An Assessment of the Existing Structure of Water Service Provision System and Water Security in Informal Settlements in Nairobi County, Kenya

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ABSTRACT

Accessing clean water and sanitation is a constant challenge for urban residents in informal settlements and marginal areas. For most residents, informal local water and sanitation service providers meet these basic needs. These local entrepreneurs or enterprises provide services paid for directly by the clients. They are not planned, authorized, supervised, or acknowledged by the formal authorities as part of the official system. These services include water tankers, bottled water delivery, provision and management of shared or community latrines, unregistered pit emptying, container-based sanitation, or piped water to a private household or shared tap. These informal service providers, or intermediaries, have emerged in response to a significant essential service gap. Since the unstructured nature of water provision in Nairobi County is a major problem that needs to be addressed, this study evaluated the structure of the system of water service provision that is in existence in Nairobi County. The study utilized descriptive research design. The research was informed by the systems theory. Target population for the study consisted of households from the informal settlements and other water related stakeholders. Data was collected from a sample of 388 households from nine slums in 12 sub-counties derived through simple random sampling. Household questionnaires were used to collect data. The data was analyzed through descriptive and inferential statistics. Findings from this study indicated that 51.0% of the respondents had no water service structure, 8.7% had basic structure, 2.9% had intermediate structure, and 37.5% of the respondents had full water service structure. It was also established that, water structure had a significant relationship with availability, access and quality. Examined, against sub-counties, there was a significant influence between water structure and the sub-counties. Based on the findings, the study concludes that, provision of infrastructure alone may not lead to household water security and recommends that while planning the development of a water supply system structures (production, treatment, storage and distribution), the decision should be based on whether the investment will improve availability, access, quantity, quality, affordability and reliability of service. Accordingly, this decision should help inform the investment by policy makers to ensure water security.

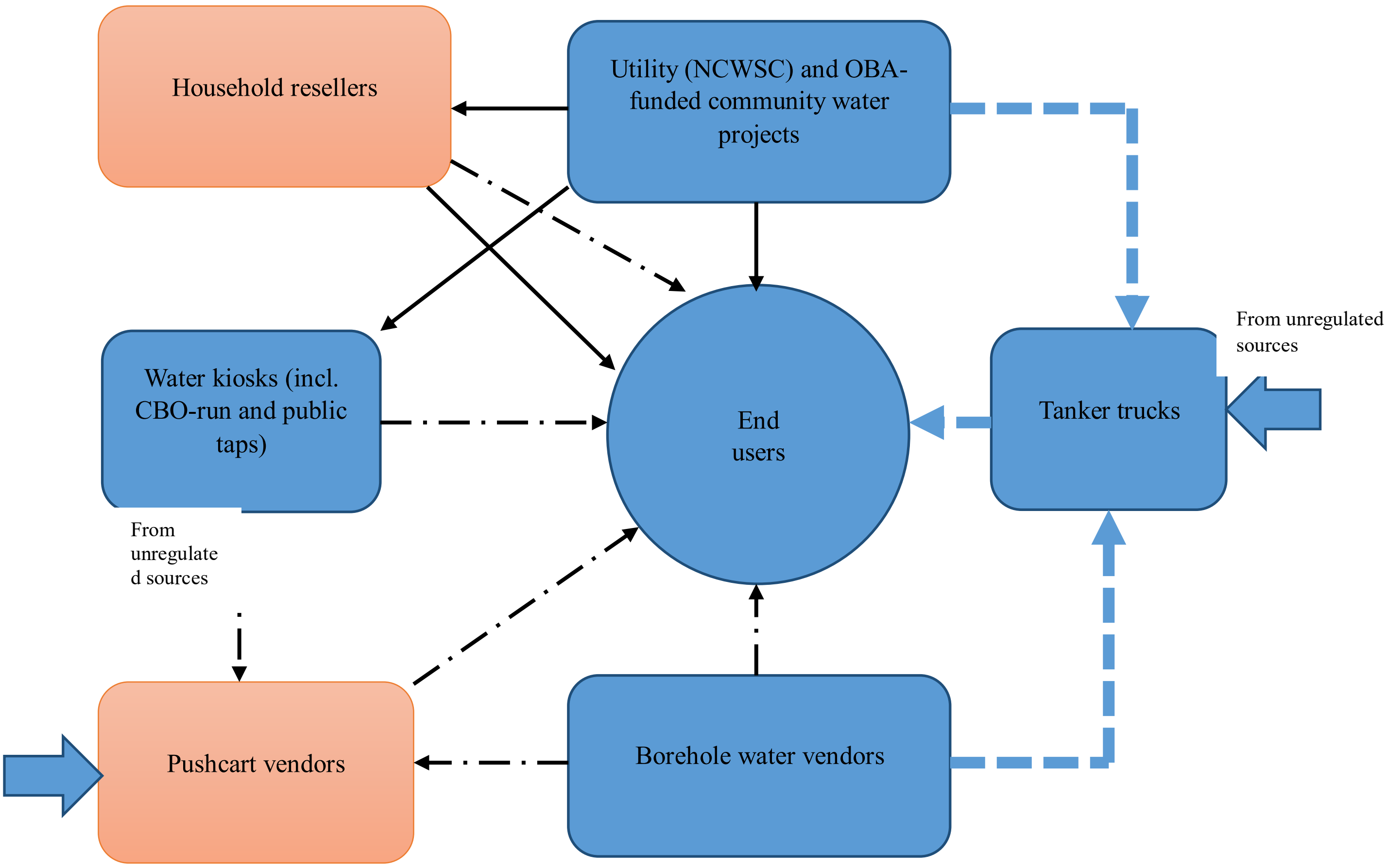
Keywords: Water Lord, Water Safety, Water Service Level, Water Service Structure, Water Stress, Water Supply

I. INTRODUCTION

The Government of Kenya (Government of Kenya [GoK], 2016) through the Water Act 2016 defines a formal water service provider as a company, non-governmental, organization or other person or body providing water services under and in accordance with an agreement with the licensee within whose limits of supply the services are provided. The Act on the other hand, defines "informal" service providers as all types of water suppliers who are not operating in the legal framework of water management in a given area (the Water Act, 2016). According to the American Water Works Association (AWWA), both informal and formal water service providers are characterized by public utilities, commercial organizations, community endeavors or by individuals, usually via a system of pumps and pipes (AWWA, 1974; Dieter & Maupin, 2017). These entities are supposed to work efficiently in a collaborative manner to ensure effective provision of appropriate quantities of water. For a household that depends on an efficient water service provision system, it should access a minimum of 20 lpcd when water is supplied through multiple taps continuously.

This is sometimes difficult to attain in the informal settlements where the system of water provision is not well structured. The unstructured nature of water provision in Nairobi County has been described by United Nations Development Programme(UNDP , 2011), as shown in Figure 1, to be that where the entities involved are supposed to operate within a defined and regulated system. What leads to unstructured nature of water provision is when the approved providers operate outside the defined service standards.

As depicted, the water supply chain in Nairobi County, comprises of both formal and informal water service provision structures. Tanker trucks who are considered a formal service provider and licensed to transport water from safe sources, do also source water from unsafe sources; a possible cause for water borne diseases (Mollah et al., 2009; Jouravlev, 2004; and Black et al., 2003).



	Piped water connection		Regulated providers
	Transported water (jerry can)		Unregulated providers
	Transported water (tank truck)		Water from non-improved or illegal sources

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Water Supply Chain in Nairobi County
Source: UNDP (2011)

On the other hand, Figure 2 introduces a public water-supply system and shows how various water sources, treatment and storage facilities are interconnected to form an integrated scheme that makes it easier to account for water quantity and quality and hence a possibility of attaining water security.

As depicted in Figure 2, a well-structured public water service provisioning is that which has a coordinated process of water source development, treatment, storage, and a dedicated distribution network. Further, all other secondary public water suppliers plug into a central distribution network after which the water is then delivered to various customers. This network has been applied to create a hybrid system that involves co-production of water infrastructures (shared taps, water tanks) that involves connection of private providers to the municipal network in Tanzania and Ethiopia (Faldi et al., 2021). The goal of such a system is help account for the quantity of water delivered and also monitor the quality of water thereby addressing the problems of water insecurity. This can be made possible when entities involved in water service provision collaborate through a well-defined system – structure, which is not always the case in developing countries.

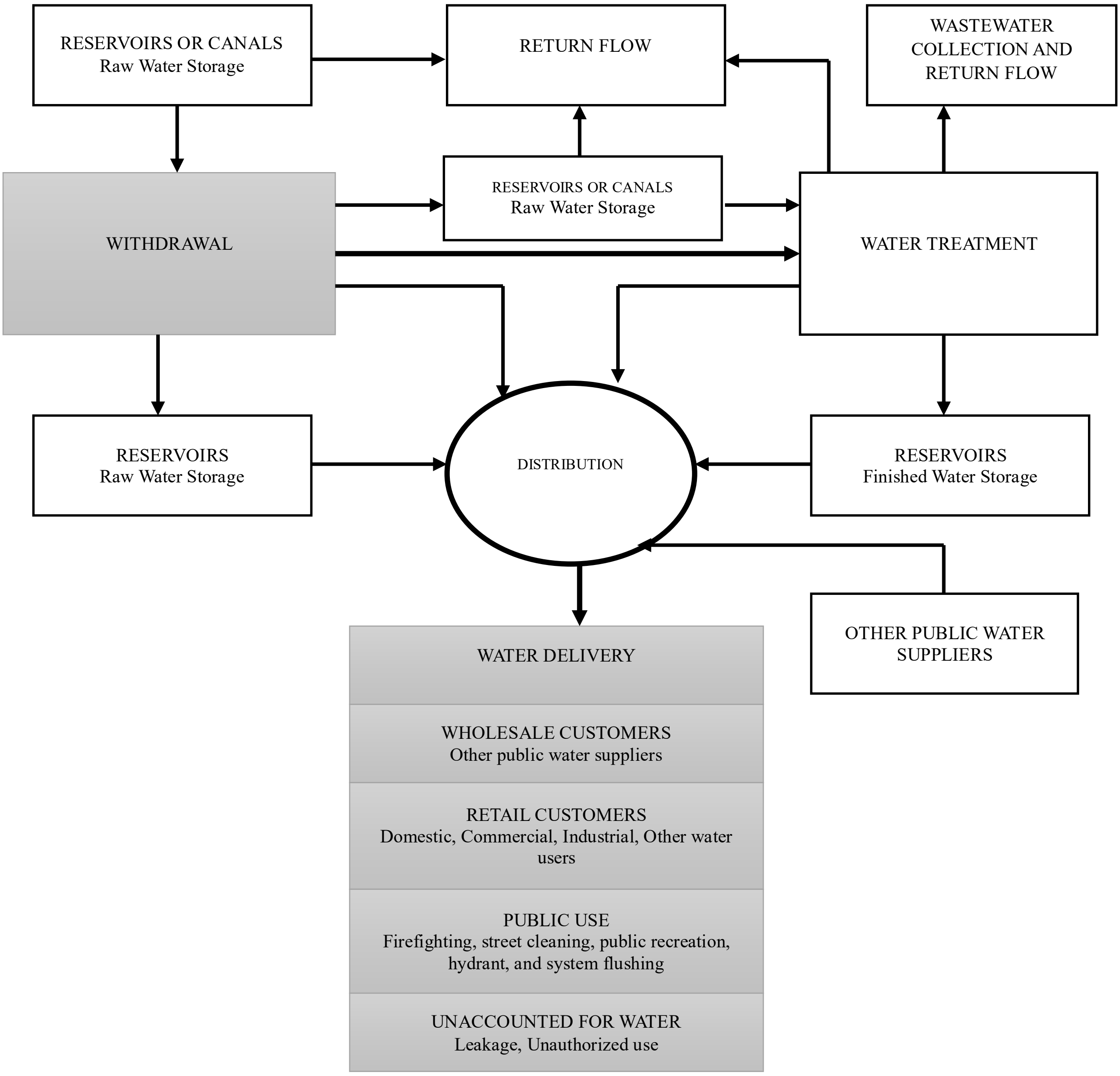

Figure 2
An Organized Water Service Provision System
Source: US EPA (n.d.)

To have a well-defined system and structure in place a number of factors come into play. These factors can be considered to be supply and demand-related characteristics. Maryati & Humaira, (2018), have identified some of the supply and demand characteristics that influence water service provision to include water source, production, distribution, service coverage, tariff system, number of consumers, utilization, non-revenue water (NRW) and consumption. In urban informal settlements, these characteristics may be shaped by a number of other factors such as intermittence or reliability challenges, tenancy (a prove of land ownership) and existence of alternative sources or suppliers (The World Bank, 2019). In Kenya, the government has invested in developing new water sources to increase production and therefore making available quantities to be supplied by the service providers. For instance, in Nairobi, the government is investing in a new source dubbed the Northern Corridor Tunnel, 11.8 km long, 3.2 m diameter diverting water from Rivers Maragua, Gikigie and Irati to Ndakaini Dam and it is projected to add 140,000 m3/day to the city and the neighbouring counties of Kiambu and Muranga (GoK, 2016). As shown in Figure 1, there exists formal and informal water service providers in the provision of water services. This therefore calls for an integrated working relationship among these entities. Rosenzweigh et al., (2011) advice that, collaboration between informal and formal water service providers can be beneficial to people living in informal settlements, hence the need for this study.

1.1 Statement of the Problem

Urban informal settlements in developing countries are faced with water insecurity issues, which can be traced to insufficient water quantities, unreliable water supply, aging pipes, infrastructure coverage among others (Hanna-Attisha et al., 2016; Majuru, 2015; UNDP, 2011; Bruggen, et al., 2010). Further, many developing countries are struggling with infrastructure development leading to under-coverage in low-income areas (LIAs) like in urban informal settlements. This has led to low water pressures in the water distribution system and due to aging pipes, huge water losses are experienced, hence high unaccounted for water [UfW] (Lai et al., 2020). Due to high levels of poverty of people living in these settlements, they end up sourcing water from unsafe sources leading to water borne diseases (Mollah et al., 2009; Jouravlev 2004; & Black et al., 2003). In informal settlements and slums, water insecurity is seen as a critical public-health challenge (Adams et al. 2022).

There has been quite a lot of interest in urban water management globally. As noted by Wuysang et al., (2018), Integrated Water Resources management (IWRM) has been adopted by governments across the world. The IWRM process promotes the coordinated development and management of water, land, and related resources (Agarwal et al., 2000). By adopting this model of IWRM, countries experiencing insufficient water quantities have instituted various measures like extension of distribution network, increasing production and storage capacity (Dziegielewski, 2003). Other models such as the approach developed by the World Bank on Integrated Urban Water Management [IUWM] (Feilberg & Mark, 2016) and Marlow et al. (2013) Sustainability of Urban Water Management (SUWM), have been efforts to unbundle water service provision. On the other hand, development of alternative supply channels including drilling of boreholes and allowing for tank truck distribution have been used to address unreliable water-supply (Cronk et at., 2024; Griffin & Mjelde, 2000).

However, what is missing is a well-coordinated water-supply system that reflects on the context in terms of flexibility and adaptability in which it has been designed. This could be the case since the water service providers have not been able to explore diverse and flexible solutions through a system-wide collaboration among entities involved in the water service provision. It observed in Nairobi County that players involved in the water service provision tend to operate in silos or even compete with each other (UNDP, 2011). Whereas the ultimate goal is to ensure water security, the challenge of working in a collaborative manner is still a bottleneck. This advances that if these challenges were not addressed, there is continuation of non-adherence to formulated standards and uncoordinated water-supply systems. Further, this leads to lack of proper plans to exploring local alternative water sources to supplement the existing water quantities. In essence, this situation continues to have an impact on socio-economic development, peace and political stability, water related disasters and waterborne diseases.

1.2 Research Objective

The study objective of the study examined the different existing structures of water service provision systems against domestic water security in informal settlements within Nairobi County.

1.3 Research Question

How do the different structures (production, treatment, storage, and distribution) of the water service provision system relate with existing domestic water security in informal settlements within Nairobi Country?

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1. Systems Theory

The research was informed by a systems theory. The major proponents of systems theory include the physician Alexander Bogdanov as studied by Gare (2000), sociologist Talcott Parsons (Parsons, 1970), the study of management by Senge (1990), and the study of organizational theory by Capra (2022), among others. Systems thinking is a world view in which objects are seen to be interrelated with each other (Whitchurch & Constantine, 2009). The systems theory helps us to identify elements of a system and the role they play; helps to predict how the element may impact other elements in the system either because of endogenous or exogenous conditions; and how making use of the information generated can help inform optimal decision-making hence maximizing the utility derived from the system. The study of water security in Nairobi County's INSEs involved framing the water supply system through six variables whose integration would lead to a water secure household or settlement. The variables include availability, access, quantity, quality, affordability and reliability of water services. The systems theory helped the researcher to put into perspective the importance of considering all the six factors during design of water supply systems, without which attainment of water security will continue to be an elusive effort.

2.2 Conceptual Review

The organization of water service provision determines how the development, treatment, storage, and distribution of water are interconnected to efficiently meet the needs. Figure 2 illustrates the transformation of a public water system from a basic supply system to a more intricate system in response to growing demand. Efficient functioning of the system also depends on important structural factors, such as design, construction, operation, and maintenance (Chang & Zyl, 2014). The growth of water sources is determined by the need for water services. The need to accommodate a growing average daily demand (ADD) on the public water supply system requires the construction of larger sources, storage facilities, and distribution networks, leading to the gradual formation of the system shown in Figure 2. Extensive public water-supply systems consist of numerous reservoirs, either a single reservoir or multiple separate reservoir systems, as well as wells, well fields, and springs, from which water is extracted.

Water treatment can be classified into progressively more intricate treatment systems. The spectrum of treatment options for water can vary from a basic approach of no treatment or simple chlorination to a more intricate system that incorporates corrosion control chemicals, coagulation, flocculation, sedimentation, and filtering. An uncomplicated method for treating groundwater extracted from boreholes involves the processes of aeration and chlorination. However, treatment facilities become significantly more intricate when surface water is utilized as a source of supply. Water storage occurs at multiple stages, including raw water storage, clear water storage after treatment by the supplier, storage along delivery lines by the supplier, and ultimate storage by the water consumer at the household level.

Consumptive use mainly occurs as water evaporates from open reservoirs and canals while it flows through the system. This is particularly significant in arid regions or areas with extensive open water bodies. Following the treatment process, water is typically directed to either finished water storage or directly into the distribution system. The distribution process involves supplying water to three primary groups: (1) wholesale customers, which are other water suppliers; (2) retail customers, including domestic, commercial, industrial, thermoelectric, mining, and agricultural users; and (3) public users, such as municipal buildings, parks, and for activities like street washing, firefighting, and hydrant and system flushing.

The presence of unaccounted water in the distribution system is caused by leaks, unlawful consumption, or erroneous meter readings. Water service provision refers to the distribution of water through pumps and pipelines by governmental utilities, commercial organizations, community efforts, or individuals. According to AWWA, a water distribution system encompasses all the components of a water utility that are responsible for distributing finished or potable water (Dieter & Maupin, 2017). This distribution is achieved through the use of gravity storage feed or pumps, which are connected to distribution pumping networks. The purpose of this system is to supply water to customers or other users, including distribution equalizing storage. Thus, an urban water system encompasses the processes of water source establishment, purification, storage, and distribution.

A public water supply, as defined by the US EPA, is a water system, either public or private, that serves at least 25 individuals or has a minimum of 15 service connections for a duration of at least 60 days per year. Such water systems are required to adhere to certain fundamental principles. These principles include maintaining a distribution system that prevents contamination, ensuring adequate pressure throughout the system, providing enough water for firefighting purposes, ensuring uninterrupted water flow to all consumers even during repairs, laying distribution pipes at least one meter away from or above sewer lines, and minimizing leakage to reduce water losses. Households that rely on the water system can be categorized according to the level of service they receive. This classification is determined by factors such as distance, time, reliability, and cost of water (Bartram & Howard, 2003).

According to Bartram & Howard (2003), service levels can be classified into four categories. The first category is "no service," which refers to situations where the water source is located more than 1000m away or takes more than 30 minutes to reach. The second category is "basic service," which occurs when the water source is located between 100m and 1000m away or takes between 5 and 30 minutes to reach. The third category is "intermediate access," which means that water is delivered through one tap on the property or is located within 100m or 5 minutes of collection time. The fourth category is "optimal access," which refers to situations where water is supplied through multiple taps continuously (Bartram & Howard, 2003).

III. METHODOLOGY

The research was conducted in Nairobi County which has 17 sub counties, however the study focused on 12 sub counties which house the biggest informal settlements in the County. The research targeted a population of 308,456 people (Kenya National Bureau of Statistics[KNBS], 2019) living in the informal settlements. Descriptive research design was adopted for this study. A two-stage cluster Sampling was used with distribution based on population proportional to size (PPS). The unit of analysis in this objective was the households (water users or customers). This was undertaken by a logistical regression to assess household water security based on existing water service provision structure. A household was determined to be either water secure or water insecure (dichotomous). Table 1 gives the sample of the households interviewed in each cluster.

Table 1
Sampling Frame for the 12 Sub-Counties

Sub County	Sub County Population	Estimated Slum Cluster Population	Proportion of Population (%)	Number of households to be sampled
Dagoretti North	133,504	24,899	18.65	18
Dagoretti South	160,718	7,281	4.53	30
Embakasi	663,211	60,684	9.15	66
Kamukunji	220,659	22,882	10.37	26
Kasarani	525,624	54,507	10.37	43
Kibra	212,261	13,606	6.41	27
Lang'ata	178,282	8,790	4.93	9
Makadara	160,434	7,909	4.93	15
Mathare	193,416	9,535	4.93	19
Ruaraka	283,449	42,404	14.96	89
Starehe	159,709	37,723	23.62	18
Westlands	247,102	18,236	7.38	28
Totals	**3,138,365**	**308,456**	**100**	**388**

The study used household questionnaires as the main research instrument. The data collected was analyzed using both descriptive and inferential statistics. The descriptive statistics includes frequency, percentage, and mean scores while the inferential statistics was mainly chi-square test and findings presented in form of figures and tables.

IV. FINDINGS & DISCUSSION

This section presents the findings of the study based on analysis of the primary data.

4.1 Demographic characteristics of the Respondents

Table 2 shows the demographic characteristics of the respondents involved in this study.

Table 2
Demographic Characteristics of the Respondents

Variable		Frequency	Percentage
Sex of the respondent	Female	275	71.0%
	Male	113	29.0%
Relationship of the respondent to the Household Head	Self	18	4.7%
	Spouse	4	1.0%
	Child (with permission of Parent/Guardian)	13	3.4%
	Relative	199	52.0%
	Others	149	38.9%
Age of the respondent	18 - 35 Years.	196	50.5%
	36 - 64 Years.	183	47.2%
	Above 65 Years.	9	2.3%
Highest level of education	No Education	10	2.6%
	Primary incomplete	6	1.5%
	Primary complete	88	22.7%
	Secondary incomplete	31	8.0%
	Secondary complete	131	33.8%
	Tertiary (Certificate/Diploma)	59	15.2%
	University	48	12.4%
	Postgraduate	15	3.9%
Employment Status	Not employed	99	25.5%
	Employed salaried	53	13.7%
	Employed casual laborer	82	21.1%
	Self employed	152	39.2%
	Student	2	0.5%

Monthly income	Less than 23,670	342	88.1%
	Between 23671 to 112,929	46	11.9%
Main Source of income	Aid/Cash transfer	2	0.5%
	Formal employment	47	12.1%
	Remittance from relatives	15	3.9%
	Small scale trade	199	51.3%
	Wage earner	125	32.2%
Length of stay in the current location	≤ 3 months	12	3.4%
	≥ 3 to ≤ 6 Months	21	5.5%
	> 6 to ≤ 12 Months	12	3.4%
	>1 to ≤ 2 Years	33	8.1%
	>2 Years	310	79.7%
Where you came from	Another INSE	95	24.5%
	From an urban area other than Nairobi	159	41.0%
	From a rural area	61	15.7%
	I was born here	63	16.2%
	Other, please specify:	10	2.6%
Total Number of respondents		**388**	**100.0%**

Water Service Levels

Water service levels (WSL) were computed based on access levels classified as optimal, intermediate, basic and no service levels. From the findings in Table 3, 255 (65.7%) had intermediate access, 81 (20.9%) had basic access, 28 (7.1%) had no service while 24 (6.3%) had optimal access to water services.

Table 3

Water Service Levels

Ref.	Service Level Accessed by household	Frequency	Percentage
1	Optimal access	24	6.3
2	Intermediate access	255	65.7
3	Basic access	81	20.9
4	No service	28	7.1
	Total	**388**	**100.0**

The findings on water access were classified into, acceptable and unacceptable access based on intermediate and optimal access, as shown in Table 4. It was observed that 276 (71.2%) of the respondents had acceptable access to water while on the other hand, 112 (28.8%) had unacceptable access.

Table 4

Water Service Overall Access

Ref	Acceptability of access	Frequency	Percentage
1	Unacceptable access	112	28.8
2	Acceptable access	276	71.2
	Total	**388**	**100.0**

Water Service Structures

Water service structures was classified based on 4 categories. From Table 5, 197 (51.0%) had no water service structure, 34 (8.7%) had basic structure, 11 (2.9%) had intermediate structure, and 146 (37.5%) of the respondents had full water service structure.

Table 5

Water Service Structure

Ref	Water Service Structure available to household	Frequency	Percentage
1	Full structure	146	37.5
2	Intermediate structure	11	2.9
3	Basic structure	34	8.7
4	No structure	197	51.0
	Total	**388**	**100.0**

Water Service Structure versus Sub-County

The study established the relationship between water service structure and the sub- counties in Nairobi County. Table 6 summarizes the findings.

Table 6
Water Service Structure Versus Sub-County

Sub-County	**Water service structure**										
	No structure		**Full structure**		**Intermediate structure**		**Basic structure**		**Total**		**X^2**
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	
Dagoretti North	12	66.7	1	5.6	0	0.0	5	27.8	18	100.0	
Dagoretti South	16	51.6	10	32.3	0	0.0	5	16.1	31	100.0	
Embakasi South	39	54.2	22	30.6	2	2.8	9	12.5	72	100.0	
Embakasi West	0	0.0	1	100.0	0	0.0	0	0.0	1	100.0	
Kamukunji	13	50.0	13	50.0	0	0.0	0	0.0	26	100.0	
Kasarani	25	50.0	14	28.0	2	4.0	9	18.0	50	100.0	144.55
Kibra	25	92.6	2	7.4	0	0.0	0	0.0	27	100.0	**(0.001)**
Langata	8	88.9	0	0.0	0	0.0	1	11.1	9	100.0	
Makadara	14	87.5	2	12.5	0	0.0	0	0.0	16	100.0	
Mathare	12	63.2	1	5,3	3	15.8	3	15.8	19	100.0	
Ruaraka	24	25.8	66	71.0	1	1.1	2	2.2	93	100.0	
Starehe	13	68.4	6	31.6	0	0,0	0	0.0	19	100.0	
Westlands	11	35.5	14	45.2	4	12.9	2	6.5	31	100.0	
Total	**197**	**51.0**	**146**	**37.5**	**11**	**2.9**	**34**	**8.7**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	144.554[a]	36	.001
Likelihood Ratio	147.929	36	.000
Linear-by-Linear Association	.021	1	.884
N of Valid Cases	388		

From the findings, those with full water structure for the various sub-counties were; Dagoretti North 1 (5.6%), Dagoretti South 10 (32.3%), Embakasi South 22 (30.6%), Embakasi West 1 (100.0%), Kamukunji 13 (50.0%), Kasarani 14 (28.0%), Kibra 2 (7.4%), Langata 0 (0.0%), Makadara 2 (12.5%), Mathare 1 (5.3%), Ruaraka 66 (71.0%), Starehe 6 (31.6%) and Westlands 14 (45.2%). A chi- square value of ($\chi^2_{12,0.05}$=144.554, P<0.05) showed a significant relationship between water service structures and sub- counties.

Water service structure versus National quantity standard

The study established water service structure against national standard quantity. The respondents were classified into non-compliant with standard of 60 lpcd and those who are compliant. From the findings in Table 7, only 5 (45.5%) were compliant with the full structure. A chi- square computation of ($\chi^2_{4,0.05}$=2.676, P>0.05) showed that there was no significant relationship between water service structures and national standard quantity.

Table 7

Water Service Structure versus National Standard Quantity

Compliance to National Quantity Standard of 60 lpcd	Water service structure coded: No structure		Full structure		Intermediate structure		Basic structure		Total		X^2
	F	%	F	%	F	%	F	%	F	%	
Non- Compliant with National Standard of 60 lpcd	207	54.9	118	31.4	16	4.2	36	9.5	377	100.0	2.676
Compliant with National Standard of 60 lpcd	4	36.4	5	45.4	0	0.0	2	18.2	11	100.0	(0.444)
Total	**211**	**54.4**	**123**	**31.7**	**16**	**4.1**	**38**	**9.8**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.676[a]	3	.444
Likelihood Ratio	2.940	3	.401
Linear-by-Linear Association	1.525	1	.217
N of Valid Cases	348		

4.1.1 Water Service Structure versus Sphere Standard Quantity

On those who had water service structure and had a sphere standard quantity were classified in terms of the households able to access water of 15 lpcd. From the findings, 30 (26.3%) had full structure and were accessing less than 15 lpcd of water while 98 (35.7%) had full structure and could access more than 15 lpcd of water. A chi-square value of ($\chi^2_{3,0.05}$=3.478, P>0.05) showed that there was no significant relationship between the two variables (Table 8).

Table 8

Water Service Structure versus Sphere Standard Quantity

Households meeting SPHERE Standard Water Quantity	Water service structure coded: No structure		Full structure		Intermediate structure		Basic structure		Total		X^2
	F	%	F	%	F	%	F	%	F	%	
Households accessing <15 lpcd	66	57.9	30	26.3	5	4.4	13	11.4	114	100.0	
Households accessing ≥15 lpcd	148	54.0	98	35.7	7	2.6	21	7.7	274	100.0	3.478
Total	**214**	**55.2**	**128**	**32.9**	**12**	**3.1**	**34**	**8.8**	**388**	**100.0**	0.324

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	3.478[a]	3	.324
Likelihood Ratio	3.470	3	.329
Linear-by-Linear Association	.281	1	.596
N of Valid Cases	388		

4.1.2 Water Service Structure versus Affordability

On the relationship between water service structure and affordability, the study established that 102 (32.7%) had full structure but were buying water at more than the set standard of KSh. 2/20L jerry can. Only 26 (30.3%) of the households had full structure and were buying water at or less than KSh. 2/20L container in the study area (Table 9). On whether there was relationship between water service structure and affordability, the Chi-square value ($\chi^2_{3,0.05}$=2.203, P>0.05) established that there was no significant relationship.

Table 9
Water Service Structure versus Affordability Based on Cost of 20L Container

Compliance to standard cost of water based on 20L container	Water service structure coded										X^2
	No structure		Full structure		Intermediate structure		Basic structure		Total		
	F	%	F	%	F	%	F	%	F	%	
Households buying water at more than the set standard KSh. 2/20L container.	158	50.6	102	32.7	16	5.1	36	11.6	312	100.0	2.203
Households buying water at or less than the set standard KSh. 2/20L container.	46	60.5	23	30.3	2	2.6	5	6.6	76	100.0	0.531
Total	**204**	**52.6**	**125**	**32.2**	**18**	**4.6**	**41**	**10.6**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.203[a]	3	.531
Likelihood Ratio	2.274	3	.551
Linear-by-Linear Association	2.636	1	.104
N of Valid Cases	331		

4.1.3 Water Service Structure versus Consolidated Reliability of Water Services

A relationship between water service structure and water reliability was established. From the findings in Table 10, households with water unreliable and had full structure were 100 (39.4%) while those who were water reliable and full structure were 42 (31.3%). A chi- square value of ($\chi^2_{3,0.05}$=2.222, P>0.05) showed that there was no significant relationship between the water service structure and water reliability.

Table 10
Water Service Structure versus Consolidated Reliability of Water Services

Household reliability based on existing structure	Water service structure coded										X^2
	No structure		Full structure		Intermediate structure		Basic structure		Total		
	F	%	F	%	F	%	F	%	F	%	
Water unreliable household	126	49.6	100	39.4	7	2.7	21	8.3	254	100.0	2.222
Water reliable Household	72	53.7	42	31.3	5	3.8	15	11.2	134	100.0	0.528
Total	**198**	**51.0**	**142**	**36.6**	**12**	**3.1**	**36**	**9.3**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	2.222[a]	6	.528
Likelihood Ratio	2.022	6	.519
Linear-by-Linear Association	.925	1	.536
N of Valid Cases	388		

4.1.4 Water Service Structure versus Consolidated Overall Availability of Water Services

The study established the water service structure and water availability of water (Table 11). From the findings, those who had full structure and water was readily available were 50 (28.0%). On the other hand, those who had full structure, but water was not readily available was 92 (43.8%). A chi- square value of ($\chi^2_{3,0.05}$=11.170, P<0.05) showed that there was significant relationship between the water service structure and overall water availability.

Table 11

Water Service Structure versus Consolidated Overall Availability of Water Services

Availability of water based on structure	Water service structure										X^2
	No structure		Full structure		Intermediate structure		Basic structure		Total		
	F	%	F	%	F	%	F	%	F	%	
Water not readily available	92	43.8	92	43.8	5	2.4	21	10.0	210	100.0	11.170
Water readily available overall from all sources	106	59.6	50	28.0	7	3.9	15	8.4	178	100.0	**(0.010)**
Total	**198**	**51.0**	**142**	**36.6**	**12**	**3.1**	**36**	**9.3**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.170[a]	3	.010
Likelihood Ratio	11.668	3	.010
Linear-by-Linear Association	4.639	1	.031
N of Valid Cases	388		

4.1.5 Water Service Structure versus Household with at least one Source with Acceptable Water Quality

The study established water service structure against household with at least one source with acceptable water quality. From Table 12, it was observed that 98 (40.2%) had a full structure and at least one quality source of water. Those who had full structure but had no quality water were 28 (19.4%). A chi- square value of ($\chi^2_{3,0.05}$=21.558, P<0.05) showed that there was a significant relationship between water service structure and at least one source with acceptable water quality.

Table 12

Water Service Structure versus Household with At least One Source with Acceptable Water Quality

Household access to quality at least one acceptable quality water source	Water service structure coded										X^2
	No structure		Full structure		Intermediate structure		Basic structure		Total		
	F	%	F	%	F	%	F	%	F	%	
No quality water source	85	59.0	28	19.4	10	6.9	21	14.7	144	100.0	21.558
At least one quality source	115	47.1	98	40.2	13	5.3	18	7.4	244	100.0	**(0.001)**
Total	**200**	**51.5**	**126**	**32.5**	**23**	**5.9**	**39**	**10.1**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	21.558[a]	3	.001
Likelihood Ratio	21.951	3	.001
Linear-by-Linear Association	.002	1	.964
N of Valid Cases	388		

4.1.6 Water Service Structure versus Household Overall Water Access

The study sought to determine the relationship between water service structure and household overall water access. The households with unacceptable access and had full structure were 34 (32.1%) while those who had an acceptable access and had a full structure were 108 (38.3%) as shown in Table 13.

Table 13
Water Service Structure versus Household Overall Water Access

Water access	Water service structure coded										X^2
	No structure		Full structure		Intermediate structure		Basic		Total		
	F	%	F	%	F	%	F	%	F	%	
Unacceptable access	43	40.6	34	32.1	8	7.5	21	19.8	106	100.0	26.972
Acceptable access	155	55.0	108	38.3	4	1.4	15	5.3	282	100.0	**(0.001)**
Total	**198**	**51.0**	**142**	**36.6**	**12**	**3.1**	**36**	**9.3**	**388**	**100.0**	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	26.972[a]	3	.001
Likelihood Ratio	25.750	3	.000
Linear-by-Linear Association	22.873	1	.000
N of Valid Cases	388		

From the analysis of water service structure against water security variables the Chi-square value ($\chi^2_{3,0.05}$=26.972, P<0.05) that was computed showed that there was an association of water service structure and availability, access and quality.

Overall, there was no association found between water service structure (or level of infrastructure development) and quantity, affordability, and reliability. It was evident from the study findings that various water security parameters in Nairobi's informal settlements significantly varied across different sub-counties, reflecting disparities in infrastructure, investment, and resource management. This was supported by K'Akumu & Appida (2006) who concluded that the political landscape in Nairobi influences water access, with sub-counties that have strong political representation and advocacy enjoying better water services. This was the case with Bartram & Cairncross (2010) who highlighted those areas with better-developed infrastructure had relatively higher water access, emphasizing the role of governmental and non-governmental investment in improving water services.

In a study conducted by Purshouse et al., (2017), in eastern part of Nairobi County, they found that average per capita water consumption had a correlation with the water source choice. The findings also demonstrated that, household wealth, education, and cost of water, did not have significant effects on per capita water consumption. This is contrary to the study by Joshi et al., (2023) who found a strong influence of socioeconomic status on both availability and cost of piped water. There was a glaring contrast in water access based on monthly income; with high and middle income households enjoying more reliable water supply through in-house connections, while lower-income individuals faced higher costs and limited access.

Other studies have shown that education impacts awareness, advocacy, and water management practices. For instance, Jagals & Mokoena (2010) found that higher educational levels improve water access, as educated individuals were more knowledgeable about their rights and better equipped to negotiate with providers. Seager et al., (2012) noted that higher education correlates with better water conservation and hygiene practices, reducing waterborne diseases. Mutisya & Yarime (2014) highlighted that educated community members in Kibera effectively lobby for improved water services, benefiting the entire community. Gulyani et al., (2005) emphasized that education enhances community development and informed decision-making on water resources. Hope (2006) argued that education bridges the gap between policy and practice, leading to more effective implementation of water programs. Bartram & Faldi et al. (2021) stressed that educational initiatives on water, sanitation, and hygiene are crucial for sustainable water access improvements in informal settlements. Lack of correlation of education and water access in informal settlements might be due to the fact that, the context doesn't favour those with education to make better access choices given limited availability of water.

Monthly income is a direct determinant of water access in Nairobi's informal settlements. Higher-income households generally have better and more reliable water access. Agreeing with the findings of this study, Whittington et al., (2009) demonstrate that income levels significantly influence a household's ability to maintain a stable water supply, as higher-income households can afford to pay for water services or invest in storage solutions. This financial capability is crucial in environments where water is often a commodity sold at high prices due to scarcity.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

For the informal settlements in Nairobi County, the existing water structures of water service provision system influenced only three of the six water security factors, and that is, availability, access and quality. The level of structure did not have any impact on quantity of water accessed by household, the affordability of the water, and how reliable the water service was. This pointed to households' coping strategies where there was dependency on multiple water sources in order to improve household water security. The study therefore concludes that, provision of infrastructure alone may not lead to household water security.

5.2 Recommendations

The study recommends that there is need for formal and informal water service providers to collaborate in order to achieve water security in informal settlements. Based on the findings the study recommends that while planning the development of a water supply system structures (production, treatment, storage and distribution), the decision should be based on whether the investment will improve availability, access, quantity, quality, affordability and reliability of service. Accordingly, this decision should help inform the investment by policy makers to ensure water security.

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