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Exploring the State of Municipal Water Supply Infrastructure: Towards a Sustainable Water Provision in Informal Settlements of Jos Metropolis, Nigeria

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Abstract

This paper explores the state of water infrastructure, concerning the obligation of the government municipal water supply agency (Plateau State Water Board) responsible for urban water supply. The study employs the qualitative method; a structured closed-ended questionnaire was prepared, and face-to-face interview was conducted with eight management staff of the board, thereafter interviews were transcribed verbatim and then analyzed using NVivo 12 software. Results from the analyses show that water infrastructures are in a deplorable state characterized by; bad condition of dams and water treatment plants, lack of stable electricity, lack of metering of customers as well as frequent cases of pipe bursts said to be connected to illegal connection by the residents of informal/slum settlements. The novelty of this study is anchored on the reality that infrastructure challenges negating the efficiency of PSWB were unveiled, and strategies that could improve and promote sustainability of water provision such as the 'smart city' concept that uses modern technology and 'stakeholder's involvement' in the water governance process was suggested.

Keywords: Informal Settlements, Water Supply, Water Infrastructure, Challenges, Plateau State Water Board (PSWB).

Introduction

Statistics and reports have revealed that over 60 percent of the world's population lives in urban areas (UN-HABITAT, 2016). During the past forty years, there has been an unprecedented growth in the size and number of cities in developing countries (Lekwot et al., 2015). Urban population growth also means greater demand for water as a basic requirement for daily living (Guarino, 2017). Rapid urbanization has however stimulated a high demand for water without a corresponding increase expansion of infrastructures especially in countries that are developing (Fonjong & Ngekwi, 2014).

Nigeria just like any other developing country of the world has experienced a tremendous increase in population over the years. The trend of urban population growth has been highly significant over the years, a report from the 1991 census by the National Population Commission placed Nigeria's population at 88 million people, and the census of 2006 was estimated to be over 140 million people (Samson 2013). Presently, there are more than 200 million people in the country. It is also important to know that this tremendous increase in

urban population and the number of cities has given rise to the emergence of slums or informal settlements. In Nigeria, the percentage of the urban population living in slums or informal settlements was reported at 53.9% in 2018 (World Bank, 2021). This population is spread unevenly over the thirty-six states and the Federal Capital Territory Abuja, with a total land coverage of about 923,770 km square (Idu, 2015). All three levels of government (Federal, State, and Local Government) are active in the development and management of water resources through a variety of agencies to carry out specific roles and duties within their area of jurisdiction. Water Boards/ corporations exist in each of the 36 states of the Federation and the Federal Capital Territory, whose responsibilities among several others are the establishment, operation, quality control, and maintenance of urban and semi-urban water supply systems and in some cases rural supplies (Akpobio, 2012).

Statement of the Problem

The emergence of informal settlements is an urban transformation process, an accelerated urbanization in several forms especially in poor countries, which has also overtaken optimal urban infrastructure development (Nzeadibe & Anyadike, 2012). These settlements tend to have the worst water access scenarios (Adams & Halvorsen, 2014). According to Ensor (2016), the majority of urban residents live in informal settlements that are not connected to local water networks and are not recognized by municipal government or policy. In informal communities, water demand may not correspond with availability. It is however claimed that inhabitants are denied access to these fundamental public infrastructures, amenities, and services (Daniel et al., 2015; Kariuki et al., 2003). The sixth Sustainable Development Goal is 'Clean Water and Sanitation' and target one is to 'ensure the availability and sustainable management of water and sanitation for all' by 2030 (WHO/UNICEF, 2017). The phrase "ensuring availability and sustainable management of water and sanitation for all" simply means that social fairness in service delivery is required (Sam Kayaga et al., 2018). According to the UN-Habitat 2016 report, residents in both formal and informal settlements have the right to decent, dignified, and rewarding lifestyles, as well as the opportunity to reach their full potential (WHO/UNICEF, 2015). The fulfilment of international responsibilities, including those relating to the human right to water and sanitation, is a fundamental duty of the government (Camkin & Neto, 2015). The right to water and sanitation is enshrined in the Universal Declaration of Human Rights and stipulates that water should be sufficient and physically accessible, among other things (UN-Habitat, 2014). In developed countries, one of the public service obligations required of service providers is the provision of water (Kayaga & Franceys, 2008). Previous studies on informal settlements have focused more on the private sector's role (water vendors) in supplying water to informal settlements to substantiate the level of exclusion and deprivation of informal settlements to municipal water supply (Ishaku et al., 2010; Olajuyigbe et al., 2012; Daniel et al., 2015; Ahmad, 2017). A recent study conducted in Jos Metropolis indicates that most residents of informal settlements rely on multiple water

sources to meet their daily needs (Nanle et al., 2023). Little is known about the involvement of the government utility responsible for municipal water supply in informal settlements and the challenges that negate their efficiency in service delivery. This study therefore seeks to find out the infrastructure and technology challenges confronted by the Plateau State Water Board (PSWB), the government institution responsible for urban water supply (informal settlements inclusive) and to make necessary suggestions for addressing these challenges for a sustainable water supply in informal settlements.

Research Question

What are the infrastructure and technology challenges associated with municipal water supply in informal settlements?

Research Objectives

1. To review related literature on infrastructure and technology challenges, and strategies associated with municipal water supply.
2. To identify the specific infrastructure and technology challenges of PSWB in supplying water to informal settlements.

Theoretical Framework

Theory of Constraint

Eli Goldratt created the theory of constraint (TOA) in the mid-1980s, and it is regarded as a global theory of organizational management (Goldratt, 1988). The constraint theory is based on the idea that at least one constraint or bottleneck is found in every system. A constraint is any situation that prevents the system from performing well in terms of its intended purpose (Goldratt, 1990). In other words, it is something that prevents a system from achieving higher performance compared to its target (Goldratt, 1988). The theory of constraint is a management philosophy, and it focuses on the weakest ring(s) to help improve the performance of a system, the philosophy supports the working principles which are stated as TOC's 'Logistics' paradigm and the method for investigating, analyzing, and resolving complex problems. In general, termed the thinking process (Şimşit et al., 2014). TOC's working principle serves as a focal point for the process of continuous improvement and it consists of five steps: identify the constraint, exploit the constraint, subordinate everything to the constraint, elevate the constraint, and lastly, find your next constraint (Eby, 2017). In application of the theory of constraint (TOC), this study intends to adopt the first two steps. To identify the major challenges or constraints of the government institution in charge of water supply, explore the possible strategies, and then decide the most suitable strategy that will help ameliorate these challenges.

Literature Review

Infrastructure Challenges

Poor water resource management and deteriorating infrastructure are major contributors to the problem in many developing countries. The ageing and weak water infrastructure in the cities cannot adequately serve the people. Most pipes in the network system have failed from over-use and lack of maintenance over the years (Otieno, 2013;Jideonwo, 2014). Ageing infrastructure is therefore said to increase the unpredictability of water resource availability (Fonjong & Ngekwi, 2014). For example, in Dhaka growing per capita demand and growing population without access and non-functionality of infrastructure constitute more than 50% of the state of water infrastructure (DWD, 2011). Yunusa (2000), suggested that in Nigeria, water infrastructures are not evenly distributed across and within the towns and cities. In Lilongwe Malawi, the problem of infrastructure is also evident, due to system leakages, up to 37.5 percent of Lilongwe City's water supply is not accounted for (Harawa et al., 2016). Therefore, water use is considered highly inefficient, due to leakage and other related infrastructure issues (Baylouny & Klingseis, 2018). In many developing countries, water loss that cannot be accounted for is very common, it can be as high as 50% (Haddadin, 2006). It is estimated that half of the missing water in developing countries is caused by leaks (Galaitsi et al., 2016), and 40 % of water system loss in the Philippines is primarily due to aging infrastructure (BWD, 2011). Another aspect of infrastructure is electricity. Electricity supply is instrumental to an adequate supply of potable water to the masses, hence generation and distribution of water to a large extent depends on enough power supply (Samson, 2013). A study carried out by Yunusa (2000) succinctly informs that water plants require a minimum of 22 hours and 4 seconds of electricity supply per day. On the contrary, the public corporation that supplies electricity to the water plant and pump station supplies electricity for only 10 hours daily. The result is therefore a gross undersupply of water to the entire city under consideration (Samson, 2013). Due to a severe lack of electricity, water agencies invest money in diesel, backup generators, or even the construction of independent power plants (IPP), which raises production costs and lowers efficiency (Jideonwo, 2014).

Technology Challenges

In informal settlements of developing countries, water supply depends highly on the technology selected, this is, however, a challenge (Isoke & Dijk, 2013), high technical specifications in the form of inflexible technical standards established by a government or the main service provider which are meant to improve the quality of construction may not be attainable due to high cost (Kariuki et al., 2003). Overreliance on traditional/conventional types of service delivery systems is another factor contributing to informal settlements' poor access to water services. In most cases, such technologies are economically viable but not financially appealing, and they may not be socially, technically, or environmentally friendly to connect informal settlements (Liang & van Dijk, 2011;

Montgomery & Elimelech, 2007; Murphy et al., 2009; Sharma & Vairavamoorthy, 2009; Solo et al., 1993). This is also evident in cases where authorization to deliver services does exist in slums or informal settlements, but utilities continue to give priority to service expansion because they are technically challenged, and hence serve only formal urban communities (Schrecongost & Wong., 2015). In Melanesia, it is more difficult to provide services to peri-urban areas that may be farther away or outside of formal utility service districts, as well as to territory that is technically difficult to access with traditional infrastructure. Furthermore, relying solely on traditional customer engagement models makes it more difficult to collect connection fees and enforce bill payments from informal settlement customers (Schrecongost & Wong., 2015).

Strategies

The Smart City Strategy

A smart city is frequently referred to as a "system of systems," in which the Internet of Things (IoT) and analytics coexist with traditional infrastructure, buildings, and a 24-hour operations center. To achieve operational efficiency and enhance service levels, sustainability, and economic vitality, smart cities leverage IoT and analytics capabilities (Peley, 2018). It is a paradigm shift of water utilities or companies from being responsive to proactive and effective. A transition to customer relationship management (CRM) technology from an analogous system within their areas of jurisdiction, is therefore a complete revolutionization of the way water utilities deal with customers (Peley, 2018). The Smart City Concept can be of great significance in resolving those infrastructure challenges highlighted. Through this concept, water utilities can be more efficient to increase water efficiency, decrease water loss, and improve customer service through digital management tools. This will help in the aspect of network visibility, proactive maintenance, and prompt reaction when there are issues related to pipe leakages, bursts, or failure (Peley, 2018).

Additionally, the smart city concept is not just about how the citizens benefit from the services the government provides, but most fundamentally is about valuing citizen participation. A city is said to be "smart" when investments in human and social capital, as well as traditional and modern (ICT) communication infrastructure, fuel long-term economic development and high quality of life, while also managing natural resources wisely through participatory governance (Caragliu et al., 2011). The smart city concept from this perspective emphasizes the need for community participation, this is the only way citizens' voices can be heard. Working together for the good of the neighborhood is known as community engagement or involvement, and it can provide residents with a feeling of inclusion, legitimacy, and confidence (Jaafar et al., 2017). Additionally, because more people are involved in the process, there is better identification of the issues that are most important to the community, a wider range of input into decision-making, and frequently higher levels of acceptance of choices (Camkin & Neto, 2015; Kholisa, 2015). A paradigm shift in respect to water supply in informal settlements requires the inclusion of inherently

marginalized informal residents in the local governance processes, a mechanism that will encourage their participation and amplify their voices (Williams et al., 2018). Therefore, households and neighborhood communities have a crucial role to play in addressing water and other services problems (Putri & Moulaert, 2017).

The FACIES Technology

In the FACIES technology, the FACIES testbed is a fictional High Lake City water supply and distribution system. Different areas in this city are distinguished by the structure of their water distribution network and customers varying water demand patterns. In each of these areas, tanks for storage are installed at the highest vantage point and then water is delivered to customers by gravity via a valve system. that regulates the flow of output, with a centrifugal pump that induces the flow of water from the low to the high level is applied to supply the tanks (Miciolino et al., 2017). The FACIES Technology is made up of tanks and reservoirs. In residential and industrial areas, these tanks are to be supplied with water from the reservoirs and there are also 16 valves simulating each area's water demand (Miciolino et al., 2017). The water system of the High Lake City is monitored and controlled through a SCADA system that was created making use of a framework. In addition, the management of the FACIES testbed technology has a centralized architecture in which all sensors/actuators are directly linked to PLCs (Modicon M340, Schneider Electric) which is in charge of the entire system (Miciolino et al., 2017).

Methodology/Materials

This study employs the qualitative research method. A method for investigating and comprehending the meaning people or groups assign to a social or human situation is qualitative research. Emerging questions and procedures are used in qualitative research, usually gathering data in the participant's environment, data analysis is done inductively, moving from specifics to broad themes, and the researcher then interprets the data (Creswell, 2014). The data collection technique used is the in-depth interviews and literature review. A structured closed-ended interview questionnaire was prepared and administered through face-to-face interviews to eight participants (management staff of PSWB): Assistant General Manager Administration, Assistant General Manager Finance, Assistant General Manager Quality Assurance, Assistant General Manager Operations, Assistant General Manager Technical Services, Assistant General Manager Commercial, Legal Adviser, Head of Project Implementation Unit. Subsequently, these participants will be identified by the identification: S1, S2, S3, S4, S5, S6, S7 S8. The choice of these eight participants is informed by the opinion that four to twelve (4 to 12) participants are recommended in the case of homogeneous samples (Saunders, 2012). The study is focused on the experience of the Plateau State Government Institution (PSWB) in charge of water supply. Interviews were conducted from the 10th of February 2020 to the 26th of that same month. The interview time varies between a minimum of 21mins and a maximum of 35mins.

Data collected was recorded after which it was transcribed verbatim and then analyzed using NVivo 12 software, during the process of the analysis five themes were developed concerning the questions developed to represent the issues under consideration to conclude.

Findings

Below is a table that shows the responses from the interview excerpts concerning the infrastructure and technology challenges that impede PSWB from being effective and efficient in executing its mandate (water supply) in informal settlements (see Table 1).

Table 1: Infrastructure and Technology Challenges

Themes	Responses
Theme 1: Electricity	*We have challenges of infrastructure"(S2)* *"We have issues with power/electricity supply, that is why at times we augment with generators and diesel fuel is expensive" (S4).* *But then, we are having other challenges. One of these challenges is the power that you need to operate this equipments, as you know power/ electricity supply is inadequate in the country generally, and because of the inadequacy, we are only given power that is limited. For us for example we want to run or work for twenty-four hours every day, but we may just have two days of power supply and that affects water supply" (S5)* *"We have problems of non-power supply, very erratic in our treatment plants and to run stand by generators is very costly" (S8)*
Theme 2: Treatment Plants/Dams	*"Dams are not too good, the treatment plans need to be rehabilitated and make sure they are good, as well as our distribution lines" (S2),*
Theme 3: Equipment's	*"In terms of the treatment plants, some of the plants have equipment that are obsolete and dilapidated" (S5).* *"In terms of the present state of water production infrastructures, we have equipments that are aged, we have equipments that are partially in operation, we have equipment's that are fully functional, we have a mixed kind of equipment's..." (S5)* *"Also, we have challenges in terms of equipment's, mobility, etc. In terms of mobility challenge, some of the operating units in the treatment plants are a distance away. For you to move to and from these treatment plants is quite challenging(S5).*

Theme 4: Metering Issues	*"Another challenge is that in our distribution lines we are supposed to have district meters. For example, if we identify a slum area and then we know the quantity of water we are sending into that unit and whether it gets finished or not we will be able to ascertain where the meter stops, but currently we do not have the meters in the districts. So, we are estimating rather than the getting the correct data" (S5)* *"In terms of metering, none of our customers is metered, though the process is on the pipeline. There is efficiency in metering…(S6).* *"Lack of metering causes revenue lost; we are losing revenue seriously. Recently, a consulting firm brought some samples of meter for us to experiment as a pilot and so we chose where water supply is consistent like millionaire's quarters (High-income area), we experimented that, the meter is prepared; once a meter is install to a premise, depending on the credit unit that you have and ones it is finished or exhausted the water will automatically stop flowing. Therefore, using the metering system we don't have to be going around from house to house to solicit for payment of water rates but rather the customers will come to us to recharge their water credit unit. so, based on our pilot survey we observed that metering is more efficient. Another aspect with metering is that the consumers will not allow their water to be wasted" (S6).*
Theme 5: Pipe Burst	*"In terms of the slum settlements you are talking of it is quite challenging, particularly with the old settlements not low-income settlements. For example, in Gangara which is an old settlement, in this settlement some of the pipes in use are aged and because they are old, they do not stand the test of time so the brake constantly and this therefore prone to water infection, there are lot of seepages and because of the unplanned nature of such settlements characterized by lack of well dug drainages, so you see a lot of things infiltrating into the already weaken pipes due to aging (50 years and above) …" (S3).* ***Yes,** the challenge we have is that after the provision of pipe borne water to them, most of their houses do not have proper drainage system (S4).* *Therefore, wastewater from their bathrooms, soakaways are filled up, as such wastewater flows anyhow and at times it enters the pipelines, the service pipelines. In slum areas, the population is high, children who are uncontrollable break the pipelines while playing, and when there is no pipe water for some period, then there will low pressure from the service pipeline, wastewater from the gutters goes into the service pipeline and then to the main line. By the time we start to pump water again, that wastewater will be pump alongside*

	the clean water therefore contaminating it when it eventually reaches the consumer." *As such, ones there is a leakage then there will be an infiltration of pathogens into the pipe because water is not provided for 24 hours. There are times we give water for three or four hours, when water is off the line the pressure from the line is reduced so water from the gutter or drainage will penetrate by way of osmosis. However, if there is steady water supply in the pipeline the leakage will drive the pathogens away" (S3)* *"Issues related to pipe burst. Because those are problems we are passing through, ones you release water you will see a lot of water flowing because of pipe burst; this implies the agency should make sure that all these leakages are taking care of" (S2).* *"Because certain area there is, depending on the size of the main, depending on the capacity how the area is getting water, if you are turning there is a few turns that you are supposed to throttle the valve towards but if you open it totally the water will go with full force and will cause pipe burst. Ones there is pipe burst, it will take us one or two days before that pipe burst will be mended, we are using resources to do that, and it is affecting water to slum areas" (S6).* *"Also, in terms of service lines, people buy this service lines pipes according to what they can afford, sometimes they make use of plastic pipes which may not be well coupled and therefore exposing the water to all forms of impurity. Even though it is our desire that water should be safe but because of these challenges sometimes you don't achieve the desired result" (S3).*

Source: Authors Field Survey, 2020

Discussion of Findings

Findings from this study show that to a greater extent, the condition of water infrastructures used in the production and distribution of water is in a deplorable state. Characterized by inadequate and intermitted power supply, obsolete (aged), equipment, lack of operational vehicles, lack of district meters and metering system, aged pipes, and leakages because of pipe bursts. This agrees with previous studies conducted in other developing countries (Otieno, 2013; Jideonwo, 2014; Fonjong & Ngekwi, 2014; Schrecongost & Wong,2015). There are technology issues connected to overreliance on

traditional/ conventional methods of service delivery and, a lack of basic modern technologies that are used for effective and efficient water delivery. Given these, there are several implications: lack of district meters and metering of customers have economic implications in the sense that they encourage water theft, and lack of payment of water bills, which in the long run will negatively affect the revenue generation of the agency. Thus, constituting a colossal loss of resources on the part of the government. Additionally, the lack of district meters invariably means that the agency cannot have accurate data on the actual quantity of water distributed to these settlements and cannot account for the water that is lost during the process of leakages from pipe bursts, and illegal diversion of water by the residents. Concerning the condition of the water pipes, the deplorable state of the pipes means that issues related to pipe bursts, and pipe leakages are eminent. The economic implication indicates that water is wasted at the expense of the government's minimal resources. The health implication is that there will be constant infiltration of disease-causing pathogens in situations where water pipes are laid alongside gutters or drainages that channel wastewater from houses. Thus, the final consumer is vulnerable to being infected by water-related diseases such as typhoid, cholera, and dysentery. The management and policy implication of this study indicates that unless the government takes a deliberate and holistic approach to tackle these issues, the desired efficiency and effectiveness in the provision of water in informal settlements may not be feasible.

Conclusion

This study has been able to explore the infrastructure challenges of PSWB concerning water supply in informal settlements. It is, therefore, significant because it considers water supply as a major obligation of the government and has improved on previous studies by examining the infrastructure challenges that affect the government institution in charge of urban water supply from carrying out its mandate effectively in informal settlements. Findings revealed that Plateau State Water Board (PSWB) the municipal government agency responsible for water supply in informal settlements of Jos metropolis Nigeria, is confronted with several infrastructure and technological challenges related to overreliance on traditional/ conventional methods of service delivery, inadequate and poor power supply, lack of metering system resulting to inefficient collection of water rates. There are also challenges associated with water leakages because of a pipe burst, and this has frequently led to a colossal waste of water and a lack of mobility for the movement of equipment. This study therefore highlights the need for policymakers' attention to be drawn to these issues that are most specific to water supply as they affect informal settlements, in line with the suggested strategy.

Recommendations

Based on this, this study therefore recommends the adoption of the following:

1. Smart Water Management Strategy: A Smart Water Management strategy should be adopted by Plateau State Water Board (PSWB), to enhance customer service, cut down on water waste, and increase water efficiency, a vast quantity of network data is recognized and harnessed by water utilities, digital technologies are considered to have great potentials to change the management of water in cities (Peley, 2018). Hence Plateau State Water Board can be more efficient in enhancing services to customers, reducing the amount of water lost, and increasing the efficiency of water usage through digital management tools such as district meters, a metering system, and a central control system monitoring all activities of the agency and settlements connected to municipal water supply.
2. FACIES Tested Technology: Since the use of reservoirs is already adopted by PSWB to provide water in hilly terrain areas. This study therefore suggests its improvement through the adoption of the FACIES-tested technology, where there will be a central control system that connects all the sensors/actuators in the reservoir. This will help in responding to the water demand of the people in informal settlements.
3. Community Engagement: Through community participation, issues that relate to illegal connection, water theft, and infiltration of disease-causing organisms through infiltration of wastewater can be discussed with the residents of these settlements, to arrive at sustainable solutions to these problems.
4. Modern technologies in the form of solar power electrification will equally help in the aspect of electricity or power disruption.
5. There is a need for policymakers' attention to be drawn to these issues that are most specific to water supply as they affect informal settlements, in line with the suggested strategy.

Limitation and Further Research

To proffer solutions to the numerous infrastructure and technology challenges associated with water supply in informal settlements, a series of strategies were recommended. The application of these strategies suggests areas where further studies could be carried out to improve the effectiveness of government water utilities in developing countries confronted with similar issues.

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