5.1 PRIORITIZING WATER DISTRIBUTION AND SEWER NETWORK MAINTENANCE ACTIVITIES

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ABSTRACT

Asset management in water supply and sewerage infrastructures seeks correct planning and prioritization of the maintenance activities on their network elements. To determine the replacement priority for each network asset, an original priority model is utilized. It is based on a risk index that integrates both the probability and consequences of failure. Besides, when designing and performing work programs, water companies generally abide by the street's topography and other urban elements, such as complete streets or street sections. This work considers street sections between the two nearest intersections as the operational unit.

INTRODUCTION

The long-term sustainability of hydraulic infrastructures is based on a correct and effective maintenance strategy. Establishing the right time to replace a water distribution and sewer network element is essential to properly manage the infrastructure. In this regard, an adequate definition of the replacement needs of each network element is key to the right infrastructure management. Also, this process depends on the reliable condition and criticality information of every asset, for which an integrated, complete, and up-to-date data system is fundamental.

Moreover, this replacement priority has been usually computed for individual water and sewer pipe objects. Nonetheless, when designing intervention programs, the use of this hydraulic element constitutes an ideal and abstract approach. As a matter of fact, water utilities do not consider pipelines to plan interventions but perform work programs according to the street's topography. The inclusion of geographical and urban criteria into the planning process helps minimize the affection on the traffic flow and the neighborhood, as well as fosters coordination with other public infrastructure projects.

STATE OF THE ART

The reviewed literature in this field addresses methodologies to develop and implement different infrastructure asset management strategies. More specifically, the reviewed works target the two following aspects: the utilization of a priority model to determine the replacement urgency of the network assets and the consideration of infrastructure 'units' that represent the smallest replacement element and abide by the street's topography or urban factors.

For example, Elsawah et al. (2016) define corridors as the street section between the two nearest intersections. When intervening a corridor, all the water, sewerage, and road infrastructure assets within that segment are simultaneously replaced. Also, the authors developed an overall risk index for the whole corridor segment, integrating the replacement needs of the three coexisting infrastructures. This methodology is applied to a borough of the City of Montreal (Canada).

A similar example can be found in Tscheikner-Gratl et al. (2016), where entire street sections are ranked for rehabilitation. These elements correspond to segments between valves or manholes and include the road, water supply, and sewerage infrastructures. Also, to avoid very long sections, a certain length threshold is set. Again, an overall priority index for the whole section is calculated. A case study of an Austrian city with 130,000 inhabitants is presented.

Lastly, Shahata and Zayed (2016) developed another risk assessment model for road, water distribution, and sewer networks. This model was implemented in the City of Guelph (Canada).

From the reviewed literature, it can be drawn that the utilization of pipe objects as operational units is not practical to develop water replacement strategies. Thus, the definition of a workable intervention unit complying with urban elements, such as street sections, is essential.

Then, the replacement needs for a given corridor or street segment have to be established. The reviewed works propose an overall criticality index that is computed on the basis of the previous calculation of an index for each infrastructure separately. This approach can lead to some difficulties when setting the relative importance of each infrastructure. The utilization of an index that addresses a section as an integrated and indivisible unit, whose replacement priority does not require the definition of the relative importance between the diverse infrastructures is still missing in the literature. Our contribution to the literature in this regard is described in the following section.

CONTRIBUTION

Our main contribution has been to establish the replacement needs for every network operational unit and rank them for intervention. In the first place, the operational unit had to be defined. Thus, we proposed complete streets or street sections between intersections to be the smallest replacement element.

Next, an original procedure to determine the replacement needs for network assets and to rank them for intervention was required. To this end, a risk index (RI) was developed (Muñuzuri et al., 2020). This index is based on the probability and consequences of failure of a given pipe.

First, the likelihood of failure was obtained through AI technologies. More specifically, the Machine Learning techniques *logistic regression* and *support vector machine* were utilized. They serve as a predictive system, since they produce an output variable that can be used as a failure probability. Eight variables were considered to explain pipe failures: material, diameter, age, length, number of connections, network type, pressure fluctuation, and previous record of failures. The results obtained show that the number of unexpected failures could be significantly reduced. In fact, with either of both techniques, and according to the historical data from the city of Seville (where this methodology was applied), around 30% of failures could have been avoided by replacing only 3% of the network's pipes (Robles-Velasco et al., 2020).

On the other hand, the factors measuring the consequences of failure are the water leakage flow and demand for supply pipes, the maximum evacuation flow for sewer pipes, and the pipe criticality.

The RI can be easily assigned to every pipe object, providing a replacement priority for all of them. However, pipe objects do not represent the operational unit. The RI has to be computed at a "street section" level. Thus, the probability and consequences of failure of the underlying pipes have to be transferred to their corresponding street sections. To this aim, the following procedure was implemented.

First of all, it has to be noted that street sections and infrastructure objects are linked by geographical superposition: every network pipe is related to the section it runs through. So, the failure probability of a street section is computed as the average probability of failure of every pipe included in that section. This average value is weighted by the inner pipe's length. Since pipes may belong to more than one street section, only the length of the pipe inside the given section is considered. Afterward, the leakage flow, demand, and maximum evacuation flow for each section correspond to the maximum value of all their constituting pipes. Also, a section is considered relevant or critical when at least one of their inner pipes is, indeed, critical. Once every section is characterized by these five factors, its RI and intervention priority are obtained.

Finally, this methodology was fully integrated into an easy-to-use software application. It automatically processes the input data, such as the network's condition and criticality, and computes a RI value to every street section. This user-friendly tool also allows setting the planning horizon and the long-term objective and generates a prioritized list of street sections to be intervened. The development of this software was carried out by the aggregated partner GUADALTEL S.A.

The here presented methodology was applied to the water distribution and sewer networks of Seville (Spain), whose complete infrastructure system has a total length of approximately 7,000 km, combining both the supply and sewer networks.

This approach can help establish a replacement priority for every network asset and rank them for intervention, which is the basis to guarantee the long-term sustainability of the infrastructure. Besides, since this approach is based on a risk model, combining both probability and consequences of failure, it aids to target those assets whose preventive replacement could avoid much higher future economic and social costs.

Furthermore, this approach considers street sections as the smallest replacement units, which may be advantageous for various reasons. First, given that an intervention generally affects single streets, the impact on pedestrians or the traffic flow is reduced. Also, it benefits the possible coordination of the hydraulic network maintenance tasks with other infrastructures coexisting projects, which can help avoid duplicated road closures and the possible undermining of the company image.

Therefore, thanks to the integrated risk-based priority model and the utilization of workable and functional operational units, this methodology can be seen as a useful and practical decision support system to prioritize maintenance tasks and efficiently invest to guarantee the long-term sustainability of the infrastructure.

ACKNOWLEDGMENTS

This project has been carried out in collaboration with GUADALTEL, S.A. and with the support of the following researchers: Elena Barbadilla Martín, Alejandro Escudero Santana, María Rodríguez Palero, and Alicia Robles Velasco y Cristóbal Ramos Salgado.

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