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Using Performance Indicators for Non-Revenue Water Reduction: A Case Study in a Small Island State (Mauritius)

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Abstract

The paper presents a conceptual framework for using Performance Indicators (PIs) in a Small Island State (Mauritius) for evaluating water network efficiency. This study uses the IWA/AWWA PI-Concept and benchmarking from which the PIs are derived. Findings from this study show that even Small Island States can adopt PIs as tools for improving water network efficiency and ultimately reducing Non-Revenue Water (NRW), provided that they are developed to suit the specificities of the water utilities of the island. The research study shows that the NRW is 58.9% using the IWA (International Water Association) water balance table whereas the Infrastructure Leakage Index is 21.9 in the small island state of Mauritius. Both methods reveal that non-revenue water is a matter of concern for the network efficiency in the island.

Keywords: Performance Indicators; Small Island State; Non-Revenue Water.

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1. Introduction

'Water losses' is one of the biggest challenges faced by the water industry in Small Island States (SIDS). Preparing a baseline to establish current levels of water losses (by carrying out a water audit that leads to a water balance) is the first critical step for any utility wanting to reduce water losses. A water balance is a prerequisite for designing a NRW reduction strategy [1]. Performance indicators (PIs) in water utilities are getting more attention and their adopting in Performance Assessment Systems (PAS) for evaluating water losses is becoming essential. Whereas the IWA/AWWA water balance methodology and PIs are valuable tools, they cannot be directly applied and do not fully address the peculiar characteristics of water distribution systems in developing countries [2]. Most PIs that are currently used are customised, based on the 'water utilities' specificities of the country. The assessment of a network's current operating status based on the IWA Standard International Water Balance [3]and selected performance indicators (PIs) [4], is worldwide considered as a good start. However, the IWA Water Balance table does not take into consideration all the components of water losses. The % NRW derived from the IWA Water Balance table is too basic and inappropriate for assessing the efficiency of a water distribution system [3]. The general concept of evaluating the performance of a Water Supply Services is to compare its performance with established benchmarks [5]. The AWWA Leak Detection & Accountability Committee (LDAC) (1996) proposed benchmarks for acceptable level for Unaccounted-for Water (UFW) and actions required based on IWA Water Balance. Whereas the World Bank Institute proposed a Banding System to interpret the Infrastructure Leakage Index (ILI), which is an indicator used for network efficiency evaluation. The ILI is widely becoming the preferred indicator in many countries and is continuously being promoted by members of the IWA Water Loss Task Force [6].

Mauritius being a Small Island state has not yet embarked on PI system for evaluating water network efficiency. This paper aims at adopting the use of PIs by integrating these three components which are water balance table, Infrastructure Leakage Index and benchmarking into a Water Loss PI tool in a Small Island State by taking into consideration its water utilities' specificities for improving water network efficiency.

2. Methods

This research study was conducted on data collected on a water distribution network in Mauritius namely, the MAV Upper Water Distribution System as shown in the figure below.

A conceptual framework was developed based on the IWA Water Balance standardized table and the AWWA Leak Detection & Accountability Committee (LDAC) (1996) Benchmark. The data was analysed using a spreadsheet package. The Water Balance for the selected water network system was developed to calculate the percentage of all the components of the water losses and the percentage of the Unaccounted-for water (UFW). The AWWA Benchmark for UFW was used to compare the level for UFW in the network System and for actions required. The Infrastructure Leakage Index (ILI) of the network system was determined using the IWA equation for Unavoidable Annual Real Losses (UARL) and Current Annual Real losses (CARL) to evaluate the network's performance level. And finally, the World Bank Institute Banding System was used to interpret the ILI for describing the performance of the network system and for suggested range of actions required for the reduction of NRW.

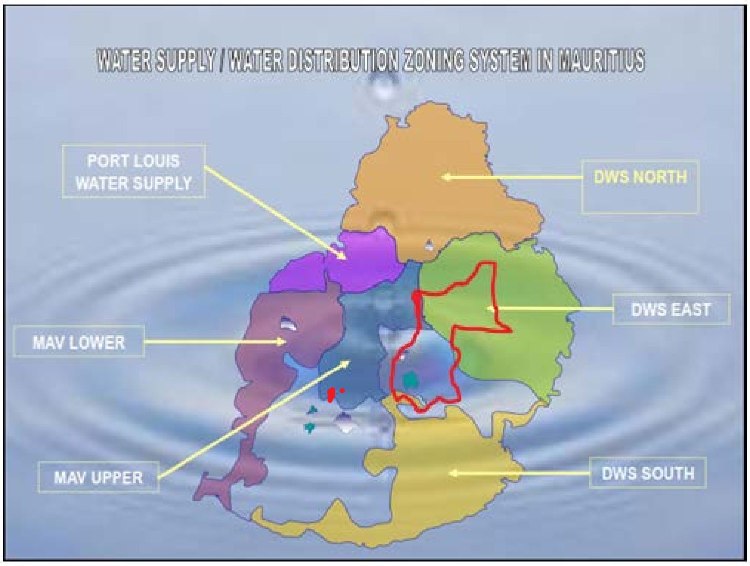

Figure 1: Water Supply Distribution Zone in Mauritius

3. Results

Water Balance Table:

The Water Balance table was developed using data collected on MAV Upper network. (Average over 12 months period was calculated from January 2015 to December 2015).

The standard IWA terminology for assessing water losses are abbreviated as follows:

- System Input Value is the annual volume input to the water supply/system
- Authorised Consumption is the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others that are implicitly or explicitly authorised to do so
- Non-Revenue Water (NRW) is the difference between System Input Volume and Billed Authorised Consumption
- Water Losses is the difference between System Input Volume and Authorised Consumption and consists of Apparent Losses and Real Losses;
- Apparent Losses consist of Unauthorised Consumption and all types of meter inaccuracies
- Real Losses are the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of the customer meter.

- **Unaccounted-For water UWF)** = System Input – legitimate consumption = 100 –(41.1+0.9) = **58%**
- **NRW** = System input – Revenue water = 100 – 41.1 = **58.9%**

AWWA benchmark:

The AWWA Leak detection and Accountability Committee (1996) recommends 10% as a benchmark for UFW.

<table>
<tr><td rowspan="5">Average System Input
100%
(107400m^{3}/d)</td><td rowspan="2">Authorised Consumption
42.0%
(45100m^{3}/d)</td><td colspan="2">Billed Authorised
41.1%
(44100m^{3}/d)</td><td>Billed water
41.1%
(44100m^{3}/d)</td></tr>
<tr><td colspan="2">Un-billed Authorised Consumption
0.9%
(1000m^{3}/d)</td><td rowspan="4">Non-Revenue Water
58.9%
(63300m^{3}/d)</td></tr>
<tr><td rowspan="3">Water Losses
58.0%
(62300m^{3}/d)</td><td rowspan="2">Commercial losses
12.1%
(13000m^{3}/d)</td><td><b>Un-authorised Use
1.9%
(2000m^{3}/d)</td></tr>
<tr><td>Customer Meter Error
10.2%
(11000m^{3}/d)</td></tr>
<tr><td colspan="2">Physical Losses
45.9%
(49300m^{3}/d)</td></tr>
</table>

Figure 2: Water balance table for MAV Upper Distribution System

The UFW derived from the water balance table is 58% and therefore it is matter of concern and action is required for NRW reduction.

Infrastructure Leakage index (ILI):

ILI is the Ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Current Losses (UARL)

UFW levels	Action needed
< 10%	Acceptable, monitoring and control
10-25%	Intermediate, could be reduced
> 25%	Matter of concern, reduction needed

Figure 3: AWWA Benchmark for UFW

The **UARL** was calculated as follows:

UARL (gallons/day) = (5.41Lm + 0.15Nc + 7.5Lp) x P

Where, Lm = length of water mains, km

Nc = number of service connections

Lp = total length of private pipe, km = Nc x average distance from curbstop to customer meter

P = average pressure in the system, psi [7]

ILI for MAV Upper = **CARL/UARL = 49300000/2254500 = 21.9**

As per the World Bank Institute Banding System to interpret ILI, an ILI above 16 in developing countries is categorized as band D. The ILI obtained for MAV Upper Distribution System is 21.9 and is categorized as Band D which states that the network system is very inefficient and leakage reduction programs are imperative and of high priority. The study had some limitations. Apparent Losses included components like: unauthorized consumption and customer metering errors and were based only on the volumetric figures from the Annual Water Balance. In real the management of Real Losses consists of the combination of four primary components: (i) pipeline and assets management (ii) pressure management (iii) speed and quality of repairs (iv) active leakage control. The IWA best practice manual suggests that the % of system input is not reliable as can be only used as a financial performance indicator and it states clearly that it is 'unsuitable for assessing the efficiency of management of distribution systems' [8]. Real Losses, as a % of system input, also suffers from deficiencies, mainly the level of consumption and variations in supply time (intermittent supply). Note: The MAV Upper Distribution System had limited hours supply per day during the year 2015 and the uninterrupted supply situation (all bursts would leak for 24 hours) could not give the actual water lost value.

Developing Countries ILI range	Developed Countries ILI range	BAND	Calculated ILI for this System	General description of Real Loss Management Performance Categories for Developed and Developing Countries
Less than 4	Less than 2	A		Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement
4 to < 8	2 to < 4	B		Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
8 to < 16	4 to < 8	C		Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
16 or more	8 or more	D	21.9	Very inefficient use of resources; leakage reduction programs imperative and high priority

Figure 4: World Bank Institute Banding System to interpret ILI

Source: World Bank Institute Guidelines: 2005

4. Recommendation

The common practice of expressing Real Losses as a % of volume input is not adequate as a technical PI since it does not take into account factors such, mains length, number of service connections, and average operating pressure which is unduly influenced by consumption. In most network systems, the greatest proportion of real losses occurs on service connections. The recommended basic Performance Indicator for Current Annual Real Losses is therefore the annual volume of real losses in litres per service connection per day, when the system is pressurized. The Infrastructure Leakage Index approach provides an improved method for technical comparisons, which takes into account management of infrastructure performance such as pipe, pressure, maintenance, renewal, replacement, time for repairs, and leakage control. Findings from this study show that the adoption and use of PIs is an important and efficient tool for Performance Assessment Systems for improving water distribution network in a Small Island State like Mauritius to tackle the water loss challenges. However the Performance Indicator applied in a Small Island State can be effective by integrating the three components together that is Water Balance table, the AWWA Benchmarking and the Infrastructure Leakage Index.

5. Conclusion

The percentage of non-revenue water and the unaccounted for water were found to be 58.9% and 58% respectively using the IWA Water Balance table. And the Infrastructure leakage index obtained was 21.9.All the values obtained indicates that non-revenue water is a great matter of concern and the network system is very inefficient and leakage reduction programs are of high priority

The study shows that PI's is very helpful to water supplier companies of small island states to report their non-revenue water, analyze the reasons for water losses and to implement loss control programs. In addition, it is necessary for water suppliers to perform regular water audits to determine the PIs. Nonrevenue water and water losses could be computed through these audits that would allow a Small Island State like Mauritius to build a standardized approach that will produce data to allow performance comparisons and establish best practices on national and international levels.

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