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Area prioritising criteria during phased conversion from intermittent to continuous water supply: The case study of Lusaka Water Supply and Sanitation Company, Zambia

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ABSTRACT

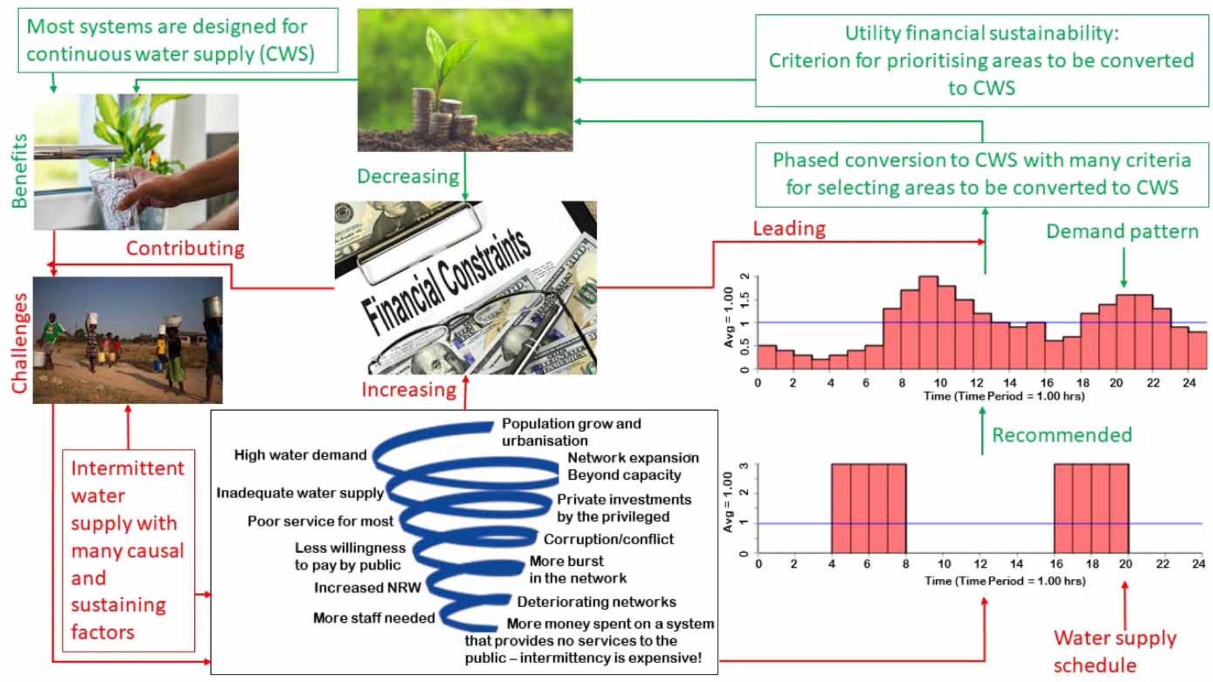
Conversion from intermittent to continuous water supply is a recommended approach for improving water supply service to communities. The conversion process is complex and requires huge financial and human resources investments. Because such resources are always limited and cannot be adequately provided at once, phased conversion is encouraged. However, there are challenges with this approach in terms of which areas should be prioritized during the conversion process so that the water supply situation for the unconverted areas is not aggravated. This article uses a questionnaire and semi-structured interviews to identify the criteria for prioritising areas to be converted during phased conversion to continuous water supply from a water utility perspective. The Lusaka Water Supply and Sanitation Company is used as a case study. Results show that the financial sustainability of the utility company is the major criterion for selecting an area to be prioritized. In countries like Zambia where tariff structures are such that industries subsidise domestic water consumption and the affluent subsidise water consumed by the poor, prioritising financial sustainability entails giving priority to areas where high revenues are expected. This is synonymous with giving priority to the affluent or the middle-class areas with high densities of water consumers.

Key words: equity, financial sustainability, intermittent water supply, phased conversion to continuous water supply

HIGHLIGHTS

- The importance of converting intermittent water supply systems to continuous water supply systems is highlighted.
- Converting intermittent water supply systems requires huge financial investments, this article suggests a phased conversion approach.
- This article gives factors to consider when choosing an area to be prioritised in the phased conversion from intermittent water supply to continuous water supply.

GRAPHICAL ABSTRACT



NOMENCLATURE

Full form of abbreviations

CWS	Continuous water supply
DMA	District metered area
GSG	Global Scenario Group
IWS	Intermittent water supply
IWSS	Intermittent water supply system
LWSC	Lusaka Water Supply and Sanitation Company
NRW	Non-revenue water
WDS	Water distribution system
WSS	Water supply systems
WTP	Water treatment plant

INTRODUCTION

Most urban water supply systems (WSS) are designed to provide continuous water supply (CWS) services by which sufficient high-quality water with adequate pressure is supplied to consumers at all times (Gupta 2015; Geta 2018). However, over time, the ability of some systems to provide continuous supply service diminishes, and intermittent water supply (IWS) sets in. This is because of high levels of water losses from dilapidated water supply infrastructure and increases in consumption water demand due to demographic and economic dynamics (Simukonda *et al.* 2018a). On the other hand, this is due to the expansion of human settlements, leading to the extension of water distribution systems (WDSs) beyond their hydraulic capacities (Ilaya-Ayza *et al.* 2016; Kumpel & Nelson 2016). To meet the increased total water demand, water utilities resort to rationing the limited water quantities (De Marchis *et al.* 2010). Consequently, intermittent water supply systems (IWSSs) are piped systems that supply water for less than 7 days a week or less than 24 h on supply days (Totsuka *et al.* 2004; Mokssit *et al.* 2018). These systems are most prevalent in developing countries (Ghorpade *et al.* 2021).

IWSSs have several negative consequences for consumers, society, and water utilities (Simukonda *et al.* 2018a). Owing to the negative consequences, IWSSs are said to be failed systems and they should only be used temporarily, while efforts are being made to revert to CWS (Klingel & Nestmann 2014). The negative consequences of IWS have been discussed by several authors and include coping costs by consumers, water wastage, inequitable water distribution, poor water quality resulting in health hazards, high non-revenue water (NRW) levels, and additional costs to utilities through frequent valve and pump operations and maintenance (Totsuka *et al.* 2004; Klingel 2012; Kumpel & Nelson 2016; Charalambous & Laspidou 2017; Dadras *et al.* 2023). IWS also leads to water meter measurement inaccuracies caused by the air flowing through them (Ferrante *et al.* 2022) and stuck moving parts. Meter inaccuracies result in poor water consumption management by utilities, which in turn transfer the costs to the customers, leading to their dissatisfaction, loss of confidence in the billing system, and poor bill payment tendencies (Charalambous & Laspidou 2017).

To overcome these problems of IWS, international agencies such as the United Nations and the World Bank and governments such as the Government of India are encouraging the conversion from IWS to CWS (Seetharam & Bridges 2005; World Bank 2010; Kumpel & Nelson 2016). However, limited financial and human resources present serious challenges (Ilaya-Ayza *et al.* 2018). As a result, phased conversion approaches are recommended in the literature (Myers 2003; Klingel & Nestmann 2014; Ilaya-Ayza *et al.* 2018). However, these approaches are complex and have several uncertainties due to the long planning and implementation horizons that characterise WSS projects (Kang & Lansey 2012).

To incorporate uncertainties in the conversion planning and implementation process, Simukonda *et al.* (2022) recommended the use of scenarios because they provide a picture of what the future may possibly look like and the means of knowing critical indicators, which when encountered can cause the need and efforts to change the course of development towards the desired future (Kosow & Gaßner 2008). In addition to uncertainties, there are other challenges to the phased conversion to CWS. One of these challenges is the determination of criteria for prioritising sectors or district metered areas (DMAs) during the conversion process. Limited studies on the conversion to CWS have considered this challenge, especially from the water utility perspective.

McIntosh (2003) recommended a phased conversion from intermittent to CWS starting with small zones or areas, which should be gradually expanded to cover the entire WSS. Improving governance, universal metering, and full cost-reflective tariffs in the CWS zones were highlighted as a key to a successful conversion process.

An area-by-area approach was proposed for the conversion to CWS in India based on financial and water resource availability, starting with a few small distribution areas. It was anticipated that the information and experience from these pilot areas would then be used to implement a full-scale conversion to CWS (Myers 2003).

Dahasahasra (2007) proposed a conversion process involving the analysis of the WSS from 'whole to part'. After the analysis, phased conversion was recommended and demonstrated by converting 10 out of 34 wards in Badlapur (India).

Biswas & Tortajada (2010) reported the major activities that led to the successful conversion of the Phnom Penh (Cambodia) WSS from intermittent to CWS. Areas that were part of the city originally were prioritised, followed by the new but affluent areas. Peri-urban areas were last as these needed to be subsidised from the income generated from the affluent areas.

Klingel & Nestmann (2014) proposed and demonstrated a phased successive sector conversion approach in Béni Abbès (Algeria). They indicated that each sector converted to CWS can be supplied with water from a tank in a hydraulically independent mode.

Ilaya-Ayza *et al.* (2018) proposed an approach for gradually converting from intermittent to CWS using the multicriteria optimization method for selecting sectors to be prioritised. The method considered seven criteria: number of users, current service pressure, distance from supply source, water supply equity, operation difficulty in the sector, network topological configuration, and satisfaction of the minimum required pressure for all nodes in the sector to be converted.

Simukonda (2021) developed a methodology for sustainable conversion from an intermittent to a CWS system in which scenarios were developed and used to (i) analyse, in conjunction with the Global Scenario Group (GSG) scenarios (Raskin *et al.* 2002), the legal and policy framework that may affect the sustainability of a WSS, (ii) determine the adequacy of water resources under different futures, and (iii) assess the hydraulic capacity of the WSS under different futures considered in (ii).

With an exception of the approach reported by Biswas & Tortajada (2010) which considered social and financial sustainability, in the remaining aforementioned outlined studies, and others that the authors have come across in the literature, either the sector or DMA selection criteria are missing or they are given from the consultant or researcher's perspective. This could be on a social and technical basis (Dahasahasra 2007; Biswas & Tortajada 2010) or technical grounds (Klingel & Nestmann 2014; Ilaya-Ayza *et al.* 2018). This study used a questionnaire survey and semi-structured interviews to identify the criteria for prioritising areas to be converted to CWS from a water utility perspective. The case study utility is the Lusaka Water Supply and Sanitation Company (LWSC), which operates the Lusaka water supply system (LWSS).

METHODOLOGY

Study area

The LWSC is responsible for water supply in Lusaka City, the capital of Zambia, with an estimated population of 3.1 million people in 2022 (Zambia Statistics Agency 2022). The city is in the Lusaka district of Lusaka province (Figure 1) and has two categories of water sources. The first category, which accounts for approximately 57% of the total water supplied to the city, is groundwater from boreholes within and around the district boundary (Figure 1(b)). The remaining 43% is abstracted from the Kafue River, which flows about 50 km south of Lusaka City. Water from the Kafue River is treated at the Iolanda water treatment plant (WTP) (Lusaka City Council 2023). The Water Supply Investment Master Plan for Lusaka city (Republic of Zambia 2011a) shows that there are plans to increase the capacity of the WTP at Iolanda to meet the increasing demand of the city by 2035. The projected city total water demand (consumption demand plus NRW) for Lusaka city in 2035 is around 800,000 m^3/day. The total contribution from the groundwater resources will be 180,000 m^3/day leaving about 620,000 m^3/day (7.2 m^3/s) to be supplied by the WTP (Ministry of Local Government & Housing *et al.* 2009; Republic of Zambia 2011a). This is about 3.1% of the 234 m^3/s, which is the average discharge of the Kafue River at the WTP intake in the dry season month of normal rainfall year (Ministry of Local Government & Housing *et al.* 2009; Republic of Zambia 2011a). Thus, considering that water abstraction for supplying by utilities is given priority when it comes to water rights because water is a basic human need (Republic of Zambia 2011b), the river has sufficient flow capacity to supply water to Lusaka city for the planning horizon up to 2035 (Ministry of Local Government & Housing *et al.* 2009, Simukonda 2021) and beyond.

The master plan demand projections do not reflect the actual consumption water demand according to the city population, but they are based on the envisaged rate of WDS extensions to new areas and changes of some communities from informal to low cost (Ministry of Local Government & Housing *et al.* 2009, Republic of Zambia 2011a). Because of these considerations, it is rather difficult to determine the consumption demand based on census data at any time. Demand based on census data

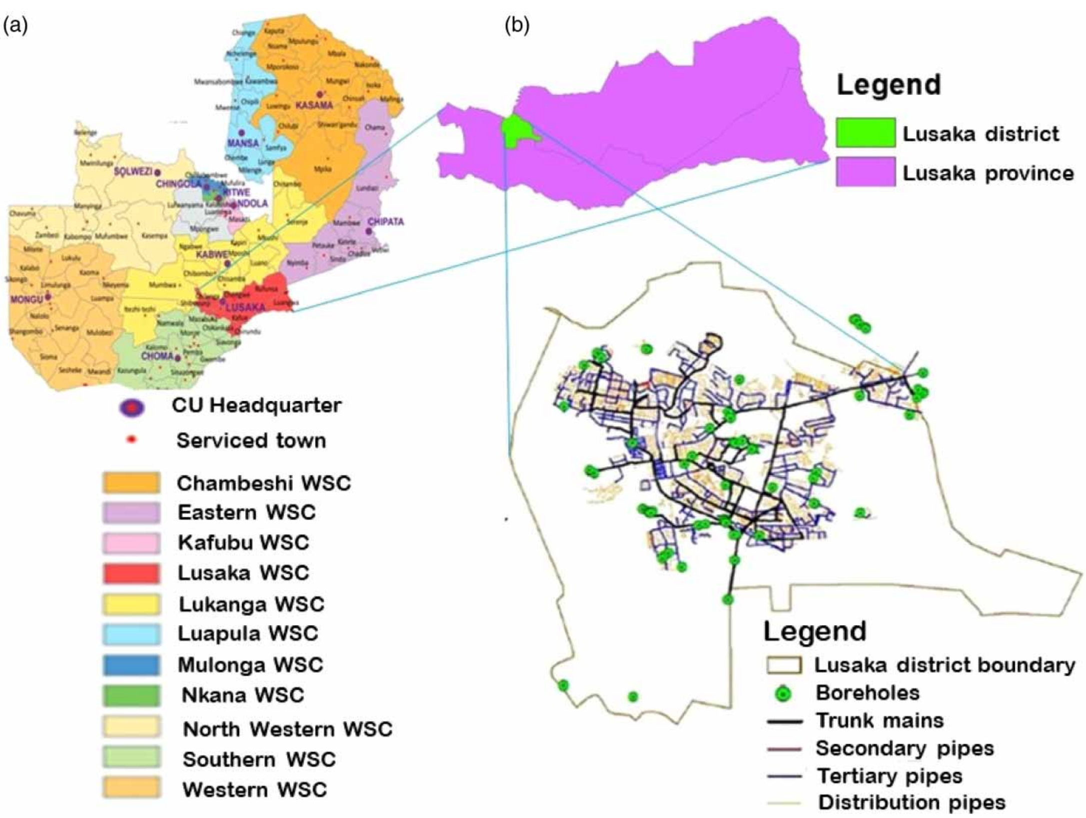


Figure 1 | (a) Map of Zambia and the regions served by different water utilities (NWASCO 2022a). (b) Lusaka Province and District with the City Water Supply system.

(the actual city population) is far much higher. Moreover, the actual levels of NRW cannot be determined with certainty due to the fact that the metering ratio is about 64%. Consequently, it is rather difficult to determine the actual total water demand (consumption demand plus NRW) at any time. Generally, the determination of water demand is one of the major sources of uncertainties during WSS analyses (Bhave 1988; Ormsbee & Lingireddy 2004). Thus, projections for the planning horizon up to 2035 are mere approximations because of the aforementioned highlighted challenges and because uncertainty levels increase with the increasing planning horizon. Even with these shortfalls in the projections, because of their being in the master plan and their being the only ones for the Lusaka City so far, they are considered to be reliable. The existence of uncertainties in the projections is what necessitates the call for the use of scenario in the planning for water improvement projects (Kang & Lansey 2012; Simukonda *et al.* 2022).

Regarding NRW, the LWSC is facing a huge challenge because the NRW levels have been above 40% since 2010 (Simukonda 2018b) and were at 54% in 2022 (NWASCO 2022a). These levels are off the National Water Supply and Sanitation Council (NWASCO) (the regulator) 25% upper limit of the acceptable benchmark for NRW. They are also not giving indications of converging towards meeting the Water Supply Investment Master Plan for Lusaka city (Republic of Zambia 2011a) target of reducing NRW to 15% by 2035. Currently, reduction of NRW is a national challenge (NWASCO 2022a). Thus, the target of reducing NRW to 15% is practically unattainable (Simukonda *et al.* 2022) and hence unrealistic. Consequently, under conditions of NRW that are far higher that the planned for target, the implementation of the projected increase in water supply will not give the intended results unless drastic measures are taken.

According to LWSC personnel, high levels of NRW are among the factors contributing to the development and sustenance of water supply intermittency. Other factors include the high consumption water demand arising from the city's expansion due to the rise in population, dilapidated old infrastructure, undersized pipe diameters, customer vandalism of infrastructure, inadequate water resources, poor electricity supply, and frequent pump failures at the water sources (boreholes, and the Kafue River intake and WTP at Iolanda). The combination of high consumption water demand and high NRW reflects the business as usual scenario characterised by the large water supply–demand deficit for the LWSS highlighted by Simukonda *et al.* (2022). In connection with the water supply deficit, the capacity of the WTP and/or the corresponding pump stations seems to be inadequate for the large total water demand. This is reflected in two aspects. The first aspect is the assertion by the LWSC personnel that the total capacity of the water distribution reservoirs (some supplied water from the Iolanda WTP while others supplied by boreholes) cannot sustain a CWS service because they run empty before 24 h, a situation that necessitates rationing to allow them to fill up. The second aspect is the influence of the seasonal changes in the water levels in the boreholes. For this, it was reported by the LWSC personnel that during the rainy season, the water table and borehole yield (output) are high, which translate to the availability of more water. However, during the dry season, the water table is low and there is less output from boreholes and more rationing hours from the reservoirs whose capacity already is not sufficient.

On average, the LWSC supplies water to Lusaka city consumers for 17.8 h per day (NWASCO 2022a). However, there are variations in the water supply durations to different regions or DMAs mainly due to the segregation of supply schedules between the affluent and poor communities and the locational altitudes of the communities. The NWASCO (2000) guidelines require utilities supplying towns or cities that have at least 100,000 inhabitants to convert to CWS six years after their incorporation as commercial utilities. However, this is not the case with the LWSC, which was incorporated in 1989 and consequently should have converted to CWS by 2006 (six years after the adoption of the regulation).

Regarding the feasibility of converting to CWS, the lack of financial resources is one major factor that brings about doubts amongst many. However, the lack of financial resources as the reason for the failure to convert to CWS is shown in Biswas & Tortajada (2010). This is because the funding of major projects relating to IWSS improvement in developing countries is not directly funded by the corresponding governmental entities or utilities, but by donors or cooperating partners within the existing policy/legal and institutional frameworks (Blair *et al.* 2005; Biswas & Tortajada 2010; International Monetary Fund 2015; Simukonda *et al.* 2018a). The institutional framework for the water supply sector in Zambia is shown in Figure 2. As shown in the figure, the Ministry of Water Development and Sanitation is responsible for the water sector policies and financing of water utilities. In the case of Lusaka, the development of the master plan set the grounds for soliciting resources either by the water utilities through the ministry or by the ministry itself directly.

Data collection

Data collection was done using a questionnaire survey followed by semi-structured interviews. The questionnaire was distributed to the five zones of the LWSS. At least two respondents were selected from each branch by either the branch manager or

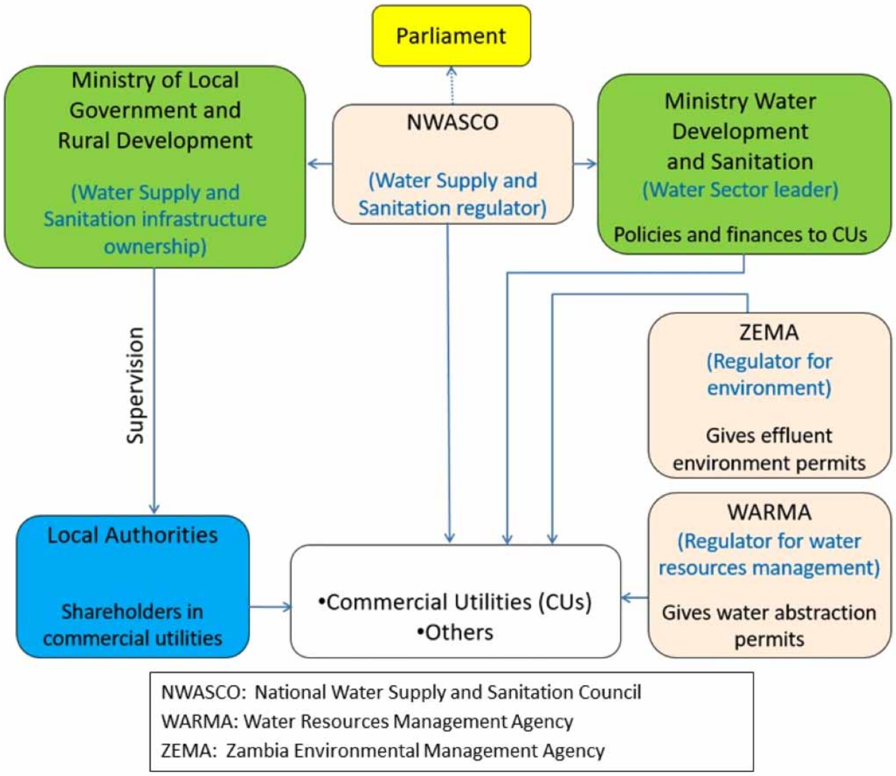


Figure 2 | The institutional framework for the water sector in Zambia (adapted from NWASCO 2022b).

the head of the branch's engineering department. The respondents were asked to select all the criteria they felt would be used to prioritise the areas to be converted to CWS. The steps followed are discussed in detail under subheadings A, B, and C:

A. *Determination of the respondents' perspective on the conversion from IWS to CWS by the LWSC*: This aimed at determining whether the respondent knew something about why the conversion was not occurring. Two factors contribute to the need for this determination. First, discussions of the conversion to CWS are rare and are not even mentioned in NWASCO's annual reports. CWS is only mentioned indirectly when classifying the levels of water supply services as safely managed drinking water service (Republic of Zambia 2019, 2022). The second is that while in the Millennium Challenge Account, the consultants explicitly stated reaching the 24/7 supply as the target in 2035, and to the best knowledge of the current authors, there was no such target set by the local stakeholders, including the LWSC.

B. *Criteria for prioritising DMAs:* If the response in step (A) indicated that the respondents supported the conversion, they were then asked about the criteria they would use to prioritise DMAs to be converted in the phased conversion process. For this step, a list of criteria to choose from was enumerated in the questionnaire, and each respondent was allowed to select multiple criteria. The respondents were also requested to add other criteria not listed in the questionnaire. The criteria provided are discussed below.

   i. *Financial sustainability of the utility company:* This criterion provided that the DMA(s) that have the greatest potential to maximise gains from water sales should be prioritised during the conversion process. One of the major premises for the criterion was that under the increasing block tariff (IBT) structure (used by the LWSC), industry subsidises domestic water consumption, and the affluent subsidise water consumption by the poor. The other premise is that in low-income communities, few households are connected to the WSS and are subject to the lower brackets of the IBT structure. Thus, since the revenue from water sales is determined as the product of the total volume of water consumed by customers and the applicable price per unit from the IBT structure, it is expected that the revenue from low-income (peri-urban) areas is low.

For the approach in this study, assessments for this criterion can be based on maps as exemplified in Figure 3. For simplicity's sake, Figure 3 is only for the Chelstone zone which is one of the five zones for the LWSS. This figure shows the location of the high-, medium-, and low-cost housing types in the zone base on the housing types classifications in the Republic of Zambia (2011a). In the figure, nodes supplying the informal housing type communities are not shown because these communities are normally part of the low-cost housing type communities and could not be distinguished from the available data.

ii. *The DMA experiencing inequitable supply, for example, in peri-urban areas:* Both planned and unplanned settlements (peri-urban areas) lack proper water supply facilities (Cohen 2006). This is because service providers are less willing to provide them with services due to technical complications in laying pipes and the high cost of network expansion in areas with isolated consumers (Lusaka City Council 2008; Van der Bruggen *et al.* 2010).

In Zambia, per capita water consumption is expected to depend on the types of housing units, as shown in Table 1. The implication of the differences in per capita water consumption is that low-income households are likely to have bills within or slightly higher than the social tariff. (They are the category subsidised both by the industry and the affluent.) It was assumed that converting to CWS in peri-urban areas would help improve sanitation and reduce the disease burden in these communities. On this basis, this criterion sought to determine whether the equitability of water supply would be the basis for prioritising conversion to CWS for DMAs.

From the system hydraulics perspective, the uniformity coefficient can be used to quantify equity amongst consumers connected to different demand nodes in a WDS (Gottipati & Nanduri 2014). However, following the simplified view of this study regarding the case study where inequitable water supply due to differences in water supply schedules

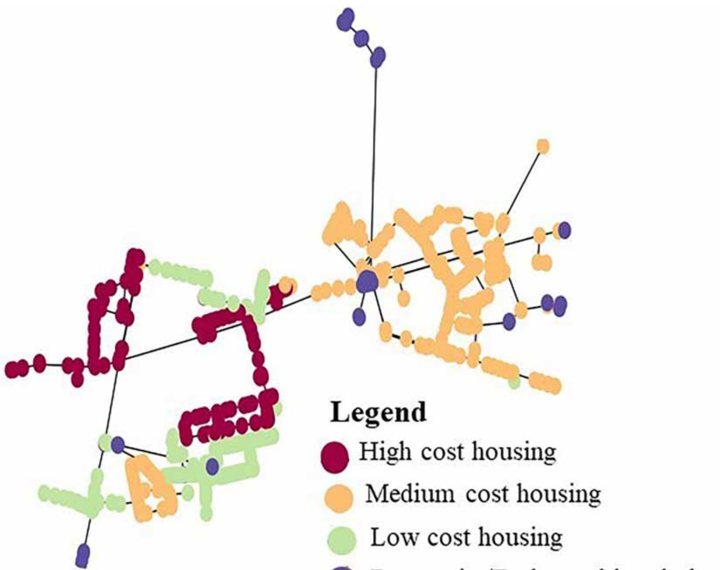


Figure 3 | Node supply high-, medium-, and low-cost housing type communities.

Table 1 | Design standards for domestic per capita water demands in Zambia (Republic of Zambia 2011a)

Housing type	Per capita water consumption (L/c/d)
High-cost housing	280
Medium-cost housing	150
Low-cost housing	100
Informal housing	40

between the affluent and the poor has been taken as the basis for decision, a map (Figure 3) is a quick and easy to apply visual tool for identifying areas that are supplied water well and those that are supplied water poorly on the basis of the housing types.

iii. *A DMA with the highest number of consumers to benefit from the conversion:* According to Ilaya-Ayza *et al.* (2018), a sector selected to work with CWS should benefit as many consumers as possible. The literature shows that peri-urban areas are poorly supplied with water due to different reasons, including technical challenges of laying pipes and low revenue because few isolated individuals connect to the installed water distribution pipes (Lusaka City Council 2008; Simukonda *et al.* 2018a). Consequently, in the Zambian context, the existence of many water consumers served by the WDS is synonymous with communities with high- or medium-cost houses. These are also likely to have high water consumption (Table 1), translating into high bills. The location of the areas with the high- or medium-cost houses can be done using maps (Figure 3). However, identifying which one of these areas should be prioritised depends on the information from the utility company's billing records which were not part of this study's enquiry.

iv. *The DMA with the poorest water supply conditions in terms of water supply pressure and duration because of elevation:* This criterion was based on the understanding that reduced water supply durations under IWS entail increased flows and high friction head losses because of undersized pipe diameters to accommodate peak flows. The large water extraction loads in the network lead to reduced network pressure and water not reaching some consumers, especially those located at higher elevations (De Marchis *et al.* 2010; Klingel 2012; Kumpel & Nelson 2016; Geta 2018; Satpathy & Jha 2022). As such, these disadvantaged areas should be converted to CWS first, which would make it easier to convert advantaged areas. The areas that are highly elevated and with low pressure can be identified using hydraulic models as exemplified by area B in Figure 4(a) and 4(b).

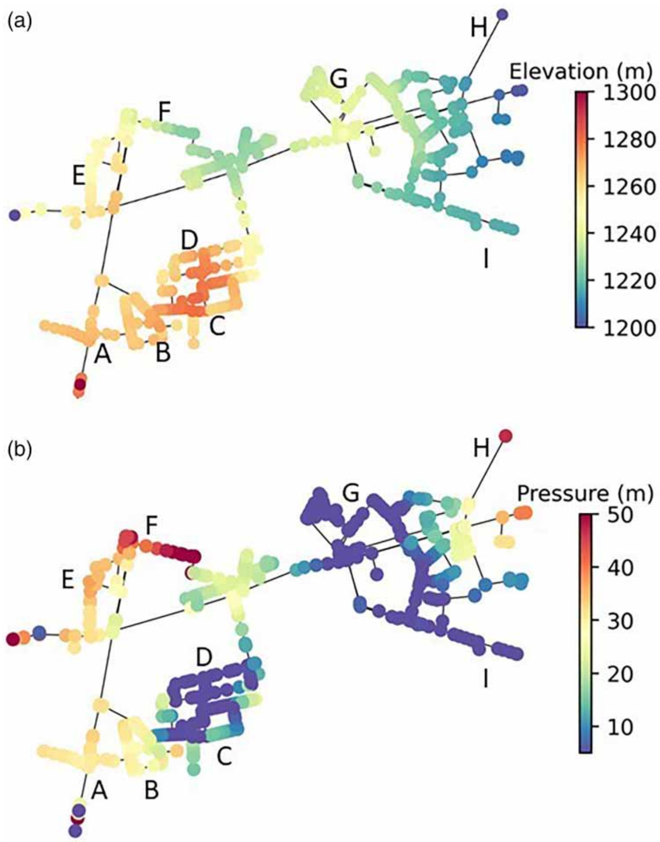


Figure 4 | Relationships of elevation and distance from the source with pressure which is an indicator of the extent to which consumer water demand are met.

v. *The DMA with poor water supply conditions due to its being furthest from the sources:* In IWS, the supply time is usually short, and consumers aim at drawing all their water demands within a short time, thus reducing the network pressure. Because of water drawing by consumers located near the source and the reduction of pressure heads due to friction, those located far from it draw less or do not receive water at all (Totsuka *et al.* 2004; De Marchis *et al.* 2010; Klingel 2012; Kumpel & Nelson 2016; Satpathy & Jha 2022). Consequently, ensuring that these far-located consumers have CWS is good for equitable water distribution. For this criterion, pipe size and elevation play major roles.

Analyses regarding this criterion can be based on hydraulic model base maps of relevant parameters. To facilitate the clear explanation of the concepts, the Chelstone zone WSS hydraulic model was used and modified by removing all the zone-specific water sources (boreholes and internal tanks and reservoirs). Only the main source (the connection of the Chelstone zone to the main LWSS water distribution reservoir) was left (Figure 4).

As shown in Figure 4(a) and 4(b), due to proximity to the main water source, areas A, B, E, and F have high-pressure heads (used as an indicator of the extent to which water supply meets demand) despite their high elevations. Conversely, area H, despite being farthest from the source, has very high-pressure heads because of its lowest elevation (around 1,100 m above the sea level). Areas G and I have average elevations and as such their poor pressure heads can be attributed to distance from the source.

vi. *The DMA which has the highest operation and maintenance costs under the IWS regime:* Poor maintenance of water supply schemes leads to their deterioration and increase in physical water losses (Dighade *et al.* 2014; Simukonda *et al.* 2018a). In addition, illegal connections also lead to an increased rate of infrastructure deterioration (Kumpel & Nelson 2016). To reduce the utility's loss of revenue and operational costs because of NRW levels (Dighade *et al.* 2014), leakages have to be reduced to allowable levels through proper system management and rehabilitation of the deteriorated parts (Myers 2003). This criterion was based on the literature that IWS enhances the deterioration rate of the WDS and that there are always areas that experience more bursts than others. Moreover, there are also areas that require the operation of more valves to supply water or cut the supply to them. These areas with the highest operation and maintenance costs can be identified from the utility company's operations and repair works records.

vii. *A DMA that provides the least technical challenges:* This criterion was used to determine if the LWSC would consider technical advantages when prioritising DMAs to be converted to CWS. The DMAs that provide technical advantages are those that already have long water supply durations, high metering ratios, and established DMAs with functional inlet and outlet bulk meters/pressure gauges. The highest DMA technical advantages translate into the lowest conversion costs. This may be a critical factor under limited financial conditions. Analyses regarding this criterion can be based on the maps that show the DMA boundaries, the location of boundary bulk meters/pressure gauges, the number and location of isolation valves, and all customer meters which can be obtained from billing records.

viii. *DMAs that are favoured by the concerned political leader such as a Member of Parliament or minister:* Where there are elements of poor governance, elected political leaders tend to interfere in the daily operations and management of water utilities, leading to their maladministration. McIntosh (2003) reported the interference by some elected Nepalese political leaders in the permitting of new connections and preventing the disconnections of water consumers for unsettled bills to gain popularity during electioneering. NWASCO (2017) reported a government directive to constitute a water utilities board of directors that lacked the suitable mix of skills and technical or analytical experience beneficial to the boards and water utilities. It is noteworthy that the lack of awareness of the need for CWS by the board members translates to a lack of drive towards the conversion process. The study investigated the significance of political leaders' influence on the conversion to the CWS agenda considering that the LWSC is a registered private company that is owned by the government through the Lusaka City Council. The criterion cannot be quantified or shown on a map before the political leader identifies the DMA usually for the interest of the leader.

DMA targeted by a donor in the case that the funder has such a condition: Raskin *et al.* (1996) stated that during the planning and implementation of projects, there are attractors that can redirect beliefs, behaviours, policies, and institutions towards some futures and away from others. The attractors include working towards attaining sustainable development goals and showing demonstrable commitments to poverty reduction by the heavily indebted poor countries to qualify for debt relief during the Millennium development goals error. Simukonda *et al.* (2022) observed that donors can develop attractors that influence water utilities with an abundance of water resources to achieve 24/7 water supply services. This is premised on the fact that donors are the major funders of water supply improvement projects in most developing countries. For instance, the implementation of the water supply improvement master plan for Lusaka City depends on donor funding (Government of the Republic of Zambia 2010). However, observations show that donors, working with non-governmental organisations aimed at poverty reduction, tend to work more towards improving water supply in peri-urban areas not with the view of converting to CWS, but to ensure that at least there is some safe water at some nearby place, even for a few hours in a day. This criterion cannot be quantified nor shown on a map prior to the donor's identification of the DMAs.

C. After listing the criteria of choice, the respondents were then asked to rank the criteria chosen from the most important to the least important. This was followed by interviews so that the respondents could provide more details on their choices and ranking of the criteria.

RESULTS AND DISCUSSION

Support of the conversion to the CWS idea

A total of 17 respondents participated in the survey. These respondents were employees of the LWSC from different professional backgrounds, including engineering, accounting, business administration, customer services, and finance. Their work experiences at the LWSC ranged from five to more than 10 years. Of the total, 16 supported the conversion to CWS, whereas one was against. The reason for not supporting the conversion to CWS was that people do not need water at night; therefore, there is no reason to convert to CWS. According to this respondent, water supply during the day is sufficient. An improvement in water supply from, for example, 2–8 h a day is seen as adequate. However, according to Charalambous & Laspidou (2017), customers settle for the bare minimum because they do not have a better reference point since they have never experienced high-standard CWS services. They are made to believe that storing water in containers or privately owned tanks is a normal thing to do, and since their efforts in developing coping mechanisms are not observed, there are no policies in place to address intermittency (Galaitsi *et al.* 2016). Customers lack knowledge of their rights; hence, they cannot claim better services (McIntosh 2003). Moreover, some utility experts lack knowledge of the detrimental impacts of IWS on the system due to insufficient human resource development and training; thus, they see no reason to convert to CWS (Myers 2003).

Criteria for prioritising an area or DMA

For the 16 respondents who supported the conversion to CWS, the number of times they selected each criterion is shown in Figure 5.

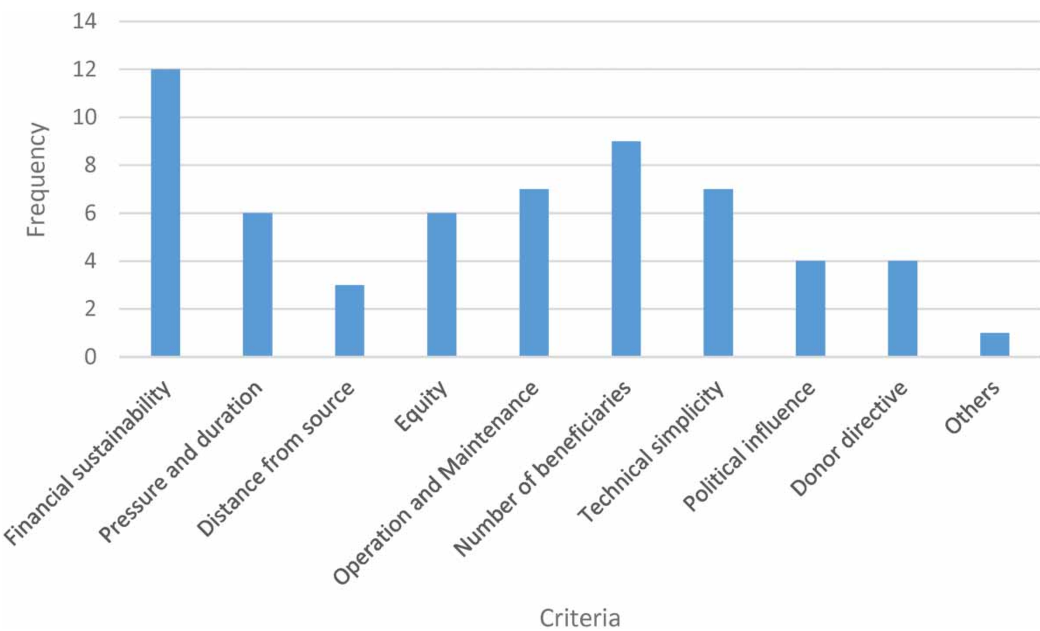


Figure 5 | Frequency of criteria selection.

Figure 5 shows that the financial sustainability criterion had the highest frequency, followed by the greatest number of consumers benefitting from the conversion. 'Others' refers to a criterion that was added to the list by a respondent and was 'new areas with newly built houses that are not connected to the existing network (extension of the WDS to new area)'. In this case, the areas are those legally approved and planned by city planners. For Zambia, as a developing country, there are still many people in both planned and unplanned settlements who should be supplied safe piped water as required under the Sustainable Development Goal 6.1 (United Nations General Assembly 2015) and Vision 2030 (Government of the Republic of Zambia 2006). For Lusaka city, the extension of the WDS to new areas is reflected in the Ministry of Local Government & Housing *et al.* (2009) and the Republic of Zambia (2011a). The criterion referred to as 'others' had the least frequency, followed by the one based on a DMA located far from the source.

Ranking of the criteria

The ranking of the criteria from the most important to the least important is shown in Table 2. The table shows that the significance of the criteria almost matched their frequency of selections except 'distance from the source' and 'political interference'.

Financial sustainability was ranked as the top factor when prioritising DMAs, followed by the greatest number of benefitting consumers. This is understandable because water utilities are run as a business; therefore, the financial aspect is important as it sustains the running of the business. The loyalty of customers to paying water bills motivates the utility company. These two criteria show that DMAs where the middle class and affluent live should be prioritised during the phased conversion process so that they can subsidise improved water consumption for low-cost and informal areas. To this effect, one respondent stated:

'Customers from low-cost houses in Lusaka whose water charges are subsidised misuse water and damage infrastructure more than those in high-cost houses who pay more. Hence not only do they pay more but they also use water responsibly. As such, DMAs that bring in more gains in terms of money to the utility must be prioritised for the conversion from IWS to CWS.'

Providing CWS services to an area with the greatest number of consumers benefitting increases revenue (sales) to the utility. CWS results in satisfied customers who are willing to pay for the services rendered. Thus, the greater the number of satisfied customers, the greater the sales to the utility company. Considering that few people connect to the WDS pipes in low-cost and informal sectors for economic reasons, this criterion favours households in high- and medium-cost houses. An observation was made by one respondent with respect to the number of benefitting consumers:

'Institutions, such as hospitals, with several benefitting consumers have to be supplied regardless of whether they bring in significant revenues or not to the utility company.'

This observation should be understood from the fact that bill payments by some government departments are poor in Zambia, thereby making revenue collection from the government a performance indicator (Millennium Challenge Account – Zambia Limited 2013).

Table 2 | Criteria ranked from the most important to the least important

Factor	Rank
Financial sustainability	1
Number of benefitting customers	2
Pressure and duration	3
Technical simplicity	4
High operation and maintenance costs	5
Equity improvement	6
Donors directive	7
Distance from the source	8
Political influence	9
Others (extension of the WDS to new areas)	10

Some respondents considered elevation and distance from the source to be major factors in water supply pressure and duration. Areas that are highly elevated and/or distant from the source experience less pressure and supply times than low-lying and/or near the source areas. Therefore, these areas should be prioritised to improve equity. Most of the parts of the LWSS are supplied water by gravity, and areas far from the sources usually do not receive water due to head losses along the network pipes. These areas have booster stations to boost the pressure in the system; however, in case of electricity cuts, the booster pumps cease pumping. The use of fuel generators as an alternative power source is expensive; therefore, people in areas far from the sources tend to experience more rationing hours (supplied water inequitably) and have to be prioritised.

Other respondents regarded areas with high operation and maintenance costs as priority. The LWSS network still has asbestos cement pipes in some parts. These old pipes are prone to fracturing and cracking, resulting in an increase in the operation and maintenance costs as these pipes need replacement. In addition, some pipe diameters are so small that they cannot withstand great pressure, resulting in frequent pipe bursts.

Equity improvement was seen as the criterion for prioritising the DMAs to be converted to CWS. Some respondents view water not just as an economic good but as a basic right that should be accessed by all. Poor people living in peri-urban areas experience an inequitable water supply. They have poor water infrastructure and experience poor service provision. In these areas, meter readings are inaccurately captured. Thus, many houses (consumers) would benefit if these DMAs are prioritised. One respondent stated:

> *'Providing water to such areas as peri-urban areas will also support improved sanitation.'*

Regarding donor directives, the respondents indicated that donors normally do not intervene unless there are complaints and pleas made by consumers. It was stated that in some cases, donor funding is granted with conditions, and therefore, the utility must respect the conditions. However, the utility should also have the same interest as the donor to prevent the utility from withdrawing services to an area when the donor leaves the project. This ability of donors to impose conditions when funding a project agrees with the assertion that donors can develop attractors that would direct water utilities towards converting to CWS (Simukonda *et al.* 2022).

The respondents who indicated that political influence was considered a factor in the decision-making process for the area to be converted first stated that political leaders influence where resources are channelled, even though respondents felt that should not apply. One respondent stated:

> *'Utility personnel fear going against political leaders' wishes to improve their targeted areas as a way of gaining people's support. As a result, they would prioritise those areas.'*

Influence of the respondent profession on criterion selection

To understand whether the respondents' criteria selection was influenced by their professional backgrounds, the respondents were grouped into two groups: technical and non-technical groups based on their professions. The technical group professions were water engineering, civil engineering, and plumbing, while the non-technical professionals were accountants, a senior commercial officer, a customer services assistant, and a business administrator. Table 3 shows the spread of their criterion selections. The percentages in the technical group were calculated from the 11 respondents, and the percentages in the non-technical group were calculated from the five respondents. The respondent who was against the conversion to CWS did not participate in the criterion selection.

Table 3 shows that the respondents in the technical field's choices were spread across all criteria. The table shows that the top four criteria for the technical group alone were 'Number of benefitting customers', 'Technical simplicity' and the two at par 'Financial sustainability' and 'Pressure and duration of supply'. The table shows that the non-technical field did not select some criteria, and for this group, 'Financial sustainability' was the top most criteria. The failure of the non-technical to choose other criteria could be due to the limited understanding of those aspects or a bias towards their area of expertise. This signifies the need for studies that involve multidisciplinary research groups to consider the implications of professional bias on the selection of criteria and find means of minimising them in cases where the biases lead to completely divergent views. As can be observed in the current case, 'Financial sustainability' became the leading criterion because of the non-technical group. However, in the Zambian water supply systems context, 'Financial sustainability' and 'Number of benefitting

Table 3 | Percentages of the grouped respondents' criterion selections

Criteria	Professional groups	
	Technical (%)	Non-technical (%)
Financial sustainability	72.7	100
Pressure and duration	72.7	20
Distance from the source	36.4	0
Equity	36.4	40
Operation and maintenance	54.5	40
Number of benefiting customers	90.9	20
Technical simplicity	81.8	0
Political influence	45.5	0
Donor directive	45.5	20
Others	9.1	0

customers' have the same overall implication on which type of DMAs to prioritise: DMAs with medium- and high-cost housing units. This prioritising of the affluent communities agrees with the approach described by Biswas & Tortajada (2010).

CONCLUSION

Converting from IWS to CWS ensures that safe water is supplied from piped WSS as expected. Moreover, the conversion will solve most of the problems associated with IWSSs. However, the conversion process is complex with many uncertainties, and due to limited human and financial resources, it is expected to be done in phases. One aspect of uncertainty is the criteria for prioritising areas or DMAs to be converted. This study used a questionnaire survey and semi-structured interviews to determine the criteria for prioritising the areas to be converted from the water utility perspective. This study was based on the LWSC in Zambia. The results show that DMAs that would increase the financial sustainability of the utility would be prioritised. This implies that DMAs that would provide maximum gains in terms of water sales would be converted first. In connection with the maximisation of revenue, the second criterion for prioritising DMAs was the greatest number of people benefitting from the conversion process. In the Zambian context, these two criteria imply that priority DMAs would be those for affluent communities as they fit medium- and high-cost housing units.

Furthermore, the results show that when conducting studies with a multidisciplinary respondent sample, care should be taken because the choices of criteria may be influenced by the profession of the respondents. This implies that even decision-making can be biased by the decision-maker's profession, thereby overlooking some factors that are important because they are less known by the decision-maker. It would be more interesting and helpful if further research verified these findings by conducting similar investigations with more utilities and more respondents.

DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

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