UTILIZING A DECISION TREE FOR SCENARIO-PRIORITY WDN RESTORATION STRATEGY

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1. INTRODUCTION

Water distribution networks (WDN) are extremely vulnerable to natural hazards, particularly seismic events. Losses and damages from these events are inevitable. These can lead to water disruptions which can affect the functions of a community. Numerous factors affect restoration strategy decisions, especially which to prioritize first. Here, we propose using the results from a decision tree (DT) to determine a restoration strategy depending on which parameter should be prioritized, and how to optimize the loss. Current studies use DTs as a predictive tool to obtain the optimized output depending on the input variables. In this paper, cost, labor, time, and demand are the factors to consider when prioritizing WDN restoration.

2. THEORY AND METHODOLOGY

2.1 Probabilistic Seismic Hazard Analysis

Earthquake hazards were obtained from a previous paper (Jarder et al, 2020). Historical seismic data of the area were the parameters for the analysis. Probabilistic Seismic Hazard Analysis (PSHA) was used to obtain the peak ground velocity, V, throughout the city (Kramer, 1996).

2.1 Damage Estimation

Pipeline seismic damages can be estimated using the Isoyama et al (2000) method of estimating damages of pipelines per grid. Eq. 1 is the standard rate of damage.

$$R(V) = 3.11 \times 10^{-3} \times (V - 15)^{1.3} \tag{1}$$

$$n_i^j = C_p \times C_d \times C_g \times C_l \times R(V) \tag{2}$$

The variables C_p, C_d, C_g, and C_l are the correction coefficients for pipe materials, pipe diameter, ground condition, and liquefaction effect, respectively. Correction Coefficients are shown in Table 1.

Table 1. Correction Coefficients

Pipe Material	C_p	**Pipe Diameter**	C_d	**Surface ground**	C_g	**Hazard Level**	C_l
Asbestos Cement (ACP)	3.0	−Φ75	1.6	Modified mountainous region	1.1	No liquefaction	1.0
Cast Iron (CIP)	1.1	Φ100 − Φ150	1.0	Modified hilly areas	1.5	Medium Liquefaction	2.0
Ductile Cast Iron (DCIP)	0.3	Φ200 − Φ450	0.8	Valley, old water routes	3.2	Significant Liquefaction	2.4
Steel (SP)	0.5	Φ600 −	0.5	Alluvial plain	1.0		

$$r_i^j = n_i^j \times L_i^j \tag{3}$$

The Average Damage Spots per Mesh, can be obtained using Eq 3. Where, r_i^j is the Average Damage Spots per mesh *i* in category *j*; and, L_i^j is the length of pipes *i* in category *j*.

2.3 Decision Tree

This study proposes the use of decision trees as a tool to determine restoration strategy depending on the factors decision-makers want to prioritize. Here, Classification and Regression Trees Analysis (CART) is used to determine which factors contribute the most to cost, damage, or loss demand in the system. Using CART, it can show which factor contributes more to the output. (Hajjej et al, 2022)

3. RESULTS AND DISCUSSIONS

The concept of CART was used to determine which pipes in certain areas should be prioritized in restoration. A sample for prioritizing areas with a higher volume of damaged pipes is shown in Figure 1. It shows which parameters or variables to focus on that could lead to higher damage. Since the system has numerous different variables to consider, CART can help organize and determine which parameters, such as diameter size, material, or vulnerability, are in need of intervention to minimize losses.

Keywords: Restoration Strategy, Pipeline Damages, Decision Trees
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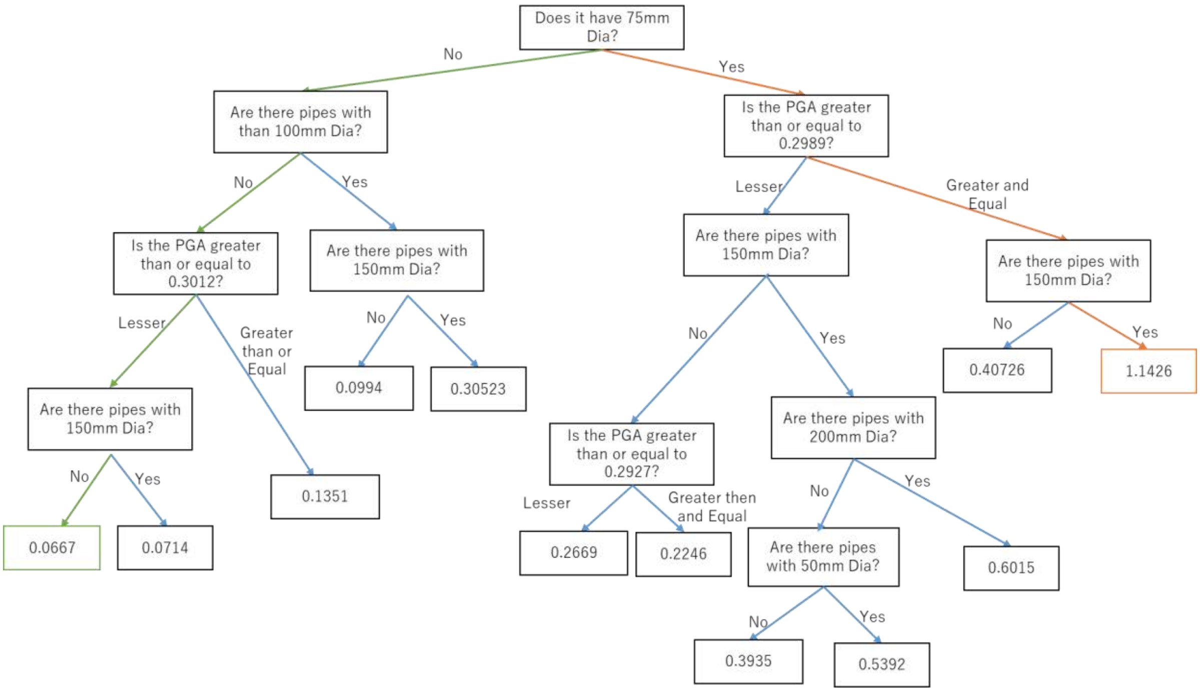

Fig 1. Restoration Strategy Prioritizing the number of damages in the area

Based on the produced decision tree which prioritized the number of damaged pipes (Fig.1), areas with a combination of existing 75mm and 150mm diameter pipes exposed to 0.2989g PGA or higher have the highest number of broken pipes. The DT also shows the combination of parameters that could produce the least damage.

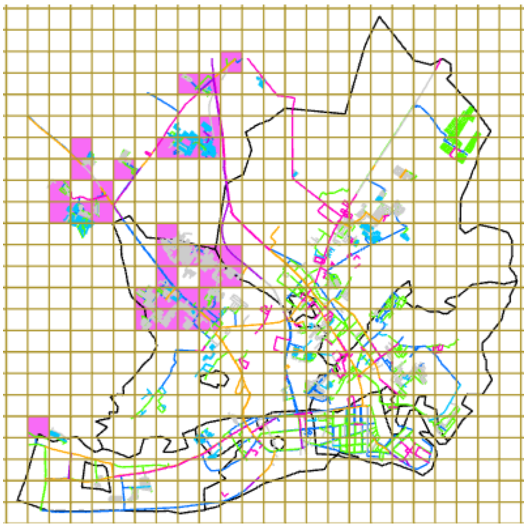
Figure 2. Areas for Restoration Priority Based on damages

Figure 2 shows areas to prioritize for restoration based on the conditions set by the decision tree. Areas for restoration prioritization are highlighted in Fig 2.

4. CONCLUSION

The decision tree can assist and help decision-makers create a restoration strategy. Results will vary if the priority will change. Future studies include analyzing restoration strategies prioritizing cost, vulnerability, number of affected people, and loss minimization. An optimum restoration

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