IMPROVING THE COMMUNICATION WITH STAKEHOLDERS: THE INFRASTRUCTURE DEGRADATION INDEX (IDI) AND THE INFRASTRUCTURE HISTOGRAM (H_I).

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Abstract

Water infrastructures are rapidly ageing without being properly replaced. Communicate the state of the network and the sector' needs to stakeholders is key for guaranteeing the sustainability of water and sewerage systems. The Infrastructure Value Index (IVI) is becoming a standard in the water industry as a communication tool. However, as a single value metric can mask key information. The complementary use of the Infrastructure Degradation Index (IDI) and the Infrastructure Histogram (H_i) can provide a better understanding of the network's state while maintaining the simplicity of the analysis needed for public dissemination. The IVI is focused on the value of the infrastructure, the IDI on its median remaining life. The H_I provides a detailed but simple picture of the network's remaining life, providing a clear idea of the magnitude of the investments needed in the future for maintaining the infrastructure.

Keywords: long-term planning, Infrastructure Degradation Index (IDI), Infrastructure Histogram (H_I), water services, Stakeholders' communication

1 Introduction

Water infrastructures are capital intensive and are designed for a long operational life (Alegre & Covas, 2010). Besides, they are generally buried, making difficult the diagnosis of their state and increasing their rehabilitation costs. The need of strategic asset management has become crucial for water supply and sewerage utilities as infrastructures are gradually ageing without being properly replaced or rehabilitated (ASCE, 2011). With the actual rehabilitation rates and if the actual approach of this issue does not change, water services could collapse in the medium-long term, as stated by H. Alegre (Nottarp-heim et al., 2015). Therefore, it is urgent address this issue.

Water infrastructures are the most capital intense utility service (AWWA, 2012). They have been in service for decades and the time to reinvest has arrived. However, customers are not aware of the elevated capital cost of the water services and, because they are hidden and the service is maintained, stakeholders are not aware of the criticality of their state (AWWA, 2012). Finally, the fact that tariffs seldom cover capital costs (Pulido-Velázquez et al., 2014) difficult the reinvestments in the network in order to maintain the quality of the service.

The water sector has an attitude, in general, reactive concerning the infrastructure maintenance and renovation. This behaviour entails severe consequences such as the fact that the 40% of the European water networks need to be rehabilitated (Frost & Sullivan, 2011) or the increasing renovation requirement of the USA water sector (ASCE, 2011). There is a need to shift to a proactive point of view by the application of Infrastructure Asset Management (IAM). Asset management could be described as the "coordinated activity of an organisation to realise value from assets" as defined by the ISO 55000 standard (ISO, 2014a, 2014b, 2014c). This is a broad concept that comprises all the assets an organization has. When the focus is in physical assets, then the term is referred as Infrastructure Asset Management (IAM) (Alegre & Coelho, 2012).

In order to revert from this critical situation, it is essential to find the proper communication tools. The Infrastructure Value Index (IVI) (Alegre, 2008) is an index that reflects the rehabilitation needs of a network. This index resumes in a single value the state of the infrastructure given a specific moment in time. It enables to simulate future scenarios that differ in the rehabilitation strategies implemented, being a powerful long-term planning tool (Alegre, Vitorino, & Coelho, 2014). In addition, it is a useful communication tool for stakeholders as enables an easy and intuitive interpretation (Alegre et al., 2014, Alegre, Vitorino, & Coelho, 2014). It can be calculated as follows:

$$IVI\ (t) = \frac{Infrastructure\ current\ value}{Infrastructure\ replacement\ cost} = \frac{\sum_{i=1}^{N}\left(rc_{i,t} \times {}^{rul_{i,t}}\!/_{eul_i}\right)}{\sum_{i=1}^{N} rc_{i,t}} \qquad (1)$$

Where:

t is the reference year when the index is calculated; N is the total number of assets considered; $rc_{i,t}$ is the cost of the asset i in the year t, ruli,t is the residual useful life of asset i in the year t. eul_i,t is the expected useful life of asset i.

The expected useful life of an asset is the average life for an asset since its moment of installation. This value depends on the asset's characteristics and working conditions. The residual useful life is the remaining life the asset is expected to have and it is calculated as the expected useful life minus the actual age of the asset in the moment of the calculation.

This tool provides a value between 0 and 1. An IVI of 0 means that the infrastructure has not any value left. A value of 1 belongs to a completely new infrastructure. Ideally, IVI values for a mature and well-maintained infrastructure should be between 0.4 and 0.6. Values over 0.6 belong to new infrastructures, old infrastructures in a growing phase; or over-invested infrastructures. Values lower than 0.4 belong to old infrastructures with urgent need of rehabilitation (Alegre & Covas 2010).

IVI is a relatively new tool, with roughly 10 years of existence. However, due to the aforementioned benefits, it has been adopted by a significant number of utilities, especially in Europe. For instance, it has been included in the performance indicators system of the Portuguese water and waste regulator, ERSAR, (ERSAR, 2018). In Spain, the Spanish Water Utilities Association (AEAS) has included this tool in their new IAM manual of best practices (AEAS, 2019).

However, IVI may not be enough, as a single metric, to assess the condition of the network. This work presents two supplementary tools in order to get a more complete overview of the network's state and improving the communication with stakeholders, without losing the simplicity of the IVI: The Infrastructure Degradation Index (IDI) and the Infrastructure Histogram (H_I).

2 Infrastructure Degradation Index (IDI)

The Infrastructure Degradation Index (IDI) represents the average remaining life of the network weighted by length (Cabrera Jr. et al., 2019). Remaining life is expressed as the expected working life minus the age of the pipe. It is expressed in years and provides a sense of urgency in network renovation. This index considers all pipes in the calculation, even those that already have expired their expected life and continue in service, regardless they expired 5 or 25 years ago. The IDI is calculated as follows:

$$Infrastructure\ Degradation\ Index\ (t) = \frac{\sum_{i=1}^{N} L_i \times rul_{i,t}}{\sum_{i=1}^{N} L_i} \qquad (2)$$

Where:

t is the reference year when the index is calculated; N is the total number of pipes considered; L_i is the length of the pipe i, $rul_{i,t}$ is the residual life of the pipe i in the year t. If a pipe has expired its life, $rul_{i,t}$ will be negative and will account for the amount of time the residual life of the pipe has been exceeded.

IDI values can be either positive or negative. The maximum value expected for IDI would be in the case a network is completely new. In this case, IDI would be the mean expected life of new materials, weighted by length. Values of a well-maintained average network would be between 25-30 years, which coincide with half of the expected remaining life of the materials installed.

If IDI is equal to zero, this means that the average weighted residual life of the network is zero. In this situation, although there can be pipes completely new, the weight of those with their expected working life expired is more important, making the balance zero. This situation is not recommended as implies that the renovation needs are urgent and cannot be postponed. In this situation, not renewing the network entails a serious risk in the quality of the service and its sustainability. Negative values of IDI would further increase this problem.

The life expectancy of a pipe depends of several factors such as: material, diameter, working condition, soil characteristics, etc. Therefore, the life expectancy depends on one hand on the pipe’s characteristics and on the other, on the utility’s context. It is recommended that life expectancy values are estimated from the utility’s historic registers as the IDI measure will be more accurate. Unfortunately, this data is seldom available. Thus, values can be obtained from literature (ISO 2016, Covas et al. 2018).

An interesting feature this tool has is that it considers in its calculation the length of those pipes with their expected life expired. However,

in IVI calculation an asset with its expected life expired has a cost of zero, regardless of the amount of time this asset has expired, as the tool is focused on the cost of the infrastructure. Therefore, IVI would be unable to detect if the 20% of the length expired 2 or 20 years ago. From a mathematical point of view, the IVI value would be the same. IDI is able to assess more faithfully those networks with assets that should be replaced long ago.

The consequence of this fact is that the sensibility of IDI is constant during time. However, IVI losses sensibility when approaching to lower values of the index (below 0.40) as the line becomes quasi asymptotic toward values of IVI=0. This fact occurs because in IVI calculation pipes with expired life account as zero in the numerator of the IVI equation. Therefore, the tendency of the IVI changes and its slope becomes close to an asymptotic line, decreasing slowly towards zero.

The IDI aims to complement the IVI as a public communication tool. IDI is focused on time and gives a sense of urgency on the renovation expressed in years. IVI is focused on value. The joint analysis of both indexes provides a more complete picture of the state of the infrastructure, while maintaining the simplicity of the tools.

3 The Infrastructure Histogram (H_I)

The Infrastructure Histogram (Hi) represents detailed information about the network state in a simple and intuitive way. This tool represents the remaining life of all pipes in the network classified by their percentage in length. Figure 1 displays an Infrastructure Histogram (Hi). The horizontal axis shows the remaining life of pipes. The bars represent the length of pipes in percentage classified by their expected life. Finally, the grey area highlights those pipes with their estimated life expired (negative values of remaining life). This chart allows for a quick assessment of the state of the network and the urgency of the renovation strategy.

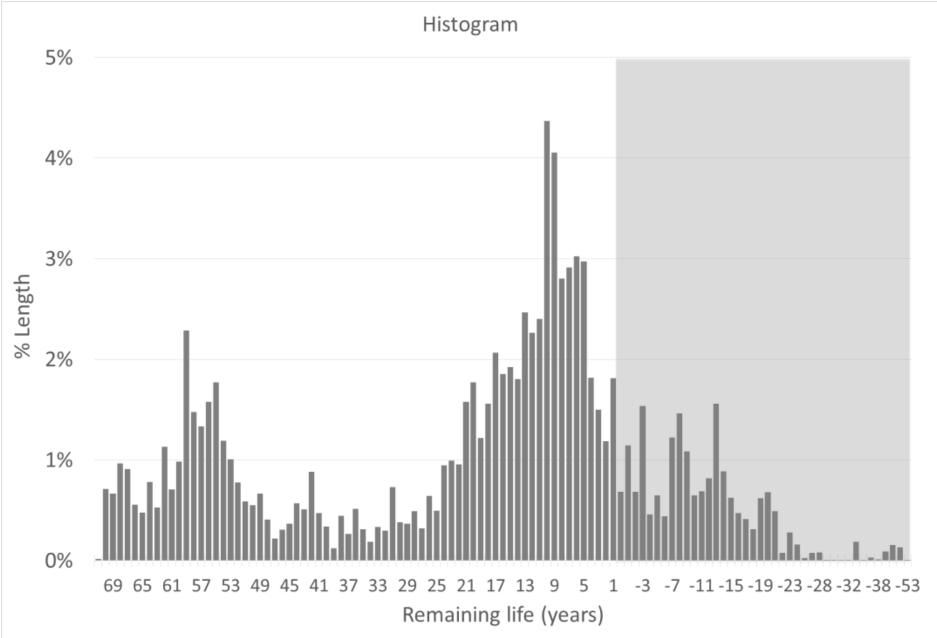

Figure 1. The Infrastructure Histogram (Hi)

The flatter the H_I is, the better the network is managed as it means that reinvestments will be constant over time. Peaks in the H_I could indicate high investment periods where significant part of the infrastructure was built. Therefore, large peaks are undesirable as they point out important punctual reinvestments.. Isolated peaks could also point to data lagoons, especially in old networks with significant uncertainty concerning the date pipes were laid out. In these cases, it was usual to estimate an age for them.

The H_I of the network displayed in Figure 1 discloses a network without large peaks of investment. This network has an IVI of 0.35 and an IDI of 19.70 years which indicate a network in low shape.

The IDI value indicates a network that is slightly lower than the values expected in a well-maintained network (25-30 years) and therefore needs some renovation. The IVI is, nevertheless, in the undesired area (lower than 0.40). In this case, the low IVI value might be misleading because of the materials that constitute the network. This network is mainly built with materials with long-life expectancy such as ductile iron. Since IVI is calculated as a cost-based ratio between the remaining life and the expected life, although the network still has almost 20 years left in average (IDI value), the IVI value is low (as the denominator is quite large due to the large life-expectancy of materials).

A close look to the chart explains why the network is in low shape. It has a part with its life already expired. However, it is not a large percentage. What decreases the value of both IVI and IDI indices is the important percentage of pipes that is about to expire.

As has been demonstrated, the IVI and IDI values provide a good starting point in the assessment of the network's state, and the H_I complements both tools, offering a more complete picture of it.

H_i can be further improved by showing groups of pipes with a selected diameter range or material, as shown in Figures 2 and 3. This option enables a deeper analysis where the criticality of the infrastructure can be further analysed. For instance, it is immediate to locate the situation of large diameters or the percentage of obsolete materials such as asbestos cement, being both, in general, expensive to replace.

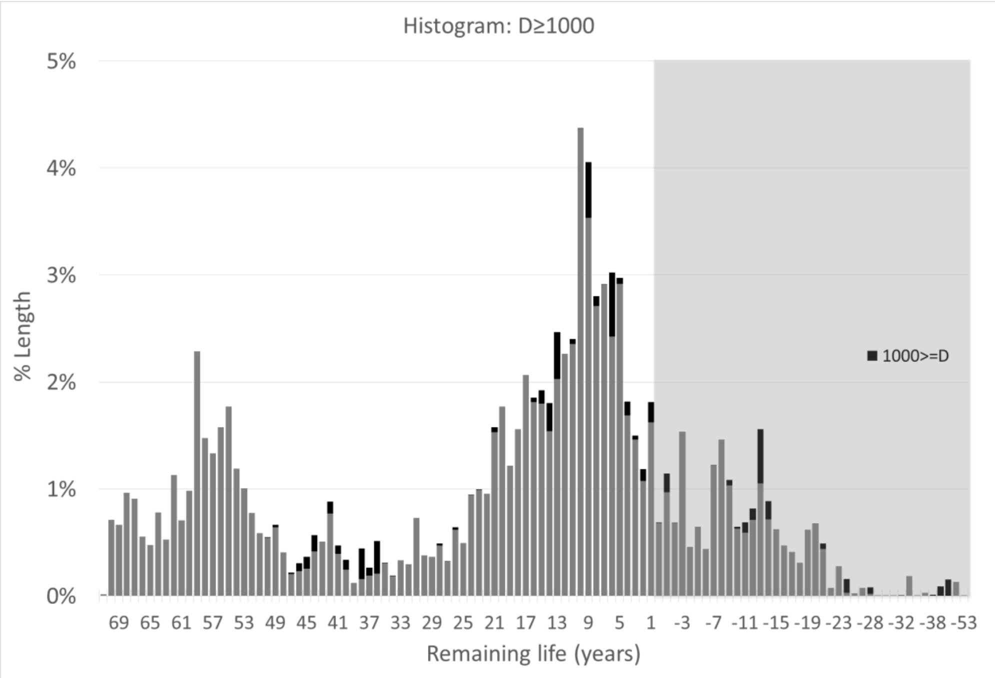

Figure 2. The infrastructure histogram displaying the length of pipes with a diameter bigger than 1000mm;

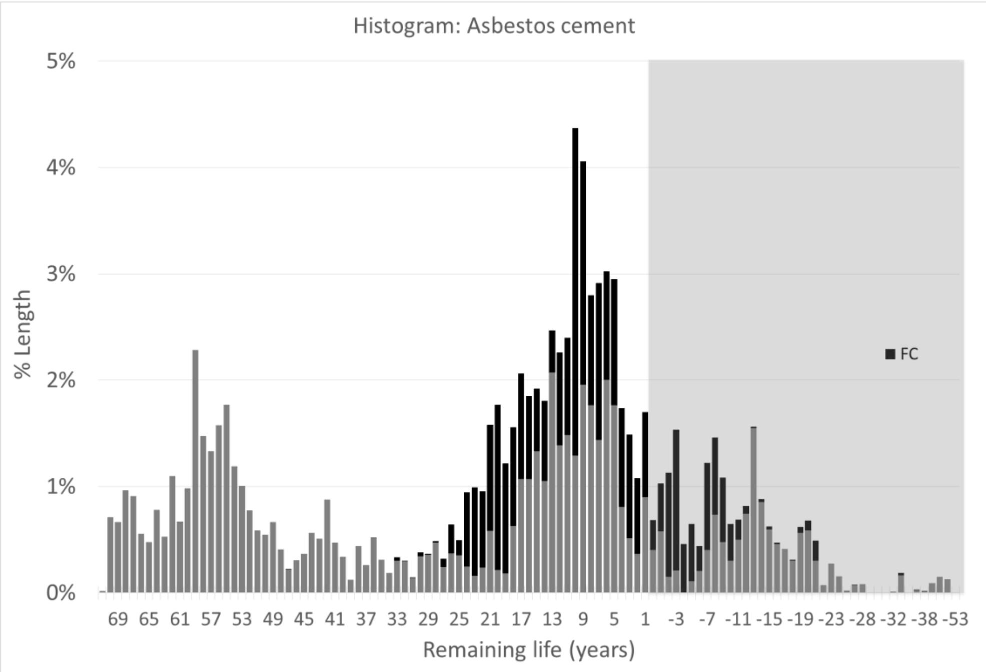

Figure 3. The infrastructure histogram displaying the length of pipes made from asbestos cement

The detailed histograms are useful tools for stakeholders' communication as they allow for an easy interpretation and analysis of the specific network state and its investment needs. Besides, they enable an easily investigation of the different factors (type of material, range of diameters, etc.) that influence in the renovation strategy.

4 Conclusions

This work analyses the use of three tools to improve the communication with stakeholders concerning the state of the network and its rehabilitation needs.

The IVI is focused in the investment needs whereas the IDI emphasises the state of the infrastructure and the urgency of the intervention. The combination of these two indices allows a deeper comprehension of the network state.

The H_I provides a further in-depth analysis and increases the information given by the two previous measures. It allows to analyse the impact on the previous renovation strategies and forecast the future needs in renovation. This tool classifies the network by its remaining life and details the length of pipes of a specific material or diameter, characteristics with a direct impact in the renovation strategies and their cost.

The potential use of these three tools is broad. They could be used, for instance, in benchmarking projects to assess the sustainability of the water networks and promote their improvement and excellence. Other use could be as regulatory tools to supervise the sustainability of water infrastructures. In fact, the Portuguese Water and Waste Regulator (ERSAR) is currently using the IVI in its sunshine regulation initiative (ERSAR, 2018).

IVI, IDI and H_I allow stakeholders to understand, in a simple manner, the magnitude of the problem. Therefore, they will be aware of the need for a long-term plan of infrastructure asset management. The sustainability of water infrastructures will be only reached if stakeholders recognize the importance of investing in water infrastructures, following a strategic asset management approach. It is important to bear in mind that these tools are for communication and do not intend to substitute detailed analysis of performance, risk and costs.

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