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How Average Operating Pressure Impacts on Infrastructue Leakage Index

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Abstract: Over the past decades, many performance indicators have been developed for water utilities to track their system performance. Since the level of water losses from potable water distribution systems is one of the key efficiency issues, it would be expected that reliable performance indicators are used for benchmarking. To demonstrate the use and value of the benchmarking performance indicators, a system dynamics model is used to present a case study for 78 water utilities in Fars provience, Iran. The importance of managing distribution systems to maintain pressures in sustainable range is widely recognised as a fundamental aspect of leakage management strategy.

Key words: Non Revenue Water, Real loss, Pressure, Leakage

1. Introduction

Water management authorities and water utilities around the world face the challenge as well as having the responsibility to find a balance between efficiency of water distribution networks in using the natural water resources, and efficiency in the use of human, financial and the other natural resources.

Management of non-revenue water (NRW) is one of the most important issues facing water suppliers around the world. The key in developing a strategy for NRW management is to gain a better understanding of the reasons for NRW and the factors which influence its components. Reducing losses is an important step to achieving long-term financial sustainability of water utilities. World Bank Group (2016).

A percentage loss figure gives you a snapshot of what is being lost in one system at any one time, but it cannot provide a reliable comparison of a system's performance over time. Low percentage of NRW is not necessarily an indication for good real losses management.

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Experienced practitioners consider the Infrastructure Leakage Index as the most appropriate performance indicator for real losses (physical losses). In many cases, however, poor data quality as well as low operating pressures; particularly in developing countries, are often cited as motivation for not using the ILI in which cases the % of system input tends to re-appear.

The Infrastructure Leakage Index (ILI) is the dimensionless ratio which is calculated as CARL/UARL (Lambert,2002). CARL is evaluated by means of the balance, while UARL is defined as a function of structural characteristics, length of mains, number and length of service connection (distance between property line and watermeter) and pressure, C. Lenzi (2014). ILI accommodates the fact that real Losses will always exist even in new and well managed systems.

The evaluation of water loss level in water supply system through performance indicator is a cruial issue. The Infrastructure Leakage Index (ILI) is derived from the structural and operational characteristic of the network and it is a more appropriate approach to use than the percentage of system input volume.

The ILI is effectively an indicator of how well a distribution network is being managed and maintained at the current operating pressure, which is its lowest technically achievable value for a well maintained and well managed system. Knowledge and management of operating pressures throughout a distribution system is essential for the management of Real Losses and some components of consumption.

The traditional performance indicators for real losses have never included operating pressure and thus the relationship between leakage and pressure was not taken into account in the comparison of different Water Distribution Networks. At the same time if the value of Average Operating Pressure is not properly and clearly identified in the estimation of UARL, the final value of ILI can be heavily influenced.

One of the worst problems, is to assume that Average Zone Pressure is the average of the Inlet and Critical Point pressures. While this may be a valid assumption for some small Zones with no variation in ground levels, in most cases it will lead to significant errors in estimates of Average Zone Pressure, ILMSS Ltd (2013).

This study proposes a set of normalized and time-integrated benchmarking performance indicators for sustainable long-term management of water distribution networks. The examples of calculation average operating pressure presented in this contribution. We compared the Infrastructure Leakage Index, Average Operating Pressure and Water loss per customer per day in 78 utilities, and then the leakage level for each group of utilities is classified.

2. Methodology

In water systems which illustrate that expressing NRW as a percentage of system input volume can be very misleading because of often very big differences in levels of consumption, network characteristics (connection density), operating pressure, and (last, but not least) supply time. The ILI, which in the first few years known to only a few insiders, is now widely accepted and used by practitioners around the world, as it best describes the efficiency of the real loss management of water utilities, Winarani, W (2009).

$$ILI = \frac{CARL}{UARL} \quad (1)$$

UARL (liters/day) = (18 x Lm + 0.8 x Nc + 25 x Lp) x P (2)

where Lm = mains length (km); Nc = number of service connections; Lp = total length of private pipe, property boundary to customer meter (km); P = average pressure (m), Saroj Sharma, (2008).

Following recent research, the lower limits for number of service connections is now 3000 and the lower limit on density of connections has been removed. The lower limit of 25 meters for pressure was introduced to avoid significant errors from extrapolating the assumption of a linear pressure, R Liemberger (2002).

Pressure management is one of the most effective forms of leakage management, particularly in systems with deteriorated infrastructure. The presence of surges and high pressures influence the rate at which new leaks occur. Flow rates from existing leaks are more sensitive to average pressure, A.O. Lambert (2002).

Water losses as a percentage of system input, which is a traditional indicator, is easily calculated and is certainly the most common indicator quoted by non specialists, this indicator is unsuitable for assessing the efficiency of management of distribution system, Winarani, W (2009).

There is no correlation between ILI and NRW as percentage of system input volume. Low percentage of NRW is not necessarily an indication for good real losses management.

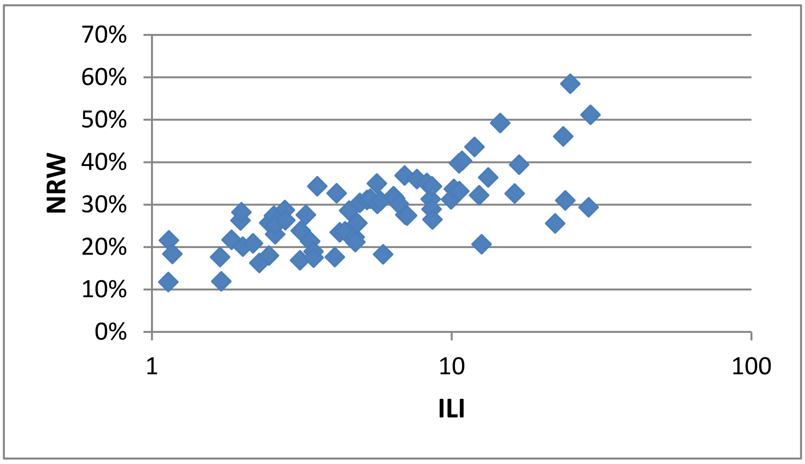

Figure 1: compared ILI and NRW using Data Set of 78 Utilities on logarithmic scale

The infrastructure leakage index (ILI) is derived from the structural and operational characteristic of the network. There are several key factors which can influence system performance and result in excessive real losses, including soil conditions, quality of pipe materials, continuity of supply, length of mains, number of service connections, location of customer meters on service connections, and average system pressure, S. Hamilton (2006).

Average system pressure Pav is needed for calculation of 'Unavoidable Annual Real Losses' (UARL), which is used in deriving the Infrastructure Leakage Index (ILI), one of the key performance indicators for Real Losses, C. Lenzi (2014).

Water pressure is an essential key parameter for leakage specialists to interpet leakage and bursts data which significantly influences burst frequency and background leakage.

The knowledge of the pressure at the nodes of the Water Distribution Networks may result from measures taken at some network nodes, or by an extended period simulation executed on a calibration numerial model.

A weighted average ground Level (WAGL) for an appropriate infrastructure parameter is calculated to measure average pressure in zones, then select an appropriate hydrant near the centre of the Zone, with this approximate ground level, as the Average Zone Point (AZP). Obtain the average pressures at the AZP point by measurement or indirect assessment. The identification of the Average Operating Pressure (AOP) is closely correlated to the pressure at the average elevation point for the whole area.

If a calibrated numerical model of a Water Distribution Networks is available, with a homogeneous level of skeltonization over the considered area, the variation of pressure during an average day will be known for each node of the network and the AOP can be calculated as , C. Lenzi (2014).:

$$AOP = \frac{\sum_{i=1}^{N} W_i \left(\frac{1}{T}\sum_{t=1}^{T} P_{i,t}\right)}{\sum_{i=1}^{N} W_i} \quad (3)$$

Where $P_{i,t}$ is the pressure at node I and time t, W_i is a weight assigned to node i (related to the structural property of the node, usually equal to 1), T is the total duration of the simulation, N is the number of nodes

The average operating pressure can be determined using pressure measurement at some points of the network. The choice of this points and their number can affect the value of AOP.

The hierarchical clustering of nodes into C clusters (C is the number of pressure transducers) was applied to the test network, the pressure value derived form the measures taken at some network nodes which are closest to the centroid of each cluster.

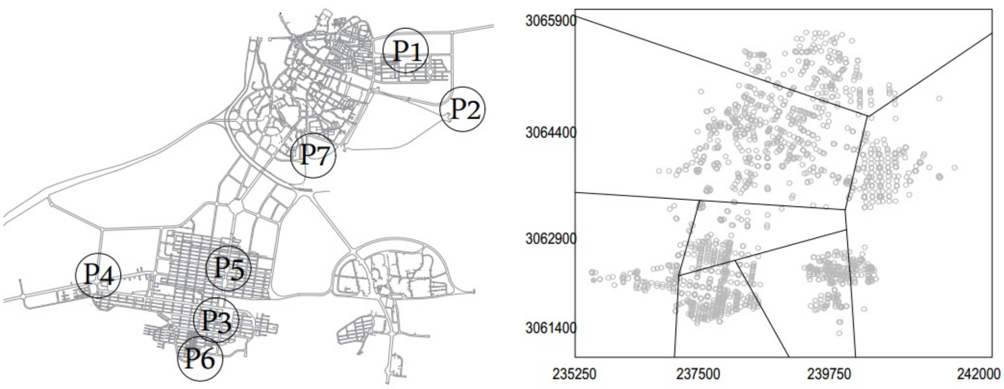

Figure 2: Thiesen polygones to calculated the weighted average pressure for an example water distribution network

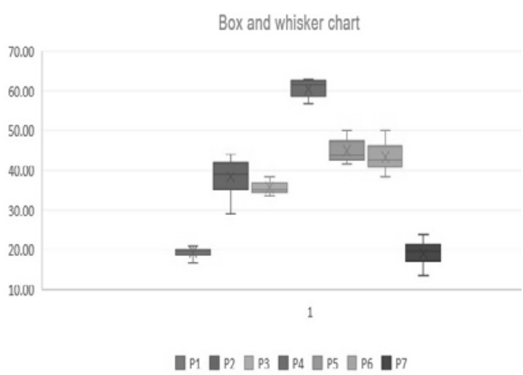

Figure 3: Boxplot of the weighted AOP versus the number of measurement point

The Average Pressure Pav for a whole system is the weighted average pressure of all the Zones in that system.

The calculated ILIs for 2016-2017 for 78 water service providers in the charts below, classified by ILI categories. The networks considered are the networks of 78 utilities in Fars Water and Sanitation company of

Iran (Lm=10852 Km, Nc= 649327). In each utilities UARL and CARL calculated then ILI derived from formula (1).

For further investigation, utilities were devided into 4 categories according to the physical loss assessment matrix for developing countries R Liemberger and R. Mckenzie (Table1). For this networks installation pressure transducers and modeling the networks allows a detailed knowledge of the average pressure.

Category A, 1<ILI<4: (Number of utilities:32, Lm: 5048Km, Nc:284181, AOP:33.9, CARL:9015022 $\frac{\mathbf{m^3}}{\mathbf{year}}$)

Category B, 4<ILI<8: (Number of utilities:22, Lm: 2627Km, Nc:150511, AOP:25.15m, CARL:7693930 $\frac{\mathbf{m^3}}{\mathbf{year}}$)

Category C, 8<ILI<16: (Number of utilities:15, Lm: 1600.34Km, Nc:123072, AOP:20.1m, CARL:8228470 $\frac{\mathbf{m^3}}{\mathbf{year}}$)

Category D, ILI>16: (Number of utilities:9, Lm: 1576Km, Nc:91563, AOP:10.11m, CARL:6430780 $\frac{\mathbf{m^3}}{\mathbf{year}}$)

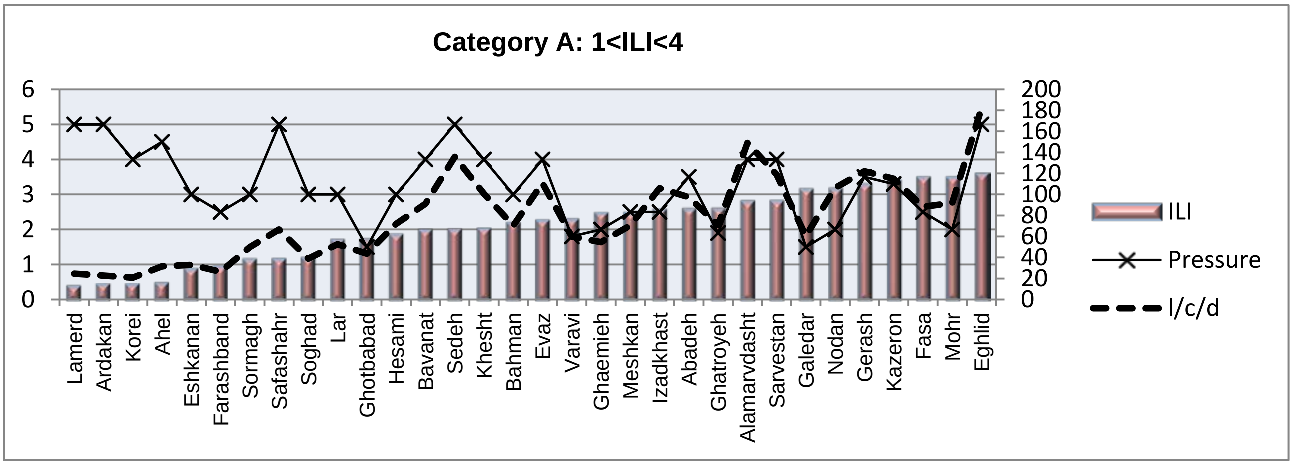

Figure 4: Utilities with 1< ILI<4

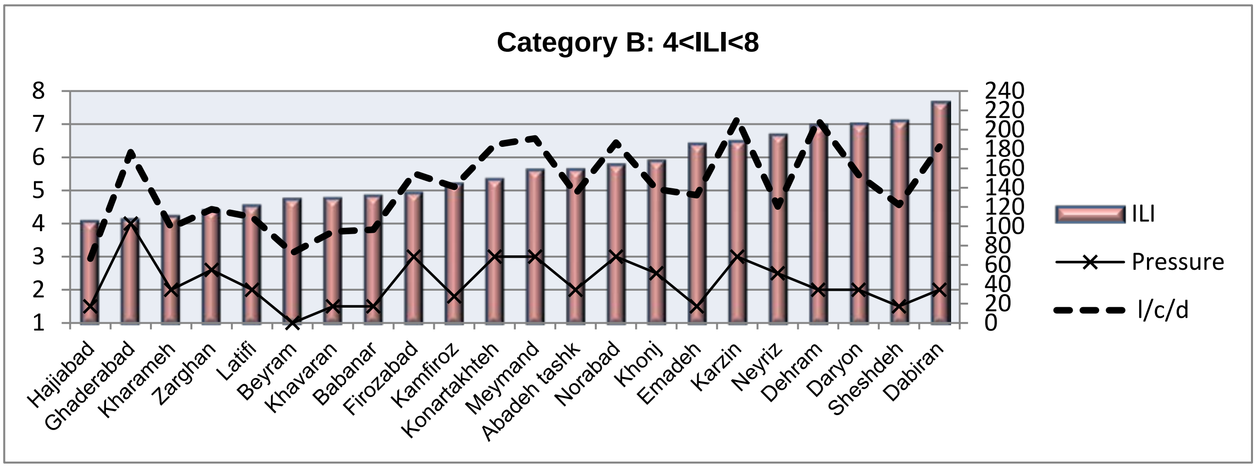

Figure 5: Utilities with 4< ILI<8

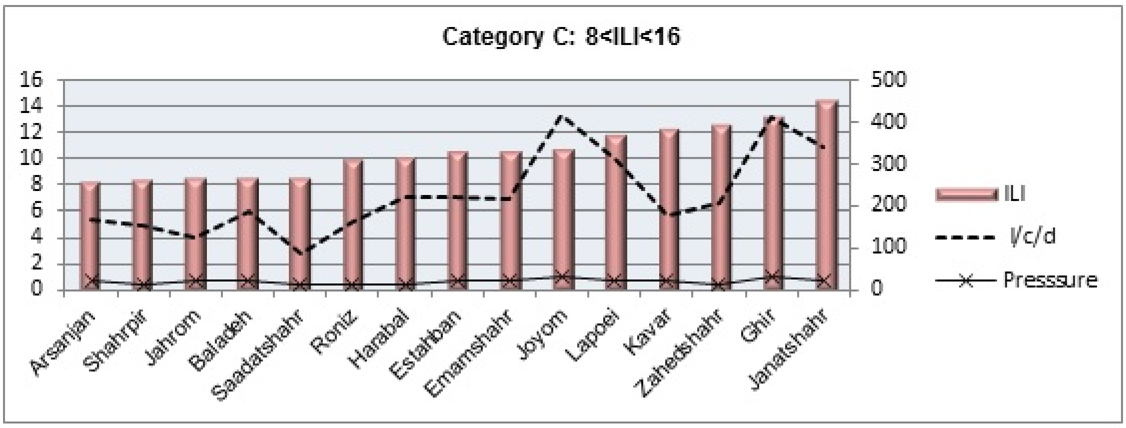

Figure 6: Utilities with 8< ILI<16

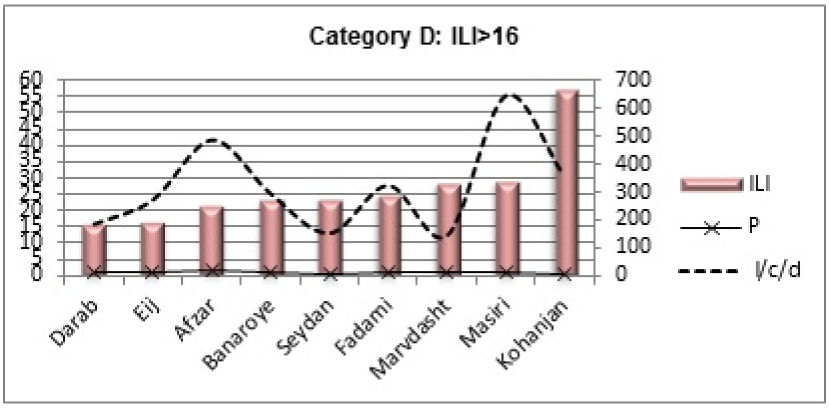

Figure 7: Utilities with ILI>16

47% of water distribution networks have achieved band A- 1<ILI<4, which is an excellent performance. (Further loss reduction may be uneconomic unless there are shortage, careful analysis is needed to identify cost- effective improvement). It is notable that almost 60% of the large water distribution networks with much more number of properties are in this category.

Real Losses will tend to increase if they are not constrained by the four Leakage Management Activities: Pipe materials management, Speed and Quality of Repairs, Active Leakage Control, Pressure Management, Allan Lambert (2000).

Pressure Management can involve both increases and decreases in pressure, at different times of the day or year. In either case, there will be a significant influence on the annual volume of both Unavoidable and Current Real Losses.

The other factor is soil conditions that can have a great effect on the real losses as well as to the ability for them to be identified and located at the ground surface.

Based on extensive experience, a simple matrix was published, that provides some insights onto typical values for different situations Ronald Liemberger et al (2006).

Table 1: physical loss assessment matrix

Technical performance category	ILI	Liters/connection/day when the system is pressurized at an average pressure of:				
		10m	20m	30m	40m	50m
A	1-4	<50	<100	<150	<200	<250
B	4-8	50-100	100-200	150-300	200-400	250-500
C	8-16	100-200	200-400	300-600	400-800	500-1000
D	>16	>200	>400	>600	>800	>1000

This approach can be used to classify the leakage levels for utilities in developed and developing countries into four categories.

Category A: Further loss reduction may be uneconomic unless there are shortage, careful analysis is needed to identify cost- effective improvement

Category B: Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance.

Category D: Highly inefficient; leakage reduction programs imperative and highpriority.

3. Conclusions

The ILI approach provides an improved basis for technical comparisons of leakage management performance which separates aspect of infrastructure management, repair, pipe and assets management, effectiveness of active leakage control policy, from aspects of pressure management.

The combination of UARL/ILI, and the IWA standard water balance with 95% confidence limits, offers a new and practical tool for rapid evaluation of opportunities and best options for further leakage management.

The UARL and ILI approach is more soundly based than previous traditional performance indicators for management of Real Losses in distribution systems. Separating the substantial influence of pressure from the ‘infrastructure’ factors has introduced clarity to the technical analysis without much additional effort. The approach can be, and is being, used for International, National, and ‘within system’ comparisons.

Although a well managed system can have an ILI of 1.0 (CARL = UARL), this does not necessarily have to be the target as the ILI is a purely technical performance indicator and does not take economic considerations into account.

For any water distribution system there is a level of leakage below which is it not cost effective to make further investment or use additional resources to drive leakage down further. In other words, the value of the water saved is less than the cost of making further reduction.

Advanced pressure reduction is becoming an increasingly popular technique to reduce both leakage and burst frequencies and in some cases utility managers try to maintain system pressures to avoid the average pressures exceeding 25 meters. Most of water distribution networks in the developing world do not even enjoy continuous supply - and pressures of more than 10 or 15 meters tend to be the exception and not the rule.

References

[1]. Saroj Sharma. (2008). Performance Indicators of Water Losses in Distribution System. UNESCO- IHE, Institute for Water Education.

[2]. A.O. Lambert* and Dr R.D. McKenzie. Practical Experience in using the Infrastructure Leakage Index.

[3]. World Bank Group. (2016). USING PERFORMANCE-BASED CONTRACTS TO REDUCE NON-REVENUE WATER.

[4]. Bill Kingdom, Roland Liemberger, Philippe Marin (2006). The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries. How the Private Sector Can Help: A Look at Performance- Based Service contracting.

[5]. R Liemberger, R McKenzzie. Accuracy Limitation Of the ILI- Is it an Appropriate Indicator for Developing Countries?

[6]. ILMSS Ltd (2013), AVERAGE PRESSURE in Water Distribution Systems and Zones.

[7]. Allan Lambert, WHAT DO WE KNOW ABOUT PRESSURE:LEAKAGE RELATIONSHIPS IN DISTRIBUTION SYSTEMS?

[8]. Winarni, W (2009), Infrastructure Leakage Index (ILI) as Water Losses Indicator, Civil Engineering Dimension, Vol. 11, No. 2, September 2009, 126-134.

[9]. C. Lenzi, C. Bragalli, A. Bologensi, M. Fortini (2014), Infrastructure Leakage Index assessment in large water systems. 12 th International Conference on Computing and Control for the Water Industry, CCW12013, Procedia Engineering 70 (2014) 1017-1026.

[10]. A. Ganjidoost, A. Unger, C. Haas (2018), Benchmark Performance Indicators for Utility Water and Wastewater Pipelines Infrastructure, Journal of Water Resources Planning and Management (ASCE)WR.1943-5452.0000890).

[11]. S. Hamilton, R. Mckenzie, C Seago (2006), A Review of Performance Indicators for Real Losses from Water Supply Systems.