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Effects of external social, economic and environmental factors affecting intermittent water supply. A case of Lusaka water supply and Sanitation Company

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Abstract
The purpose of this study was to identify social, economic and environmental factors external to Lusaka Water Supply and Sanitation Company (LWSC) that contribute to intermittent water supply. The study adopted a mixed research approach and employed a case study research design. The study was carried out in Lima, Kapwepwe and Mwembeshi wards of George compound in Peri urban West of Lusaka. The purposive sample size and population for this study was 267 with a response of 205 participants who consisted of the affected 185 households and 20 Key informants. The collection of data deployed semi-structured questionnaire for the households and interview guide for the key informants, collected data was transcribed and analysed manually using a thematic research approach for qualitative data while quantitative data was, STATA Version 14. A test of association between external factors and intermittent supply was done using chi-square to establish the social, economic and environmental factors that affect intermittent supply of water.
By and large the study revealed that social vices such as vandalism, theft and poor waste management contributes to the interruption of water supply of the water utility. Economically, increase in electricity tariffs, unscheduled power outages contribute to both high cost of water production and rationing of water due to power outages. The study established that Water tariffs are not determined by LWSC but by the water and sanitation regulator, National Water and Sanitation Company (NWASCO). LWSC therefore gets economically affected by low water tariffs which are not reflective of the cost of production. The study also disclosed that environmental impacts like extreme and prolonged dryness or precipitation do affect the production and supply of water by either losing underground water sources by declining water levels due to extreme heat or by flooding of water facilities due to extreme and extended precipitation.

Keywords: Intermittent supply, social, economic, environmental factors, LWSC

Introduction
Lusaka Water and Sanitation Company (LWSC) is a quasi-government institution formed out of the Water and Sewerage department of Lusaka City Council (LCC) but operating as a commercial utility company. Despite LWSC operating as a private company limited liability Company, it has various institutions that play a role in addressing factors external to its operations. The production, treatment, distribution and supply of water depends on many other external factors which has the potential to contribute to the intermittent supply of water to LWSC's customers.
Various external factors have significantly influenced water supply in Lusaka, Zambia, over the past five years. These include high nitrate and sodium concentrations in groundwater due to human activities and industrial pollution (Nachiyunde, 2013), governance issues, demographic shifts, economic dynamics and climate change impacts (Simukonda, 2018) [11]. Additionally, urban expansion and mismanagement have led to the overexploitation of aquifers, exacerbating water scarcity (deWaele, 2003). Concerns have arisen regarding the vulnerability of urban aquifers to pollution due to human activities (Chande, 2019). Moreover, climate change has affected water resource availability in key river basins like Zambezi, Kafue and Luangwa (Hamududu, 2019) [9]. These factors have collectively contributed to the deterioration of surface water quality, especially in smaller tributaries affected by significant anthropogenic land use changes (SDG 6), the global objective is to attain universal and equitable access to safe and affordable water for all by the year 2030 (2030 Agenda for Sustainable Development, 2015) [14].
This article has a limitation in that, the research was only restricted to Peri urban West excluding Peri urban South and Peri urban East of Lusaka Water Supply and Sanitation. The outline of the article is as follows, introduction, giving a background and guidance to the study. The empirical literature review is outlined followed by the results and discussions of findings. Lastly, the journal is summed up by a conclusion and recommendations.

Empirical Review
Various socioeconomic factors have significantly influenced water supply in developed countries in developed countries over the past years. These factors encompass arrange of indicators, including gross national income, female primary completion rate, agriculture, growth of rural population, and governance indicators, all of which have played distinct roles in shaping water availability and accessibility (Gomez, 2019) [8]. Changes in the world's economic development patterns and urbanization process have also affected water use patterns in developed countries (Zhang, 2020) [18]. China's rapid industrialization and urban expansion for instance have led to increased demands for water resources, both domestically and internationally, influencing global water consumption trends.
In Illinois, Fox River watershed is being threatened as a water source due to effects of Climate Change, increased variability in stream flows due to climate change has the potential to disrupt water supply availability, particularly

during periods of peak water use (Bekele & Knapp, 2010) [1].

Studies have shown that water supply systems in various regions of Africa, with reference to a particular study in rural areas in South Africa (MEMA and MOTHETHA, 2013) [12] suffer from wear and tear, theft and vandalism and ensuring the security of water infrastructure is essential for maintain a reliable supply of clean water to communities.

The complex interplay between social parameters and water resources varies across continents, highlighting the need for tailored approaches to water-resources planning and management (Bozorg-Haddad, 2021). In Lusaka, Simukonda (2018) [11] identifies a multitude of external factors influencing water supply. These included poor governance, demographic and economic dynamics, hydrologic regime change, poor system management and operation, unplanned system extensions, limited skilled manpower, poor electricity supply, and lack of Customers awareness. Additionally, rapid urbanization is a significant factor, with Lusaka experiencing an annual average growth rate of about 2.1 percent (Central Statistical Office, 2022) [4]. This rapid urbanization has led to unplanned settlements and encroachments, increasing pressure on natural resources such as land and clean water sources.

Pollution is another critical issue, with urban growth contributing to poor sanitation and inadequate waste management (de Waele & Follesa, 2003; Cohen 2006) [6, 7]. Vandalism of water supply facilities is a concerning problem, leading to system breakdowns and water losses (MEMA and MOTHETHA, 2013) [12]. Frequent power outages, primarily due to load shedding, have disrupted water supply operations (Umar & Kunda-Wamuwi, 2019) [15].

Low tariffs and non-payment of water bills have further strained water utilities (Dagdeviren, 2008). Climate change is also a significant factor affecting water supply, due to reduced yields from both underground and surface water sources resulting from prolonged dry spells. (IPCC, 2014 Bekele &Knapp, 2010) [1, 10]. Overall these external factors collectively contribute to intermittent water supply in Lusaka.

Studies on socioeconomic factors influencing water supply in developed and developing countries can inform policies and interventions aimed at addressing water supply challenges in Lusaka, Zambia.

Theoretical Frame

Systems theory, which traces its roots back to the 1940s with biologist Ludwig von Bertalanffy as its proponent, forms the foundation of our analytical framework (General Systems Theory, 1968). It was developed by Ross Ashby in his work "Introduction to Cybernetics" in 1956.

Systems theory was used in this study so as to understand the interactions of various variables and establish relationships and interdependencies.

This theory emphasizes that systems exist within social environments where external factors can impact their outcomes and outputs. This study resonates with this perspective, as we recognize that water production and distribution facilities exist within a social environment. Factors such as vandalism, climate change effects, power outages, and tariff structures, among others, play a crucial role in affecting the outputs of the system and its ability to meet its goals. The review of the systems theory in this study was very significant as it helped to identify the key concepts in this study as well as the collaborative power and interdependencies with other stakeholders in addressing the identified external factors affecting the water utility.

Conceptual Framework

In this framework, variables have been categorized based on their roles in the intricate cause-and-effect relationships governing water supply. They are distinguished between Independent, Dependent, Mediating and Moderating variables.

Independent variables are those that directly bring about changes in the Dependent variable, and their variations are not contingent on any other variables

Mediating Variables help elucidate the intricate processes linking two variables. Moderating Variables come into play to either enhance or diminish the relationships between independent and dependent variables.

The Dependent variable in our study is the intermittent supply of water, and it all depends on all the Independent variables such as Power outages, drying of boreholes due to climate change, low water tariffs and vandalism of water facilities among others. Each of these Independent variables possesses the capacity to induce changes in the Dependent variable.

By systematically evaluating these identified social, economic and environmental factors and establishing correlations between them and their impact on water supply, our research aims to provide invaluable insights for stakeholders within the water supply chain.

Methodology

This study employed a mixed-method approach utilizing both quantitative and qualitative methodologies to provide a holistic view of the research problem. The quantitative data was used for statistical data analysis for analyzing relationships between dependent and independent variables and qualitative data for lived experiences from key informants.

The target population for this research was 800 including households from Kapwepwe, Mwembeshi and Lima wards of peri urban west of Lusaka, community gate keepers and relevant LWSC departments.

The sample size was determined by using the Taro Yamane formula (1967) [17]:

$$n = \frac{N}{1 + N(e)^2}$$

Where

n = Sample size required

N = Total population size

e = Margin of error (expressed as a decimal)

Total population being 800 respondents, the Study's and margin of error (e) was 0.05.

It gave a sample size of 267. The study used questionnaires and in-depth interviews to collect primary data and secondary data from the literature review from similar studies. The study adopted random sampling for quantitative data and purposeful sampling for qualitative data collection.

A total of 267 sample size 185 households and 20 key informants responded giving a response rate of 77%

Collected data was transcribed and analysed manually using a thematic descriptive research approach for qualitative data while quantitative data was, STATA Version 14. A test of association between external factors and intermittent supply was done using chi-square to establish the social economic and environmental factors that affect intermittent supply of water.

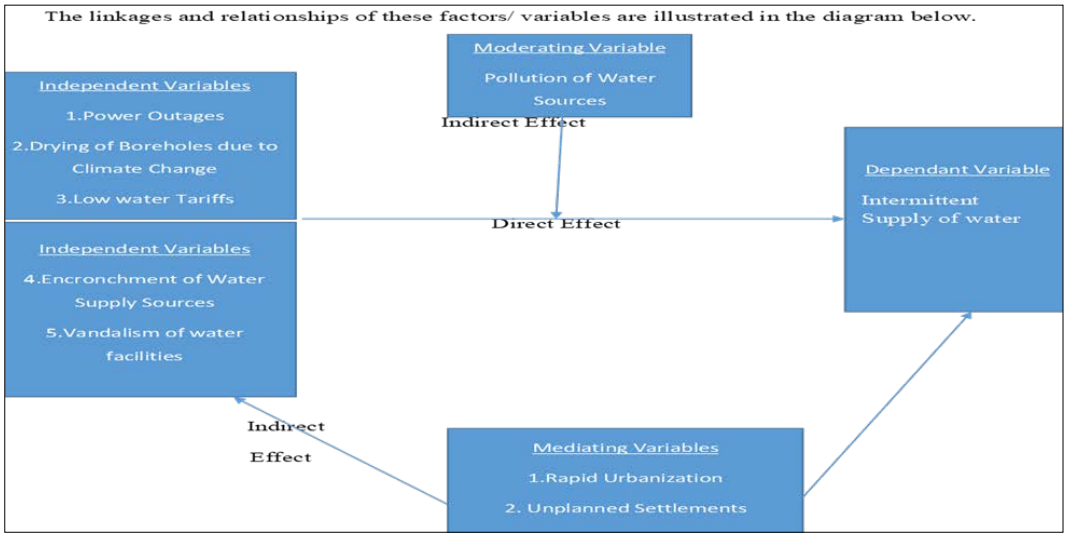

Fig 1: Conceptual Framework

Results and Discussion of Study Findings

Research results of the study are highlighted in this chapter. The research study employed a robust combination of qualitative and quantitative data analysis methods. Results were interpreted using thematic descriptive framework analysis and SATA software were reported comprehensively, including key statistics such as frequencies, percentages, chi-square values and probability values. The 0.05 threshold for statistical significance was employed, ensuring that only relationships with a high level of confidence were highlighted in the findings.

Fig 2: shows respondents by age, the results show the majority of the participants falling within the 45-54 age range at 35.1%.

Fig 3: shows gender distribution, the study consisted of more females (54.6%) than males (45.4%).

Fig 4: shows the summarised education background with those who had attained secondary school being the majority at 44.9%

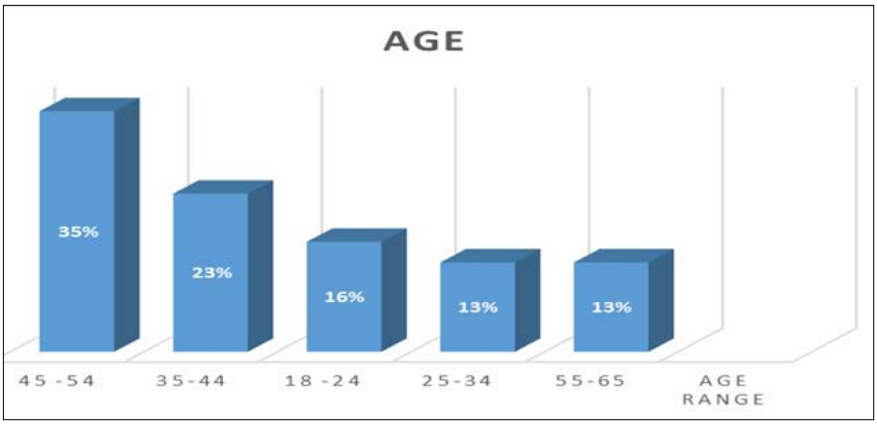

Fig 2: Respondents by Age

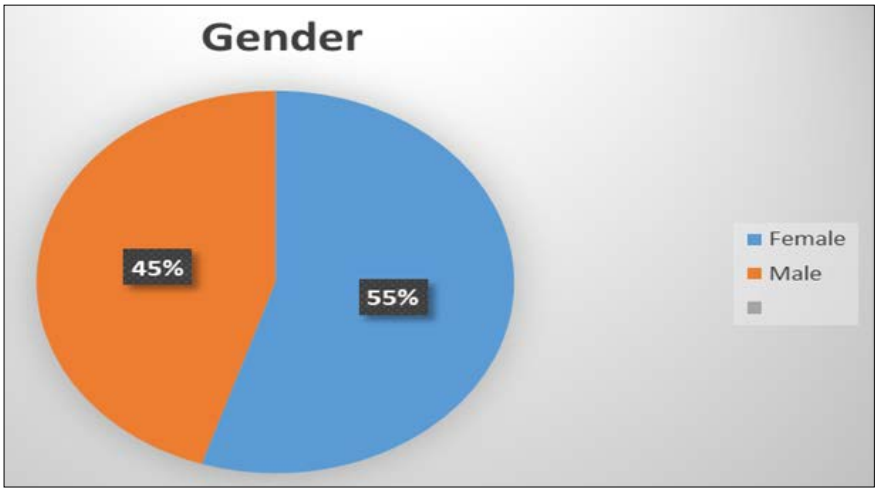

Fig 3: Gender Distribution of Respondents

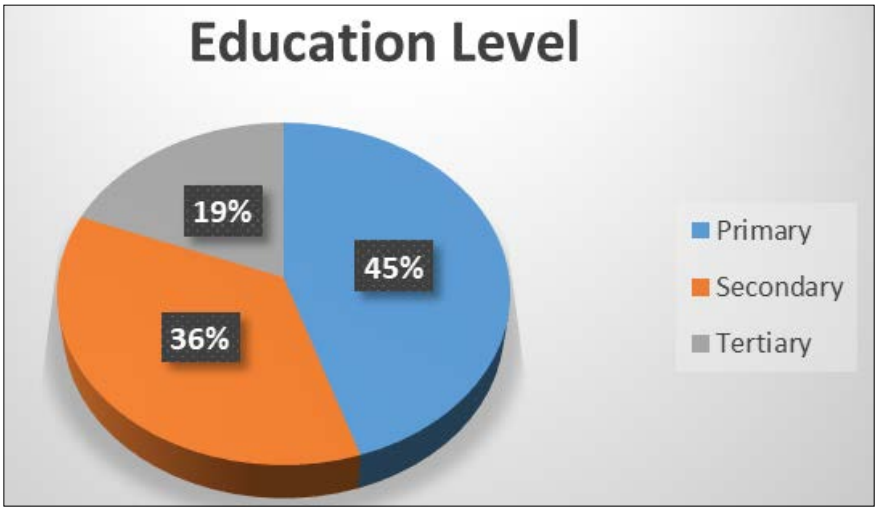

Fig 4: Respondents Level of Education

Table 1: Correlation of Factors Affecting Water supply/Rationing of External

Rationing Hours (Water supply)						
Area	**N= (185)**	**(%)**	**< than six hours N (%)**	**> Than six hours N (%)**	**X2**	**P**
Lima	60	32.4	60 (100)	0 (0.0)	64.6	0.001
Kapwepwe	66	35.7	30 (4.4)	36 (54.6)		
Mwembeshi	59	31.9	0 (0.0)	59 (100)		
Source of water						
Household Connection	30	16.2	30 (100)	0 (0.0)	6.9	0.003
Communal Tap	155	83.8	30 (16.3)	125 (80.7)		
Cause of intermittent water supply						
Unscheduled Power outages	60	32.4	11(18.3)	49 (81.7)	14.0	0.023
Vandalism of water facilities	46	24.7	9 (19.6)	37 (80.4)		
Seasonal Drying up of BH/Flooding of water facilities	54	29.2	4 (7.4)	50 (92.6)		
Theft from water facilities	23	12.4	4 (17.4)	19 (82.6)		
Theft from ZESCO facilities	2	1.1	2 (100)	0 (0.0)		
Affordability of garbage collection fee						
Not affordable	155	83.8	30 (19.3)	125 (80.7)	6.9	0.003
Affordable	30	16.2	0 (0.0)	30 (100)		
Alternative garbage disposal methods						
Engage anyone from the community to dispose (Indiscriminately)	102	55.1	30 (29.4)	72 (70.6)	29.1	0.001
Burn the waste	29	15.7	0 (0.0)	29 (100)		
Dig a pit within the yard	24	13.0	0 (0.0)	24 (100)		
Affordable	30	16.2	0 (0.0)	30 (100)		
Poor Waste disposal affect water quality/supply						
No	6	3.2	6 (100)	0 (0.0)	32.0	0.001
Yes	179	96.8	24 (13.4)	155 (83.6)		

This table above provides a comprehensive overview of the socio, economic and environmental characteristics affecting respondents and their association with the duration
of the water supply rationing, presenting a key aspect of the study's findings. The chi-square test was conducted to assess the association between causes of intermittent water supply characteristics and the duration of water supply rationing among consumers. The threshold for statistical significance was set at 0.05. Below are the findings and interpretations based on the provided table.

Area (X2 = 64.6, p= 0.001)

Lima: 60 respondents (32.4%) experienced rationing for less than six hours, and none experienced rationing for more than six hours.

Kapwepwe: 30 respondents (4.4%) experienced rationing for less than six hours, while 36 (54.6%) experienced rationing for more than six hours.

Mwembeshi: 59 respondents (31.9%) experienced rationing for more than six hours, and more experienced rationing for less than six hours.

Interpretation: There is statistically significant association between the area of residence and the duration of water supply rationing. Residents of Mwembeshi are more likely to experience longer rationing hours compared to those in Lima and Kapwepwe.

Source of Water (X2 = 64.6, p= 0.003)

Household Connection: 100% experienced rationing for less than six hours.
Communal Tap: 16.3% experienced rationing for less than six hours, and 80.7% for more than six hours.

Interpretation: the source of water is statistically associated with the duration of rationing. Those using communal taps are more likely to experience longer rationing hours than those with household connections.

Cause of Intermittent Water Supply (X2 = 14, p = 0.023)

Vandalism of water facilities: 19.6% experienced rationing for less than six hours, and 80.4% for more than six hours.
Seasonal Flooding of water facilities and Drying up boreholes: 7.4% experienced rationing for less than six hours, and 92.6% for more than six hours.
Theft from water facilities: 17.4% experienced rationing for less than six hours, and 82.7% for more than six hours.

Interpretation: Various causes of intermittent water supply show statistically significant association with the duration of rationing. Different causes result in varying rationing durations.

Determination of Institutions' Roles

Table 2: Thematic descriptive framework on water supply

Main Themes	Sub-themes	Excerpts
Identification of Factors Influencing Water Supply in Lusaka City	External Social Factors	"Poor waste management is a serious challenge in our community..."
		"Disposal of used diapers has become a menace."
	External Economic Factors	"The cost of water supply is greatly affected by two factors, increase in electricity tariffs and low water tariffs for water customers."
		"Unscheduled power outages also affect their supply and trickles down to poor billing and collection of revenue."
	External Environmental Factors	"Extreme and extended precipitation leads to floods in that particular period..."
		"Extreme and prolonged dry season brings with it lowered water table which contribute to dry taps in that season..."
Assessment of the Effects of External Factors on Water Supply	Impact of External Social Factors	"The more items were stolen or facilities vandalized, the longer hours of intermittent water supply the community experienced."
		"Poor quality of water due to contamination from indiscriminate dumping directly contributed to intermittent water supply..."
	Impact of External Economic Factors	"The cost of water supply is greatly affected by two factors, increase in electricity tariffs and low water tariffs for water customers."
		"LWSC is highly dependent on hydroelectric power for the production and supply of water..."
	Impact of External Environmental Factors	"Water Kiosks and other water facilities get flooded during the rainy causing longer hours of intermittent water supply in that particular period..."
		"Beginning from August to November, we experience increased hours of intermittent supply due lowering of water table experienced during the dry season...."
		"We wake up very early in the morning to line up for water , and sometimes walk long distances to fetch water from the industrial area during dry season…"
Determination of Institutions' Roles in Addressing External Factors Affecting Water Supply	Roles of Lusaka City Council	"Garbage collection is purely a local municipal council's responsibility..."
	Roles of ZESCO	"LWSC is highly dependent on ZESCO when it comes to production and supply of water..."
	Roles of ZEMA (Zambia Environmental Management Agency)	"In my view ZEMA has a responsibility to ensure environmental/underground water protection by ensuring compliance where waste disposal is concerned..."
	Institutional Collaboration	"For example, if the Lusaka City Council would ensure that garbage in the community is well managed and if ZEMA ensured that LCC was complying when it comes to designated dumping of waste..."

Respondents highlighted the interdependence between LWSC and institutions like the Zambia Police under the Ministry of Home Affairs and Community neighborhood watch/crime prevention committees to address vandalism and theft challenges.
The study findings underscore the pivotal role that various institutions such as Lusaka City Council and ZEMA should play in addressing external factors by ensuring that waste is collected from the communities and dumped at designated sites to protect both the environment and quality of underground water.
The study findings also showed that collaborative efforts need to be enhanced between LWSC and other institutions in addressing external factors affecting their operation.

Conclusion
The study concluded that social, economic and environmental factors external to LWSC operations play a critical role in shaping the availability and reliability of water supply in Lusaka City.
Theft and vandalism of water facilities were attributed to external social factors. Additionally, poor waste

management practices during the rainy season contributed to water contamination, further affecting water supply.

Economic factors, including the cost of water production and supply influenced by electricity tariffs, unscheduled power outages and water tariffs, had a significant impact on water supply operations.

Environmental conditions directly correlates with water supply interruptions. Seasonal water

shortages during prolonged dry season, and on the other hand conversely, prolonged wet seasons resulted in flooding, introducing debris, garbage, and effluent into water sources, leading to water pollution and disruptions in supply.

These findings collectively underscored the multifaceted nature of water challenges in Lusaka City, demonstrating that addressing these issues requires a holistic approach that considers the collaborative efforts of various institutions in managing the water supply infrastructure. These institutions are not only responsible for their core functions but also play an integral role in mitigating external threats to the water supply system.

Recommendations

Effective Government Involvement in facilitating collaboration among institutions, enforcing existing regulations and providing oversight is vital. Establishing an integrated framework among various

Institutions in the water sector would help in addressing the social, economic and environmental factors affecting intermittent water supply.

Involving community structures social factors such as theft and vandalism within communities by enhancing youth engagements, empowerments and community led collaborative efforts. Lastly, there is need to build capacity within LWSC in mitigating and adopting to effects of climate change as well as responding to the early warning signs in environmental changes.

Limitations

The findings of this study are only restricted to peri-urban West of Lusaka as zoned by the Lusaka Water Supply and Sanitation.

The study was only conducted in peri-urban West excluding Peri urban South and Peri-Urban West which could have given a broader view of the external factors affecting water supply intermittent in these other peri-urban areas.

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Conflict of interest

Authors declare no interest in the publication of this paper.

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