriers, such as the negative mindset of utility staff about serving the urban poor, inadequate capabilities and capacity of service providers to cope with the complexities of servicing low-income urban settlements. Hence, many urban water utilities in

low-income countries achieved Millenium Development Goals (MDG) targets for drinking water supply in slums mainly through the provision of public standpipes/kiosks connected to piped water distribution networks (Kayaga *et al.* 2020).

These water supply delivery systems cannot satisfy the Sustainable Development Goals (SDG) targets of 'safely managed' water services, i.e. drinking water from an improved source that is accessible on premises, available when needed and free from faecal and priority chemical contamination (WHO & UNICEF 2021). To overcome the aforementioned barriers and transit towards safely managed water services, prepaid dispensers (PPDs) have been applied by several progressive water utilities in cities of low-income countries. The National Water and Sewerage Corporation (NWSC) of Uganda is one of the earliest utilities that applied the PPD technology in its biggest service area of Kampala.

It is estimated that about 60% of Kampala's 1.6 million dwellers live in urban poor settings (UBOS 2017). The conventional water supply approach in Kampala, just like in many other African cities, usually excludes a group of water users due to their circumstances such as lack of land holding rights, or inability to afford individual new connection fees. The PPD technology offers an important avenue for rectifying these inequalities. Originally tried out in Kampala in the early 1920s, prepaid water distribution was (re)introduced in 2006 with the purpose of enabling over 200,000 low-income people to access safe water at a social tariff. The prepayment system is modelled around a public standpipe, accessible by whoever has a prepaid electronic 'token'. Customers buy credits from appointed agents, who load the credit onto tokens and can then access safe water cheaply, whenever it suits them, from any prepaid standpipe, without being affected by distorted vendor pricing and irregular service hours (Heymans *et al.* 2014).

Implementation of the PPD technology has not been scaled up and scaled out as expected. In implementing the PPD technology in Kampala's slums, NWSC, the water service provider has faced numerous challenges such as those concerned with the socio-political, business model, technical functionality, and internal misalignment dimensions (Blomkvist *et al.* 2020). To explore these challenges, this study investigated user perspectives on the performance of PPD technology in improving the delivery of equitable and affordable water services to dwellers of low-income urban settlements of Kampala. The next section of the paper describes the background to this study; the third section describes the conceptual framework applied for the study, and the methods used; the fourth section presents the findings and discussion of the Kampala study in the context of a related study in Nairobi, Kenya; and finally, the last section provides conclusions, recommendations, and implications of the study.

BACKGROUND TO THE STUDY

The methodology applied in this study was adapted from a similar one done in a sister water utility of Nairobi City Water and Sewerage Company (NCWSC), in neighbouring Kenya. The operating environments are similar, in that both utilities operate in the East African Community's countries' capitals, with high proportions of low-income urban settlements. Furthermore, NWSC (Uganda) and NCWSC (Kenya) collaborate closely under the UN-HABITAT-organised Water Operators' Partnerships (WOPs) umbrella. The first subsection presents key findings from the NCWSC-Kenya study, which will form a basis for comparing with findings from the NWSC-Uganda study. The second subsection provides the context of urban water services in Kampala, Uganda. The study in Nairobi was conducted about 3 years earlier than the Kampala one, as reported by Blomkvist *et al.* (2020).

PPD: Key findings from the Nairobi case study

In 2009, NCWSC, the service provider in Nairobi City, Kenya expanded its scope of operation by integrating the informal settlements (WSUP 2017). The establishment of an Informal Settlements Department (later redesignated as a 'Region') enhanced water service provision to the urban poor. This initiative was supported by the promulgation of Kenya's 2010 constitution, whose article 43 (1), and Kenya Vision 2030 guarantee every citizen the right to access basic services such as water and sanitation (Government of Kenya 2010). This legislation required NCWSC to come up with sustainable innovations to effectively provide water to all residents of Nairobi City, including informal settlements.

This study, conducted in 2018 in three slum areas of Nairobi, evaluated NCWSC's innovative application of PPDs to improve service provision to residents of low-income urban settlements in Nairobi. Thirty PPD installations were observed, and 17 interviews were held with users/vendors being served by these PPDs. Additionally, nine interviews were held with key informants from NCWSC, Nairobi City Council, and the Water Services Regulatory Board (WASREB), the water regulator. Drawing from a conceptual framework that is grounded in

Innovation Studies (shown in Figure 2), the study evaluated innovation activities implemented by regime actors to provide water services to residents of low-income urban settlements, without expanding the system in a traditional manner (Blomkvist *et al.* 2020). This conceptual framework, which was adopted for the Kampala study, has been described in the section Conceptual framework and methods.

Issues arising from the interface misalignment identified by the Nairobi study were related to the technical functionality, socio-political context, or business model. Signs of misalignment related to technical functionality included a lack of public land to site the PPDs; unreliable and intermittent water supply; inadequate operation and maintenance of infrastructure; and vandalism and theft of infrastructure. In the socio-political context, issues included appropriation by politicians; ethnic tensions and local power struggles; anti-establishment sentiments; and lack of public awareness about the right to access to WASH services. With respect to the business model, issues identified included appropriation and price hikes by the caretakers; difficulty in regulating private re-selling; and competition with informal water vending (Blomkvist *et al.* 2020).

In the internal environment of NCWSC, a key sign of misalignment was the competition that exists for the inadequate resources between the traditional water supply delivery systems and the PPD route, which becomes more critical when there is inadequate water supply. NCWSC tried to overcome the unreliable water supply situation by installing elevated tanks at the PPDs, which required the water utility to deliver water to the tanks using tanker trucks – an area of operation outside the core business of the company. Secondly, there were difficulties in obtaining the required spare parts for the different types of PPDs, which resulted in long downtime of the PPDs. Thirdly, the creation of a separate, pro-poor department operating under different conditions, and working with different business and technological models, created ground for conflict between the conventional water utility business stream and the pro-poor department (Blomkvist *et al.* 2020).

The context of urban water services in Kampala

Uganda's urban water and sanitation (WASH) subsector has undergone a series of reforms since 2001 to ensure that services are provided with increased performance and cost effectiveness while reducing the burden on the taxpayer. Such sectoral reforms included commercialization of WASH service operations, promotion of private sector participation in the delivery of services, institutional capacity development, formulation of business planning tools, introduction of performance and management contracts, and pro-poor service delivery for equity in service that entailed tariff review, among others (NWSC 2002).

Efforts have also been made by NWSC to improve service delivery in the informal settlements of the capital, Kampala (Appelblad & Nilsson 2013). However, water/sewerage services in Kampala, just like in other parts of the developing world, are characterized by a dichotomy between regular (connected) customers and those marginalized and unconnected, typically low-income people often residing in informal settlements (Valverde Gonzáles 2020). Informal and private services prevail in these marginalized areas, often exhibiting great ingenuity in innovative practices, which may include hybrid solutions and sometimes illegal connections. However, the growth of urban informal settlements is faster than planned infrastructural service delivery, including services for safe water and proper sanitation; leaving a gap that is often exploited by informal service providers, and often with serious health outcomes for such populations (van Welie *et al.* 2019).

NWSC, with the support of the Water and Sanitation Programme – World Bank, commissioned a participatory study to identify sustainable management options for improving WASH services in Kampala's informal settlements (NWSC 2002). The study showed that apart from increasing the distribution network and sanitation coverage, effective service delivery required an integrated approach that also takes due consideration of the socio-economic environment within which services are to be rendered. This study recommended the formation of a Community Management Department within NWSC, to be operated in collaboration with other stakeholders, including Kampala City Council, non-governmental organizations (NGOs), and the community (NWSC 2002).

In 2006, NWSC set up a dedicated pro-poor unit to provide better services in informal settlements. The objectives of the pro-poor unit were to (i) subsidize tariffs; (ii) reduce connection fees; (iii) introduce and promote various types of public water points (PWPs); and (iv) densify and expand piped scheme networks in low-income settlements. The PPD is an innovation introduced by NWSC to enhance water supply services in informal settlements. Figure 1 shows key components of the PPD technology.

By February 2020, NWSC had 1,400 PPDs, over 33,000 access tokens issued to households in 20 low-income urban settlements, and 25 strategically located vendor points where users recharge credit for water use. Average

Figure 1 | (a) Prepaid water dispenser and (b) sales point for water credit (consent granted).

consumption was about 66,500 m^3 for an estimated 300,000 residents within the PPDs' catchment area, which translates into a partial average of 7 litres/c/d (NWSC 2020a, 2020b). By installing PPDs, NWSC aimed to cut out middlemen, so that more households would receive direct services, and pay the more affordable social tariff – fixed at 25 UGX per 20-litre container (popularly known as the jerrycan), compared with the vendors' prices of at least 200 UGX per jerrycan (NWSC 2018). It is not clear, why, despite the subsidized tariff, and the low water service coverage in Kampala slums, PPMs are underutilized. This study contributes to the evaluation of the PPD technology. The next section describes a conceptual framework that has been adopted for this study.

CONCEPTUAL FRAMEWORK AND METHODS

We adopted a conceptual framework as applied by Blomkvist *et al.* (2020) in a similar case study on prepaid metering conducted in Nairobi. Hence, our study is anchored in the large technical systems (LTS) history of technology tradition as well as Innovation Theory, and the so-called multi-level perspective (MLP), emphasizing the interplay between niche innovations, regime level transformation, and the wider physical and cultural landscape (Geels 2011). In our study, NWSC, the service provider is the regime actor. The goal of any regime actor is to ensure what may be termed as intra-systemic alignment of system parts (Blomkvist & Nilsson 2017). In the case of prepayment systems in Kampala's urban poor settings, alignment is ideally about the level of synchronization (system-fit) between the service provider and the broader societal environment, as well as with local innovation activities (Geels & Schot 2007).

Service providers aiming to reach the hitherto not-yet-served customer base at the community level first need to decide on an appropriate strategy. There are two basic approaches: adopting a focused strategy or a dual (ambidextrous) strategy (Utterback 1994). A focused strategy involves the service provider concentrating on her core capabilities, technologies, and business models, and trying to grow by vertical integration (Blomkvist & Nilsson 2017). Alternatively, the dual strategy means that the service provider creates an 'ambidextrous organization' whereby a new 'exploratory' unit is established while maintaining the traditional, 'exploitive' parts of the service (Kraner 2018; Lis *et al.* 2018; Blomkvist *et al.* 2020).

Referring to the conceptual framework (Figure 2), the *critical interface* is defined as the boundary area between the service provider/the regime actor and the unserved/unconnected users at the local level (Blomkvist &

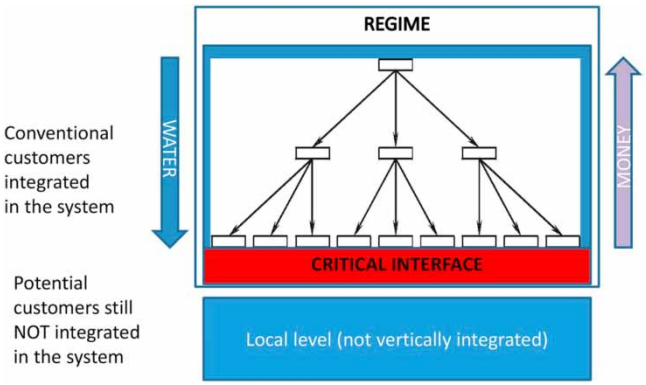

Figure 2 | Conceptual framework used for the study (adapted from Blomkvist *et al.* (2020)).

Nilsson 2017). *Critical interface* refers to a physical and institutional space at the edge of the large systems where service providers and other local actors outside of the regime such as entrepreneurs negotiate an innovation process (Blomkvist *et al.* 2020). For the regime actor to expand operations, there must be a balance between the services provided and the return flow of money across this critical interface. When potential customers cannot adapt to the dominant system logic, innovation activity must take place in the *critical interface*. Innovation activity needs to focus on solving problems arising from misalignment between the users and the service providers – i.e. the regime.

For this study, we investigated two basic types of misalignments: misalignment between the innovation (PPDs) and contextual factors at the local level (interface misalignment) and misalignment inside the water regime (internal misalignment). Concerning interface misalignment, we used three analytical categories: socio-political misalignment; business model related; and misalignment relating to technical functionality. We also used the concept of the *critical interface* as a lens for understanding the misalignment between the local level and the regime level and the innovation activities that the actors undertake to alleviate these misalignments.

A mixed methods methodology was applied for this study. We adopted a cross-sectional design to address the research questions and used both qualitative and quantitative approaches for data collection, i.e. key informant interviews, household surveys, focus group discussions (FGDs), and field observations. The study was undertaken in selected slums located in the five administrative units of Kampala Capital City Authority (KCCA) in Uganda, namely Kampala Central, Lubaga, Kawempe, Nakawa, and Makindye municipalities. Two slums where PPDs are operational in each division were selected making a total of 10 slums for the study. These geographical areas were selected because the prepaid technologies were first piloted here and have been operational since their inception in 2006.

The study adopted two sampling methods, namely, cluster sampling and purposive sampling. Cluster sampling was applied in three tiers whereby the five divisions of Kampala formed the primary cluster. The slums in each division formed the secondary cluster while the households with PPDs in those selected informal settlements formed the tertiary cluster. The main field work took place from July 2019 to March 2020, with follow-up interviews in February/March 2023.

The research project sought ethical clearance from Uganda's National Council for Science and Technology (Reference Number: SS315ES). Research assistants recruited were trained in ethical considerations such as respect for persons, informed consent, benevolence, and confidentiality principles.

After data-cleaning, the qualitative data was processed and analysed. This process involved familiarization with the data through review, reading, and identification of themes, recoding and exploration of relationships between different study variables. Quantitative data was numerically analysed with statistical procedures to carry out generalization of the findings. Qualitative data helped to describe multiple realities by providing descriptions and user experiences.

RESULTS AND DISCUSSION

Key informant interviews were held with six senior management members of NWSC; six field staff from NWSC's pro-poor unit; two management staff from NWSC's Kampala Water Office; a senior staff from the Directorate of

Public Health and Environment of Kampala Capital City Authority (KCCA); one senior staff from Uganda's Ministry of Water and Environment; and a manager at Community Integrated Development Initiatives (CIDI), a local NGO involved in water and sanitation for the urban poor. Eight FGDs were conducted, and attended by homogeneous interest groups of users of the PPDs. Of the 300 questionnaires sent to households in the sampled settlements, we received 275 usable responses, giving a response rate of 92%. We also held eight FGDs in seven low-income urban settlements. The distribution of the household questionnaires and FGDs is shown in Table 1.

Table 1 | Household interviews and FGDs conducted

Division	Ward	Household questionnaires	Focus group discussions
Central	Kagugube	27	1
	Kamwokya	21	1
Nakawa	Mutungo	29	1
	Luzira	27	1
Kawempe	Bwaise II	38	2
	Kazo-Angola	34	0
Makindye	Kibuye II	28	1
	Bukasa	23	0
Lubaga	Ndeeba	24	1
	Kabowa	24	0
Total		**275**	**8**

Findings and discussions are categorized according to service interface and internal misalignments, as highlighted in the applied conceptual framework (Figure 2).

Interface misalignment

Interface misalignments relate to the inconsistencies in the PPD system set up that leave unserved sections of targeted consumers and impede the effectiveness of PPDs in providing universal access to safe water in the slums of Kampala.

Socio-political misalignment

The PPD technology installed in Kampala slums is designed to be communally used. However, fieldwork findings highlighted the challenge of denied access to PPDs. Some caretakers of PPDs, who in most cases offered land on which the PPDs sit, were found not to be in good relationships with community members, barring some of them from using PPDs. Many PPDs are locked into small chambers and deny access to some users. For instance, in Kibuye II Ward (Makindye Division), one caretaker of PPD had fabricated a chamber around the PPD and barred people to access it using their own prepaid tokens. Instead, they had to buy water directly from the caretaker, using his token. He went on to employ a full-time attendant to sell water to the community. Similarly, in the Kipamba zone, the PPD was found inside a building, with restricted opening hours. The neighbour observed that those who come to access the PPD past 7 p.m. when the caretaker has left would find the door closed.

In this connection, one of the NWSC frontline staff had this to say:

'There are people who come with dirty jerricans, dirty saucepans and wash them at the PPD leaving behind the dirt, the food remains there. Now when the caretaker says you have dirtied this place, please don't come back here, in such instances, we receive complaints of denied access from those stopped'.

It was stated that some people in the community have 'hijacked' the services with the intention of making business through selling water. During the FGD held in the Bwaise II ward, participants noted:

'*While the PPDs are based on a model of communal use whereby whoever has a token is free to use it, some landlords have put the machines in their fences, and they do not allow people to fetch water*'.

Indeed, during our transect walks, some PPDs were found under the chamber and lock. A similar sentiment was expressed by key informant from KCCA thus:

'*NWSC should establish mechanisms for management of the prepaid meters especially in terms of breaking the barrier of restrictions of the privatizations by the landowners so that it is a free good, so that anyone can access so long as they have a token*'.

Extortion of money by NWSC staff before any repair services was mentioned during FGDs. While NWSC technicians are expected and facilitated to service PPDs, participants told us that sometimes technicians demand for money from end-users for operation and maintenance (O&M) services:

'*Sometimes our tokens are stolen by people who use them to fetch water. The other challenge we face is that of technicians asking for money from us to repair the meters yet NWSC technicians are supposed to repair them free of charge*'.

Business model misalignments

Household survey results (Table 2) show that many PPD users (32% of respondents) are not satisfied with the way the utility service provider responds to their complaints. The reasons advanced included delays to repair faulty PPDs, charges for operation and maintenance services which are otherwise meant to be provided by the utility; unavailability of spare parts and accessories, particularly user tokens; and conflicts related to communal use, among others.

Table 2 | Monthly expenditure on water among slum dwellers in Divisions of Kampala

		Division				
Variable		**Central**	**Kawempe**	**Lubaga**	**Makindye**	**Nakawa**
Satisfied with NWSC's response to user complaints?	Yes	25%	20%	20%	60%	35%
	No	75%	80%	80%	40%	65%
Monthly expenditure on water	Less than UGX 5,000	5%	20%	25%	15%	10%
	UGX 5,000–10,000	35%	25%	10%	55%	35%
	UGX 10,001–30,000	35%	45%	50%	25%	40%
	UGX 30,001–50,000	10%	10%	10%	5%	15%
	Above UGX 50,000	15%	0.0%	5%	0.0%	0.0%

The survey results also show that most respondents prefer to recharge their tokens with credits in very small amounts, below UGX 5,000 (USD 1.35). Findings indicated that 55% of respondents in Makindye Division load piece-meal amounts of money of less than UGX 5,000 ($1.35) when recharging their token. On average, users recharged their tokens twice a month. These low volumes of water use do not create economies of scale, one of the key drivers of adopting the PPD technology, whereby each PPD unit costs about $1,000.

The highest amount recharged by the water user was UGX 50,000, the minimum was UGX 1,000, and the mode was UGX 5,000 – implying great flexibility in payment terms. Token loadings illuminate the consumption behaviours of the communities, with a preference for limited use of clean water. This is corroborated by the low total monthly consumption registered on all prepaid meters. Indeed, FGD participants in Ndeeba Ward, Lubaga Division highlighted the ease of loading small currencies as an attribute of affordability.

However, households with no tokens have to buy water from those having PPDs in their compounds, at UGX 100 per 20-litre jerrycan. However, access to top-up points of the prepaid tokens is a limiting factor. In Bwaise II ward (Kawempe Division), FGD participants noted there was only one person authorized locally to load credit on their tokens, although NWSC staff showed up on motorcycles once per week to assist in loading credit on their tokens.

According to NWSC, interested households submit applications and thereafter pay an initial credit of at least UGX 5,000 to get tokens registered in their names. Tokens cost UGX 15,000 ($4). The lifespan of a token is dependent on users' handling. However, there was no mechanism to track tokens that are active in the field,

those that get lost, or, for some reason, become dysfunctional (NWSC 2020a, 2020b). It is also not possible to tell which household member already picked a token and therefore different persons from the same household can apply for a token. It is no wonder, therefore, that tokens often experience stock-outs.

Survey and FGD results showed that many deserving households in the slums did not have tokens and hence did not enjoy the benefits of the PPD technology. NWSC has an ongoing programme for the issuance of tokens to those who apply for them. After that, a token is programmed into the software and issued to the owner. While some households had since lost the tokens, others had not applied for them from the onset. In other instances, token owners had difficulty in accessing vendors authorized to recharge credit. Hence, they must use tokens owned by landlords who often charge higher amounts.

In Luzira Ward in Nakawa Division, few households had tokens. Furthermore, one PPD caretaker restricted access to the PPD and sold water at UGX 100 per 20-litre jerrycan. The caretaker justified his actions that he takes full responsibility of looking after the PPD and sometimes facilitates the transport of those who come to repair it (Figure 3).

Figure 3 | PPDs under lock by caretakers who control access in Bwaise II Ward, Kawempe Division.

Similar issues arose in the Nairobi City case study, where community groups, such as the youth or women groups owned the PPDs and resold the water at a price that was between 10 and 17 times the official PPD price, on top of obtaining a 40% commission on the water credits recharged to any ATM card (Blomkvist *et al.* 2020).

During the FGD in Kamwokya II Ward, Central Division, community members lamented about the rampant theft of tokens within the community and the apparent inability of NWSC to track down the lost tokens. One member observed:

'the tokens were registered using our national identity cards but the challenge is that even when somebody steals your token, they still can use it without being apprehended, so what was the essence of registering these tokens?'

Another one retorted:

'tokens do not break per se but when you insert the key in the machine, it does not read it. These keys are not repairable so we always have to buy new ones'.

In Bwaise II, Kawempe Division, FGD participants noted that the vendor who loads for them credit on their tokens is usually away, and users needing tore-load credit often got stuck (Figure 4). Overall, the business model of the PPD seems to be less developed. While 1,493 PPD installations are currently installed in various slums, users, even with credit on their tokens, still find a plethora of bottlenecks in accessing the services at the official pro-poor tariff. In the desired situation, more users would increase economies of scale of the PPDs, hence reducing the unit cost of water.

Figure 4 | Tokens, a key accessory to access safe water on PPDs. Author photos taken in Bwaise II, Kawempe Division.

Overall, the PPD business model is more viable in Kampala slums compared with its application in Nairobi slums, where, in the latter, it is grossly undermined by a service environment that is characterized by erratic water supply. This makes it difficult for the PPD model to compete favourably with informal water vending (Blomkvist *et al.* 2020).

Technical functionality misalignment in Kampala

The findings highlight several misalignment issues on the technology that reportedly hinder access to affordable safe piped water. Frequent breakdown of PPDs was found to be a big hindrance to users' reliable access to clean water. Frequent breakdowns were raised by 76% of the respondents.

One key informant from NWSC had this to say on technical misalignment:

> '*We have the hardware challenges which are to do with the meter failures and breakdowns. We also have the software challenges for instance, some PPD caretakers deny access to water to some people, for various reasons; some say people come and spoil their compounds, others say that when users come, they overwhelm the meter, and it gets spoilt. So, they have all sorts of reasons*'.

Another issue is the robustness of the PPDs. For instance, 57% of respondents noted that PPDs have water running uncontrollably due to faulty valves. This is like the Nairobi case, which, for the first generation of PPDs, found extreme sensitivity to pressure variation. This issue was addressed by installing elevated storage tanks for the PPDs, to ensure continuous water supply. In the case of water rationing, NCWSC were forced to deploy tanker trucks to fill the elevated water tanks, which created further problems, such as poor operation and maintenance of the water tanks, and poor water quality (Blomkvist *et al.* 2020).

The Kampala study also found that the PPD software in use is basic with minimum ability to provide timely reports to management for corrective action. For instance, the software (Cash flow 2), according to the key informant interviews with operators, is unable to track the active tokens in circulation nor can it track in real-time, the individual consumption patterns of each token issued. Only the cumulative total number of tokens issued is

known – no data exists on the usability and functionality of the tokens' circulation. NWSC noted that the lifespan of tokens is not defined, and so users do not have a guide for renewal.

Furthermore, NWSC technical staff interviewed noted that the software only allows one-way communication between NWSC and the PPDs. Patterns of purchasing credits cannot be monitored in real-time – the purchasing patterns can only be downloaded when vendors bring the hand-held token readers to NWSC offices. Hence, observed misalignments are the inability of the PPD software to directly monitor the performance of prepaid meters and tokens in real-time; and the inability of PPD software to directly and remotely recharge vendor gadgets.

Another technological misalignment is the absence of spare parts from local markets. The frequency of breakdown is rather high (e.g. a new battery breaking down after a month); and the protracted procurement processes cause occasional stock-outs. During periods of breakdown when the PPDs are dysfunctional, users are left with no choice but to resort to any available free sources whose water quality is questionable (Murphy *et al.* 2017), other conventional connections, or illegal activities such as cutting water distribution lines to access safe water.

During the FGD with users in Kamwokya, Central Division, one of the participants observed:

'*At first this machine used to run short of batteries and we would take like a month or two to get another new battery. However, this was years back – nowadays they (utility service provider) have bought a solar power, so we always have water*'.

The challenge of dysfunctional PPDs and tanks was dominant in the Nairobi City case study. It was compounded further by other contextual factors, such as intermittent water supply within the low-income urban settlements of Nairobi; and the insecurity, compounded by ethnic rivalry. Utility staff need safety and security for them to carry out the operation and maintenance of the PPDs and the related infrastructure. It was stated that sometimes NCWSC staff were threatened when they carried out patrols and inspections of the infrastructure. As expected, the state of insecurity increased incidences of vandalism and damage to infrastructure (Blomkvist *et al.* 2020).

The issue of faulty vending gadgets was frequently cited by the users. For example, one FGD participant from Kamwokya stated thus:

'*We have only one person who loads for us credit on tokens and sometimes she is not available and this means that one has to go to Kyebando bypass to reach another vendor. Other times the machine for loading tokens is faulty and so we are not able to load credit at the time we need it*'.

While PPDs are expected to provide undeterred access to safe water by users at any time, such misalignments defeat the original purpose. So far, PPDs have not fully delivered on the ambition to 'cut out the middlemen'. Instead, some influential local people or groups in the communities have been able to control the services for their own benefit.

Internal misalignment

Creation of a stand-alone pro-poor unit

The establishment, in 2006, of a dedicated pro-poor unit as NWSC's institutional home for service provision in the underserved slums was a clear sign that the regime actor embarked on an ambidextrous strategy, whereby the pro-poor unit may be an 'exploratory unit'. Evidence gathered from this study shows that there is friction between this exploratory unit and other mainstream units within the regime, in competition for the same customer base. An NWSC senior manager intimated:

'*Kampala has so many slums (almost 45 informal settlements which form the 60% of Kampala population). Our coverage so far may be 30% or 20–25%, we still have another underserved population of 35%. … so, there is still a lot of work to do to attain universal coverage. That is the challenge. Two; we have one dedicated pro-poor branch, yet we need more staffing and offices perhaps to be decentralized in different informal sectors. This we have not be able to do, we are kept in one unit, which is not linked well with the other branches, hence causing coordination challenges*'.

Supply of spare parts

One major internal misalignment was related to poor procurement planning and timely supply of spare parts. Routinely required parts have been out of stock, especially batteries, which are frequently failing and need replacement. For instance, PPD users in Ndeeba Ward, Lubaga division were told by NWSC to improvise and buy batteries from supermarkets and mechanically assemble three batteries to run PPDs until such a time when NWSC imports the required batteries. The issue of lost/stolen tokens also featured prominently as an internal misalignment. Users with tokens are currently not aware of mechanisms in place to retrieve and/or block lost/stolen tokens. One key informant noted:

> '*Besides the availability of tokens, the operation and maintenance is still a challenge on the side of NWSC. I see some of them when broken down they take long to be repaired. I am told even spare parts are not available. And in usage, some of the owners of the premises sometimes personalise the meters. They don't allow other people to use their tokens and their meters and this limits access to safe water*'.

In Mutungo, a respondent observed that when her PPD gets a problem she must first pay before technicians repair it, yet maintenance is supposed to be the responsibility of NWSC. In such situations, many consumers resort to alternative water sources such as springs, even if they are unsafe.

To gauge the efficiency of NWSC to internally resolve user complaints related to PPDs, users were asked how long it took NWSC to respond to alerts of technical or commercial faults. Table 3 summarizes the findings. The response rate varies across different divisions, which may depend on the effectiveness and efficiency of NWSC staff at the divisional branches. For instance, about 50% of respondents from the Lubaga division said it took over a month. This is a major issue given that water needs are basic to human survival.

Table 3 | Average time taken by NWSC to repair dysfunctional PPDs

		Division				
Variable		**Central**	**Kawempe**	**Lubaga**	**Makindye**	**Nakawa**
Average time NWSC takes to repair broken PPDs	Less than a week	45%	75%	20%	30%	60%
	1–2 weeks	15%	5.0%	15%	20%	10%
	3–4 weeks	20%	20%	15%	30%	5.0%
	Above 1 month	20%	0.0%	50%	20%	25%
Total		100%	100%	100%	100%	100%

Long periods of occasional PPD malfunction partly explain the low per capita water consumption through PPDs (7 litres/c/d). Moreover, the current PPD technology does not allow real-time two-way feedback to management servers – NWSC only knows of a faulty PPD when users report so. The issue of slow response to technical complaints is partly exacerbated by the high costs involved and technology limitations. A key informant from NWSC noted thus:

> '*Investment costs for PPDs are a big challenge. Secondly, there is a challenge with the acquisition of land and making sure that this infrastructure is protected. Thirdly, there is a challenge of maintaining a certain minimum pressure in the network; if it is low, PPDs don't work. The other challenge is high cost of spare parts*'.

The issue of slow response to technical complaints is partly exacerbated by the high costs involved as well as technology limitations. The high investment costs for PPD technology call for heavy resource commitments by NWSC.

Some low-income urban settlements of Kampala experience low water pressure. However, this issue is not as widespread as in Nairobi, where NCWSC had to install elevated tanks and sometimes use tanker trucks to transport water to keep PPDs operational. Additionally, NCWSC faces similar challenges pertaining to the supply and procurement of spare parts for PPDs, especially with the deployment of three different generations of PPD technologies (Blomkvist *et al.* 2020).

Reliance on donor support

A review of the literature on how the PPD technology has been propagated in the slums of Kampala since 2006 shows that there have been several development partners supporting this technology. NWSC is yet to commit a budget line to support prepaid technology and we argue that this is an indicator of low prioritization by the service provider. Most meters and accessories have so far been donor-supported. NWSC is currently struggling to replenish the stocks, hence large spells of meter dysfunctionality. A member of top management had this to say regarding scaling up prepaid metering for the urban poor:

> '*Well, ideally our vision is that all urban poor areas should be served with prepaid meters which we have not yet achieved. We have been trying but we still need to do more; the reason being not because that we don't want but because that technology is expensive, so the investment cost is high, so is maintenance. But the long-term objective is that we should do away with these conventional public standpipes and all should be prepaid*'.

CONCLUSION, IMPLICATIONS, AND RECOMMENDATIONS

Overall, our findings show that the PPD technology has great potential for improving water access to the urban poor and significantly reducing the number of middle vendors that hike the water price. While urban poor settings remain stifled by technological and providers' internal misalignments, the PPD potential in enhancing social access to safe water is underutilized. Building a robust internal capacity of utility service providers for seamlessly operating and maintaining the PPDs is key. Water utilities are yet to find an optimal point for the right technology, but also the social interaction and a business model that is adapted to local conditions. They must find an ambidextrous operational set-up – they cannot maintain the PPD in the same way they maintain the regular network. In all, there are many lessons to draw from both the Kampala and Nairobi cases.

Water users in urban poor settings, like in other areas, are actors with the agency, and should be sensitized and mobilized for buy-in. Otherwise, misalignments will manifest into user indifference, rejection, abandonment, and in some cases, tinkering with the PPDs in an attempt to customize them to user needs. Implementation of sufficient social marketing and organization of Information, Education, and Communication (IEC) campaigns are crucial for the success of the PPD technology. Livelihood-based NGOs could provide further 'software' support in propagating the PPD technology as recommended by a related study, which found that using utility-supplied water for productive purposes was predominant in the slums, albeit unrecognized by the water utility (Kayaga *et al.* 2020).

There are several implications arising from the findings of this study. Without a doubt, the establishment of the pro-poor branch in NWSC was a good measure for transiting to safely manage water services in low-income urban settlements. Beyond that, utilities ought to take further steps and fully mainstream the function so that pro-poor services can gain identity across the whole utility obtain corporate resources just like any other utility function, and not rely on international development financing. This positive step will in turn lead to timely stocking of the required parts, materials and equipment for effective operation and maintenance of the PPDs; and enhancement of the required capabilities to ensure better technical functionality of the PPDs, including the capacity to track issued tokens and monitor consumption trends. Water utilities could exploit synergies through public–private partnerships to improve their capacities – e.g. work with telecom companies in the area of software engineering.

Despite a relatively high diffusion rate of the PPD technology in Kampala, many low-income dwellers still rely on other water sources. Secondly, the PPD has not led to effective removal of the 'middlemen'. Instead, we found widespread instances of appropriation by local middlemen which tend to inflate prices. Thirdly, PPDs are still affected by high levels of technical malfunction. Furthermore, an 'automated' approach such as the PPD puts stress on the utility's organizational capacity for operation and maintenance, as well as the need for social mobilization.

PPDs, where installed, have not yielded to universal water access in slums, and scaling out to other areas has been slow. The technology still faces technological, social, and economic challenges that are hampering its growth and backtracking on the gains already made. The Kampala case, similar in many aspects to the Nairobi case, uncovers many technical, socio-political, and business misalignments of PPDs. For instance, there are challenges with frequent breakdowns and a regular supply of spares. Furthermore, there were cases of slow response to resolve user complaints. The communal-use model also has misalignments related to denied access by selfish users.

Misalignments within the critical interface continue to thrive and widen, making the technology benefit only a few people with direct contact to it, who, sometimes make huge profits at the expense of the very reason for the deployment of the PPDs. Despite these flaws, PPDs are a good innovation which should be scaled up, to enhance service delivery to the currently unserved urban poor, as a transitional method to safely manage drinking water services. Utilities should interrogate why existing PPDs deliver so little water per capita. It could be due to low sensitization of the users or due to appropriation by the middlemen or, lack of adequate user tokens and other accessories such as loading gadgets, or other internal misalignments within the utility.

PPDs require robust accompanying measures in terms of sustainable operation and maintenance plans, supply chain of spare parts, stakeholder engagements for buy-in, up-to-date IT-based management information systems, as well as the collaborative framework with other critical interface actors such as commercial banks, technicians, relevant NGOs, and research institutions. In the socio-political domain, given that the PPD technology is still novel, utilities implementing it need to continuously sensitize caretakers and users on its proper operation and management, so as to achieve the corporate objective of improved service delivery to the urban poor. Water utilities should work with leaders in the communities to acquire unencumbered plots of land for installing PPDs. On the external front, engagement of key actors along the technology value chain ought to take into consideration appropriate incentives/sanctions. Contracts could provide for assigning some repair and maintenance responsibility to the caretakers.

ACKNOWLEDGEMENTS

This article is based on data collected as part of a PhD project in the Department of Sociology and Anthropology at Makerere University. The authors are grateful for the support received from the Government of Uganda under the auspices of the Research Innovations Fund (RIF). The authors are also grateful to the Norwegian Council for Higher Education (NORHED) under the Water, Society and Climate Change project (WaSO) which sponsored the PhD student to obtain full registration. Part of the field work was also supported under the Swedish Research Council FORMAS grant no. 2015-13709-31069-42. We are also grateful to the study research assistants as well as the contributions of all study respondents and key informants. The doctoral student is grateful to the mentorship received from his Supervisors and the Doctoral Committee, as well as academic mentorship from Pär Blomkvist, PhD Associate Professor, Division of Organization and Management, Mälardalen University, Västerås, Sweden and David Nilsson, PhD Associate Professor, Division of History of Science, Technology and Environment, KTH Royal Institute of Technology, Stockholm, Sweden.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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First received 19 June 2023; accepted in revised form 23 April 2024. Available online 2 September 2024