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Unearthing Non-Revenue Water Management strategies in Commercial Water Utilities in Zambia. The Case of Southern Water and Sanitation Company in Livingstone.

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Abstract
The threat to freshwater sources vital to supporting humanity is increasing which is posing a serious challenge to the survival of humanity. These threats range from climate change, pollution, and overexploitation due to competing needs such as agriculture among others. In the past two decades, water shortages have gone up increasing the call for the optimization and sustainable use of this vital resource. In urban areas throughout the world, water utilities are used as a vehicle for extracting, treating, and delivery of water to customers. In Zambia, the water supply and sanitation act no 28 in 1997 led to the establishment of these water utilities mandated to carry out this task. However, the Urban water supply in Zambia is faced with huge amounts of water lost in the distribution network through leakages, and water theft among others. Given this problem, the government set up a Non-Revenue Water National Technical Task in 2014 as a national strategy for the management of NRW. However, for a long time now, all the commercial water utilities in Zambia have failed to reduce their water losses to the approved benchmark of 25% as set out by the IWA. The main objective of this study was to: analyze the non-revenue water levels in the water service delivery in Livingstone, then identify and assess the management practices adopted to manage non-revenue water in Livingstone, and then come up with some recommendations that would help improve the current strategies. Semi-structured interviews, document review, and participant observation were used in data gathering during the research. Thematic data analysis was used for qualitative data while descriptive, inferential statistics, as well as Before and After Designs were used on qualitative data. The findings revealed that the NRW at SWSC in Livingstone stands at an average of 43% during the period of study (2018-2021). The reduction in NRW comes after the implementation of several interventions or strategies which include; Mapping the water distribution system, reducing response time to leakages, replacement of old, dilapidated pipes, social engagement, and isolating the Network into the District Metered Areas among others. The findings further revealed that some best practices of NRW are not being implemented due to the lack of a special purpose vehicle needed to address this challenge. Considering that the state of the infrastructure often dictates the levels of water lost in the distribution network, there is a need to have a strategy on how the entire network which is obsolete can be replaced as this will go a long way in reducing NRW. Further, it is important that the observed levels of NRW might not be a true reflection of water lost in the distribution network as the metering ratio is low standing at 69% in the district.
Keywords:*Non-Revenue Water, Leakages, Management, Strategy, Apparent losses, Real losses*

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I. INTRODUCTION

Globally, the water demand is rising at a very fast rate and this pressure is being exerted on the available freshwater the major driver is urbanization which has been made worse by the rapid rise in population. In addition, climate change/variability is also putting pressure on how the available water resources as many places are increasingly experiencing droughts or erratic water rainfall which is having an impact on both above-ground and underground water. The pressure exerted on water by climate change, urbanization, and the rapid rise in population has led to an increased call for optimal utilization of water as one of the resources which are vital in supporting the current trends in population growth. It is important to note that despite 71 percent of the earth being covered by water, only 2.5 percent of this is freshwater, and a large percent of this is safe for human consumption (Baker, Aldridge, & Omer, 2016). Much of this water is saltwater which is found in oceans, seas, and certain inland water bodies, and the usable water is found in rivers, lakes, and aquifers among other sources. However, to date access to water remains a challenge in many parts of the world as the same portion of the World's freshwater is inaccessible in certain areas while in areas where it is accessible human activities have negatively affected the quality of water hence the need for purification.

The United Nations through the sustainable development goals has acknowledged the need to devise measures aimed at inculcating water efficiency considering the stress on available water sources. The sustainable development goals (SDG # 6) as cited in The Global Goals: for sustainable development Goals, (2021) adds that by 2030, the target is to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

Many countries in the world have employed the use of institutions in water resource management which have the responsibility of providing clean and affordable water. These water utilities have the responsibility of purifying and providing clean and safe water to the consumers as well as sanitation services (NWASCO, 2019, p. 2). It is important to note that the supply of water has a price attached to it which the consumers have the responsibility of paying to sustain the operations of these utilities. However, full compliance has proved to be a challenge in many countries which has led to the loss of income through non-revenue water [NRW]. Non-revenue water [NRW] is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers (Ibid: 58).

The global volume of non-revenue water (NRW) is staggering as each year more than 32 billion m3 of treated water is lost through leakage from distribution networks. An additional 16 billion m3 per year are delivered to customers but not invoiced because of theft, poor metering, or corruption (USAID, 2010, p. 1). The challenges affecting these water utilities in both developing and developed nations have reduced the revenue needed for them to function efficiently and effectively hence affecting their operations. In the African context, many water utilities are operated by district, city, and municipal authorities which makes many of them have a monopoly over the supply of water to the people in those areas under their jurisdiction.

In Zambia, commercial water utilities are run by boards that shape their institutional policy, which gives them an element of autonomy from the local authority. The detachment of these water utilities from being part of the local authorities into commercial water utilities meant that they had to run as viable and productive institutions depending less on both the local and central government. However, from the time these utilities were turned to operate as commercial, they have been faced with a problem of water losses through leakages. The country's water regulator has since the formation of these utilities been keeping a record of these water losses with the view of finding remedies that are aimed at resolving these problems. NWASCO has since the year 2000 when most Commercial Utilities were formed, been monitoring and reporting the leakage levels using the terminology of Unaccounted for Water (UFW), which was renamed early in 2000 to NRW by the IWA Water Loss Task Force (WLTF) (Water Pool-Zambia, 2011, p. 9).

It is important to note that the production of water requires expensive treatments that consume energy and chemicals, as well as raw water is withdrawn from the environment, and it requires extensive labor, capital, and other system operation and maintenance. This amount of money used by commercial water utilities in the production of water has to be generated from the consumers through billing. However, many of the utilities in Zambia are failing to generate the needed resources due to an increase in water losses leading to a loss in revenue. The National Water Supply and Sanitation Council (NWASCO) has since 2000 urged commercial water utilities to employ strategies aimed at reducing the levels of Non-Revenue water to an acceptable benchmark of 25%.

However, it is worth noting that since 2000 little progress has been made in achieving this goal as (NWASCO, 2019, p. 65) adds that there was an increase of Two Hundred and six million kwacha (K206, 000,000) in lost revenue due to NRW from the previous period (2018-2019). At the benchmark of 25% NRW, the acceptable loss would have been about K435million against the actual K943million. If nothing is done to understand how well commercial water utilities can sustainably manage the available water resources, non-revenue water will affect not only the viability of these utilities' but human existence in the view of climate variabilities. Based on this background, this research aims at identifying the strategies put in place by commercial water utilities in reducing Non-Revenue water and exploring their effectiveness in reducing water losses.

II. Materials and Methods

2.1 Study area

Livingstone is a city in the Southern Province of Zambia and is located at latitude -17° 50' 30.98" S and longitude of 25° 51' 15.30" E and situated at an elevation of 969 meters above sea level. The city is located 10 km (6.2 mi) to the north of the Zambezi River, and until 2012, it served as the capital of the province. Livingstone is a border town with road and rail connections to Zimbabwe on the other side of Victoria Falls (Kaitano&Nhamo, 2018). Figure 3.1 shows the location of Livingstone on the map.

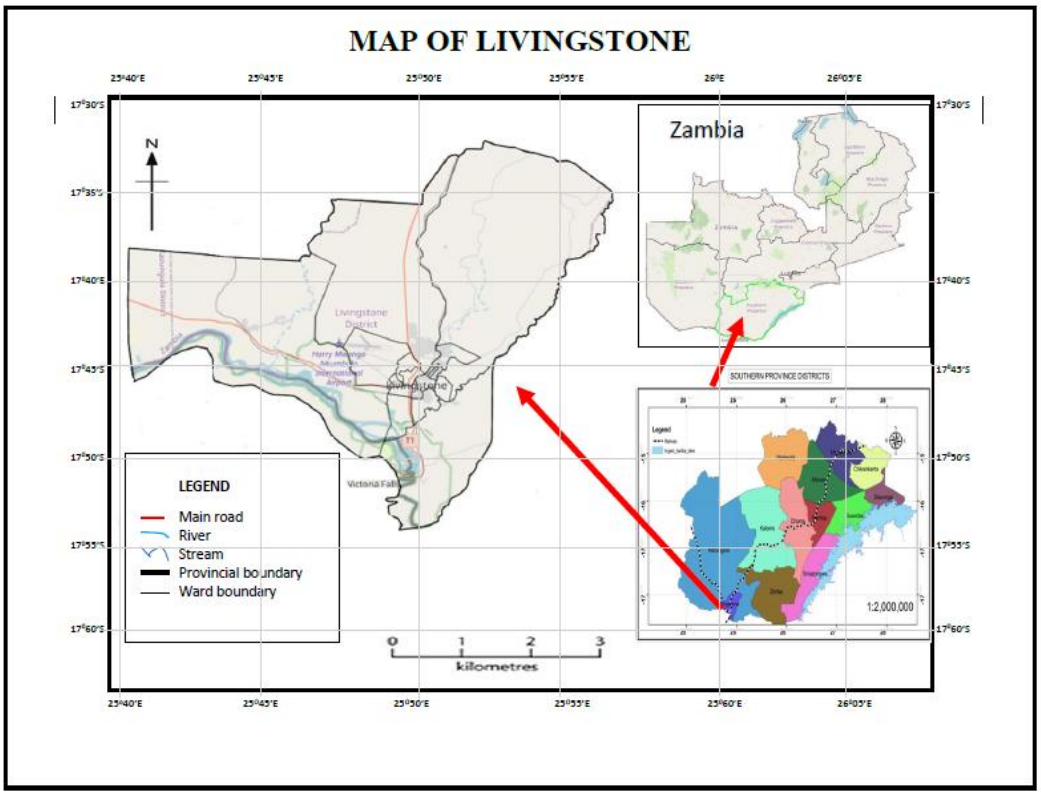

Figure 1: Map of Study Area (Author, 2022)

Climate: The climate of Livingstone is considered a local steppe climate as it receives little rainfall of only 689 mm per year and an average annual temperature of 22.6 °C. The heat is intense from September to November, with peaks of 40 °C, while the winter nights are cold with temperatures as cold as -2 °C (Kaitano&Nhamo, 2018).

Demographic characteristics: Livingstone district has experienced an increase in population mainly due to rural-urban drift, as people tend to move from the districts surrounding the district in search of employment. The figure below (figure 3.2) is illustrating the increase in population in the city of Livingstone from 1980 to the estimated population in 2020 at an average growth rate of 2.1 percent (Central Statistics Office, 2012).

2.2 Data Collection

This study adopted the mixed-method approach which is the combination of the qualitative and quantitative approaches to collect and analyze data (Creswell, 2007). Bryman (2006) explains that in recent years, integrating qualitative and quantitative methods becomes common in research because the mixed-method design can provide detailed and comprehensive data in order to achieve the research objectives and answer the research questions. The four major types of mixed methods designs are Triangulation Design, Embedded Design, Explanatory Design, and Exploratory Design (Creswell & Plano, 2006). However, this study employed the explanatory sequential model, which contains the first quantitative data collection followed by qualitative data collection.

Being a case study, the sample was purposely selected and made up of Key informants from the departments who are directly involved with non-revenue water at the utility in Livingstone and are part of the Water Audit Team (WAT). The Key informants included members of the water audit team and staff in the operations and commercial services departments at the utility. Further, the researcher included key informants in the management of the utility at the Regional Head offices in Livingstone.

Primary data were collected using Semi-Structured Interviews, and Field Observations on the aspects related to the water infrastructure of the utility. On the other hand, secondary data were collected through document review at the water utility in Livingstone which allowed the researcher to access information on the trends of Non-Revenue Water and the efforts being done to reduce water waste. Some of these documents included road maps of Non-Revenue Water, and annual reports on Non-Revenue Water, among other important documentation vital for this research. Furthermore, Kombo & Tromp (as cited in Simango, 2016, p. 84) suggests that document analysis involves gathering data that already has been collected by someone else. It also involves the collection and analysis of published material and information from internal sources.

2.3 Data Analysis

In establishing the state of Non-Revenue (waste or unaccounted for) Water at Southern Water and Sanitation Company, the researcher used the water balance method to separate authorized consumption from water losses at the utility. Dongwoo (2018) explains that Non-Revenue Water (NRW) in a water distribution network is the water lost from unbilled authorised consumption, apparent losses, and real losses compared to the total system input volume. Descriptive statistics, in this case, was also used to provide absolute percentages which helped the researcher come up with a trend of water losses from the time the utility began keeping statistics aided by the use of Microsoft office suite 2016(Excel) as a tool. The following formulae was used:

Equation 1: Determining water losses in the distribution network

NRW% = (NRW Volume/System Input Volume) x 100

Source: Makaya, (2015)

The data collected were analysed holistically by offering a detailed description of the case through a thematic approach. Data collected through interviews and observations made during the research was interpreted and analyzed qualitatively through themes. Elo et al. (2014) report that such analysis helps a researcher determine the meaning participants attribute to the data. The process for analysing the qualitative data were interactive and involved categorising, unitisation forming relationships, and making grounded conclusions.

III. RESULT AND DISCUSSION

After a number of months collecting and analysing the data collected from the utility, the following were the findings.

3.1 The current state of Non-Revenue Water at Southern Water and Sanitation Company in Livingstone

In order to establish the state of NRW at Southern Water and Sanitation Company in Livingstone, an in-depth analysis of utility NRW data provided by the water audit office was conducted. In the two weeks of engagement at the Utility ***(19th April -30th April 2021)*** using the research methods discussed in the previous chapter, while the reviewed documents provided information that has proved critical in understanding the situation regarding Non-Revenue Water at Southern Water and Sanitation Company (SWSC) in Livingstone City.

In 2018, the water utility began the process of implementing the set strategic plan aimed at reducing the amount of water lost in the distribution network leading to higher-than-normal amounts of non-revenue water ranging from 35% to 53% since the year 2001 when the sector began to monitor the indicators. Being the first year of implementing major strategies as contained in the utility's strategic plan, the trend in the levels of NRW was still generally high with very little change observed with the lowest being recorded in February (39%) while the month with the highest levels of NRW being September recording (61%) of the water produced going unaccounted for by the utility.

To fully understand the progress made in containing the levels of NRW, Figure 2 below presents a picture of NRW from 2018 when the strategic plan began to be implemented up to 2021.

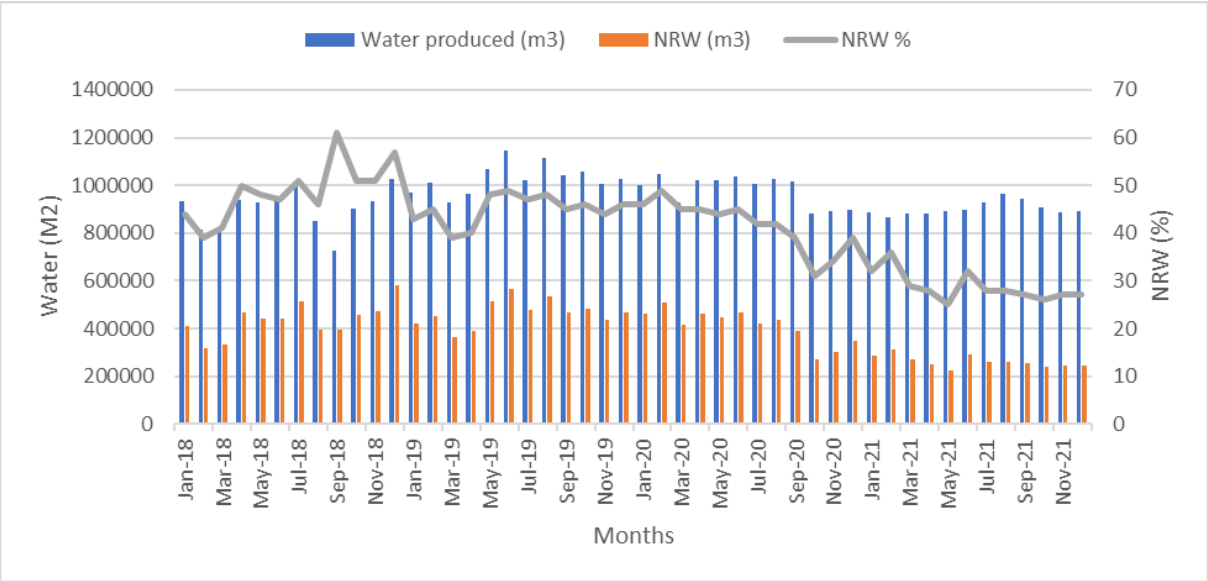

Figure 2: *Water production and NRW trends - 2018 -2021 (Field data, 2021)*

Figure 3 above provides a summary of the water produced (m3) and unaccounted for water (NRW) in form of bars and percentages. The trend shows that on average 9 million cubic meters of water was produced annually with an average of 41% or 3.5 million cubic meters of NRW recorded in the period January 2018 to December 2021.Overall, the findings show that the levels of Non-Revenue Water significantly dropped from an average of 49% in 2018 when the implementation of the utility's Strategic plan 2018-2021 to an average of 29% in 2021.

3.2.Planned Water Management Strategies aimed at reducing NRW at SWSC

From the document review, the researcher had an opportunity to go through the utility's NRW reduction strategic plan-2018-2021. Document review helped the researcher in understanding the direction where the utility is coming from and where it is going in terms of reducing NRW-incurred from various causes stretching from unbilled authorized consumption to apparent and physical losses. From the reviewed documents the following were the findings:

SWSC (2017) affirms that "NRW at the SWSC stands between 35 - 53% and that by 2018 the levels of NRW stood at 53% water loss converted in money terms to be K23, 732, 878 while also translating to 8.5 million m3 of water lost annually" (p.5). This situation also affects the competing needs of water on the Zambezi River, considering that a Hydroelectric power station exists downstream. UNESCO (2020, p. 3) confirms that "A 60MW hydro-electric power station on the Zambian side of the falls requires 175 m3/s to operate at full capacity, representing a considerable proportion of the Zambezi's total flow during the drier months (flow rates below 400m3/s are usual from early September to mid-December) (States Parties of Zambia/Zimbabwe, 2012)".

Further, constant flow is required to keep Victoria Falls healthy as a tourist attraction and national heritage site, a statement supported by UNESCO (2020, p..5) who notes that any major use or abstraction of water from the upstream catchment area would have an impact on the spectacle of the falls, particularly during the dry season.

Furthermore, according to the utility's strategic plan, for it to reduce the levels of NRW to the acceptable required benchmark rate of 25%, a planned cost of about ZMW 179 million will be required in 3 years with a simple payback period of 9 years or more than 22 years with a discounted payback period at 35% interest rate (Invest Trust Bank Limited). With this investment, the intention is that there will be a significant reduction in NRW in these towns and service centers manned by the utility.

In addition, the Utility further planned to implement various programs as stated in the two documents that were to be used in driving the reduction in NRW which are; NRW management strategy 2016-2018 and SWSC NRW management strategy 2018-2020. The utility's strategic plan identified four (4) key areas; namely, Real or Physical losses, Apparent or Commercial losses, Capacity Building Sensitization/Public Relations, and Sensitization/Public Relations (SWSC, 2017).

3.3. Implementation of Water Management Strategies by the (SWSCO) aimed at reducing Non-Revenue Water

Following document review, interviews were conducted with the view of understanding the views of the key respondents; in this case, SWSC employees in the Livingstone district on the implementation of the planned strategies and how well these strategies are responding to the challenge of Non-Revenue Water at the utility. The following themes emerged from the responses which were coded KR1 ……. KR10. **KEY**: *[Strengthen human resource structure and capabilities* ***(SHRSC****), Passive and Active Leakage Control program (****PALCP****), Water Audit* ***(WA****), Community Involvement* ***(CI****), and rehabilitation of Network (****RDN****)]*.

3.3.1 Strengthening human resource structure and capabilities (SHRSC)

In strengthening human resources structures and capabilities the findings revealed that the utility has come up with several strategies which include, among others, enhancing capacity building through (training) programmes which are often conducted at the utility in different departments that deal directly with NRW such as networks, billing, customer service among others. One of the key informants indicated that;

> *In-house training has become a priority for the institution, if you go to the board room right now, you will find a workshop for plumbers at the institution, all this is aimed at helping them gain more skills in the area of NRW using modern technologies* (KR1).

He further added that when the human resource is well equipped with all that is required to undertake maintenance, response time to system failure reduces leading to the reduction of water that goes to waste, or is unaccounted for through bursts and leakages.

Furthermore, to reduce or eliminate vices such as illegal connections which are sometimes "staff-assisted" the study revealed that the utility has enhanced its policy on discipline aimed at reducing cases of bribery, especially

among meter readers who are seen as operating in their own "world". *"This is aimed at reducing water theft activities such as illegal connections, by-passes, and tempering with water meters among others"* (KR5, 2021).

3.3.2. Passive and Active Leakage Control Program (ALCP)

System monitoring and maintenance are vital in reducing water that goes unaccounted for, hence the need to have a proper leak repair programme at the utility. In responding to this, the study revealed that the utility has a system aimed at resolving leakages in the quickest possible time, as One Key respondent from the Networks Department added that *"Leakages on the utility distribution line are a major cause of real/physical losses which are contributing a huge percent to the total water losses for the utility"* (KR6, 2021). In responding to this serious challenge that affects the amount of water lost or that goes unaccounted for, the study revealed that the utility is working hand in hand with the community to report leakages through the use of various platforms such as WhatsApp, Facebook, Mywatsan, utility phone numbers with the view of having these leakages attended to in the very short period.

In addition, the study revealed that the utility also has in the past few years trained more plumbers who conduct foot or bicycle inspections in Livingstone which has improved response time to these leakages. One Key respondent who is also a plumber indicated that *"in the strategic plan (2018-2021), a toll-free line has not been implemented and operationalized at the utility with the view of making the report easy for members of the community and this has made our job easy in identifying and attending to leakages on the network"* (KR8, 2021).

Furthermore, it was revealed that fragmenting the distribution network into District Metered Areas (DMA) has proved to be an effective mechanism in dealing with NRW in the district. A participants added that "*The design of DMA's was done this is when we want to implement, we are supposed to isolate 11 (Eleven) DMA's and so far, we have just isolated (1) one"* (KR3, 2021).

3.3.3. Water Audits (WA)

Water auditing is vital for in-demand water management as it helps in giving a clear picture of how much water is extracted from either surface or subsurface water sources, how much water is treated and pumped into the distribution network, and how much of that is accounted for while indicating how much is unaccounted for. In order to achieve this, there is a need to among other strategies make sure that the utility increases the metering ratio to 100%. Livingstone district metering ratio stands at 69%. One of the key respondents indicated that;

Meter tampering and theft are very high in Livingstone, especially in peri-urban areas and this is affecting the utility's objective of increasing the metering ratio. He further indicated that the design of the meter which is often exposed makes it easy for people to either steal or temper with it while on the other hand, very few people have been arrested and prosecuted mainly due to the fact that in these communities' people protect each other making arrests impossible (KR4, 2021).

Furthermore, the study revealed that the utility has enhanced practices aimed at monitoring and maintaining water usage through periodical checking of pressure valves, promoting the use of correct materials in dealing with leakages such as the use of couplings and other fixtures that contribute to water losses in the distribution system. In addition, a respondent from Networks added that the utility has mapped and will continue mapping the infrastructure as it expands using modern technology such as the use of GIS and this has enabled the utility to know the pipe sizes and exact location when there is a leakage, this shortens the leak resolution time.

However, field observations conducted during the study period showed that that some visible water leakages were a very common sight in most neighborhoods of Livingstone as can be seen from figure 5.7 in below. When asked why this is the case, one of the respondents from Networks who was also a plumber noted that this was most often due to exposed waterlines to the elements due to erosion.

(a) **(b)**

Figure 5.7 pictures of water leakages (Source: Field Observations)

Figure 5.7 shows an exposed water pipe with Substandard material (rubber bands) used to seal the leakage, and a serious leakage on one of the distribution lines.

3.3.4. Community Involvement (CI)

Coming from an understanding that the water distribution network is found in various communities, the need to often engage the communities who benefit from this service is greater if the problem of unaccounted-for water is to be addressed. The study revealed that in meeting this goal as indicated in the strategic plan, the utility has enhanced Community engagement programmes through radio and roadshows, and enhanced the customer care desk in all the five (5) service centers in the city *(Dambwa North, Dambwa Central, Maramba, Mushili Way or Head office, and Post Office).* One Key respondent indicated that;

We have increased awareness programs in the city and this is now leading to improved reporting of cases pertaining to the tempering of the utility's infrastructure such as illegal connections, by-passes, tempering with meter readings, and direct stealing of the water meters (KR&, 2021).

3.3.5. Rehabilitation of distribution networks (RDN)

One of the major objectives contained in the strategic plan (2018-2021) is to improve operational efficiency in water loss management by capacity-building infrastructure. This is a vital component in water loss management of any system considering that a substantial amount of water lost or going unaccounted for comes from infrastructural failure. The study revealed that the major part of the distribution network, especially the mains in the city of Livingstone is obsolete as some are more than 50 years old, making them prone to pipe bursts. This finding was in agreement with what was revealed by one Key respondent who added that;

> *Most of the pipes on the distribution network in the district were laid at the time the city was being developed which is 50 years ago and the material used to be galvanized steel weakens with time-making system failures a serious problem* (KR6, 2021).

The respondent further added that in an effort to address this problem, the utility has been making changes to the distribution network by replacing old pipes with new pipes, leading to a reduction in leakages and bursts in these areas, such as police and prison camps. However, despite the utility making head-ways, the major part of the distribution network is still obsolete and old.

IV. CONCLUSION

This study reviewed many publications on water loss management developed in both developed and developing countries. The publications were on NRW concepts, tools, and methodologies for managing water losses, bench-marking, as well as best practices used by other utilities in the world in water loss management. The findings, as well as reviewing the literature, have indicated that for any utility to curtail the levels of non-revenue water which seem to be a big problem in many of them, best practices have to be put in place.

The study drew a lot of insights about water loss management in Zambia as well as the utility in Livingstone. This was first done by looking at what the utilities in developed countries have done so far, then the status quo in developing countries like Zambia. It was discovered that developing countries lag in their water management, with Southern Africa having NRW raging between 11% and 60% and Zambia between 26% and

77% as of 2019. At the national level, the rise in NRW were attributed to water loss management that could be attributed to as being passive and hence non-proactive.

The study conducted at SWSC in Livingstone revealed that the actual levels of the components of NRW at the utility were still not known due to the lack of requisites needed to partition NRW' despite this being one of the main objectives embarked on in the strategic plan (2018-2021). Without partitioning in place, it is very difficult to channel the right strategies toward the right area of need. However, despite the utility not having a system to partition water into its core components, the study revealed that by the end of the implementation cycle of the Strategic Plan for the utility which was running from (2018 to 2021), the levels of NRW reduced significantly from 48% in 2018 to 29% in 2021, beating the expected target of 30%.

In reducing the levels of NRW to the current 29%, SWSC undertook various measures among which were; the increasing checks for water thefts (illegal connections, by-passes, unbilled consumptions, unregistered customers, malfunctioning meters, and wrong customer categories); redesigning the meters currently being installed to avert meter theft, and increase metering ratio, which however is still as low as 70%, making it difficult to quantify NRW; increasing community sensitization to help with the management of the institution's infrastructure against vandalism and also reporting leakages; initiating the process of isolating the system into segments or District Metered Areas' (DMA's) aimed at monitoring pressure, making water auditing easy.

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