A Cost-Benefit Analysis of Four Leakage Reduction Methods in Peja, Kosovo: A Replicated Study

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INTRODUCTION

Non-revenue water, also known as water pumped but not accounted for, is an unavoidable component of water distribution systems and a concern in many nations throughout the world. In Kosovo, more than half of the water pumped is not invoiced, costing the nation more than €30 million in financial losses annually. There are seven water utilities in Kosovo, which in 2018 supplied 97% of Kosovo residents with water. This paper focuses on physical water losses in one utility, Hidrodrini. Despite the physical losses, Hidrodrini has done little to control them, owing to a lack of funds, a lack of understanding about the costs of non-revenue water, and a lack of support from other institutions. As a result, this thesis presents a cost-benefit analysis of four different approaches for reducing physical water leakages. I analyse district metering, increase in leak-detection personnel, pressure reduction, and pipe replacements, all strategies recommended by Kosovo's Water Services Regulatory Authority.

- **District Metering.** By blocking valves or connections, DMAs divide the water network system into sub-regions, enabling more accurate monitoring of water input and consumption in a region.
- **Increased Leak-Detection Personnel.** The personnel who would employ traditional leak-detection methods, such as manual listening sticks and acoustic correlators.
- **Pressure Reduction.** High pressure affects pipe leaks and water utilization. Installing Pressure Reducing Valves (PRVs) in existing DMA zones would be one method of reducing leaks.
- **Pipe Replacements.** Because most leaks occur in water mains, one method of preventing them is to replace high-leakage pipes with newer ones.

METHODS

I first calculated the leakage reduction potential for the Hidrodrini utility, which presents how much a utility can truly reduce its leakages. To accomplish that, I employed a formula called the Infrastructure Leakage Index (ILI). This formula measures the ratio between current annual real losses (CARL), and unavoidable annual real losses (UARL). If the ratio is bigger than 1, then there is potential for reducing leakages.

$$ILI = \frac{CARL}{UARL}$$

While there was data available for CARL, I measured UARL with a formula originally published in 1999 and widely used thereafter. Length of mains, number of service connections, the average length of service connections, and average water pressure were used to determine the UARL.

$$UARL\left(\frac{m^3}{year}\right) = ((6.67 \times L_m) + (0.256 \times N_c) + (9.13 \times L_t)) \times P$$

Where L_m = length of mains (km); N_c = number of service connections; L_t = total length of service connections (km); and P = average water pressure (m).

Secondly, I calculated the net present value (NPV) for each leakage reduction strategy. The NPV is a financial measure that attempts to quantify the overall value of a potential investment. To calculate the NPV, I had to determine all the relevant costs and benefits related to the strategies, a suitable time frame for the analysis of the project, and a discount rate.

$$NPV_i = \sum_{t=1}^{T} \frac{1}{(1+r)^t} (B_{it} - C_{it})$$

Where i represents the particular leakage reduction strategy, t represents time, T represents the terminal period of analysis, r represents the discount rate, B represents the benefits, and C the costs of the strategy.

$$C_{District\ metering,t} = (C_{PDM}+C_{BDM}+C_{IDM}+C_{MDM}) \times Nr_{DM}$$
$$C_{Increased\ leak\ detection\ personnel,t} = ((C_S+C_T) \times Nr_{NE}) + C_{FL}$$
$$C_{pressure\ reduction,t} = ((C_{PPRV}+C_{BPRV}+C_{IPRV}+C_{MPRV}) \times Nr_{PRV}) + C_{BWL}$$
$$C_{pipe\ replacement,t} = C_{RS} + C_{RD} + C_{RDIS}$$

$$B_{District\ metering,t} = (B_{WP} \times V_W) + (N_{PPL} \times B_{PR}) + B_K$$
$$B_{Increased\ leak\ detection\ personnel,t} = (B_{WP} \times V_W) + (N_{PPL} \times B_{PR}) + B_{RU}$$
$$B_{Pressure\ reduction,t} = (B_{WP} \times V_W) + B_{APB}$$
$$B_{Pipe\ replacement,t} = (B_{WP} \times V_W) + (N_{PPL} \times B_{LR}) + B_M$$

RESULTS

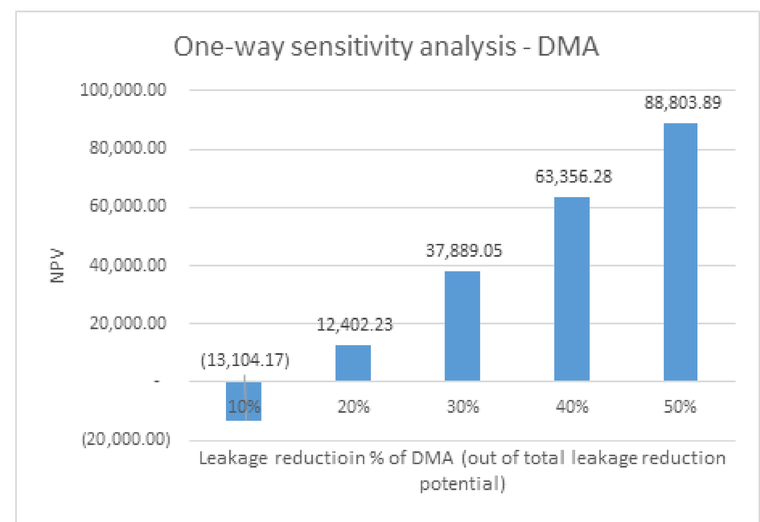
The ILI for Hidrodrini was equal to 1.9, indicating that the utility has the potential to reduce 1,642,055 m3 of leakages.

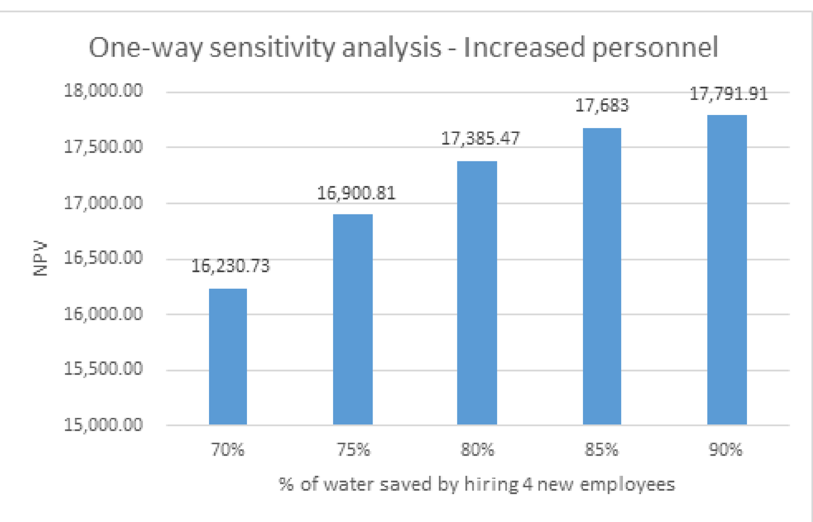
A calculation of the costs and benefits showed that for Hidrodrini, installing 8 new district metering areas and increasing leak-detection personnel by 2 teams of 2 employees each are the most cost-effective strategies to reduce leakages. As expected, pipe replacements showed to be the least cost-effective method of reducing leakages, and pressure reductions came close with an NPV value of -126,202.

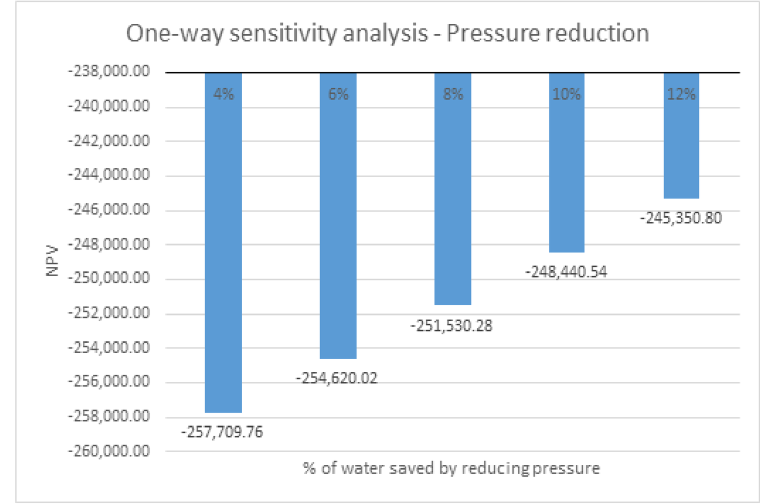
Table 1: Benefit-Cost Analysis Results.

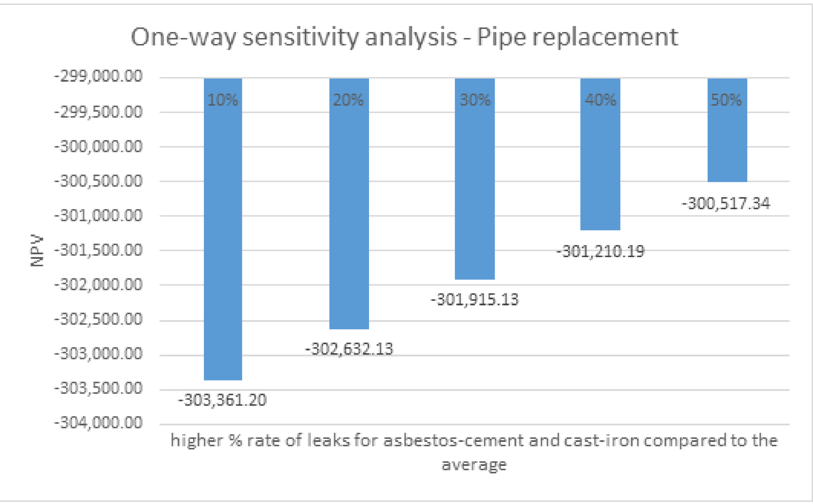
	DMA	Personnel	PRV	Replacements
Total Costs (€)	180,122	107,147	151,356	351,853
Total Benefits (€)	218,011	124,532	25,154	49,938
NPV	37,889	17,385	-126,202	-301,915
Benefit-cost ratio	1.21	1.16	0.17	0.14

The baseline discount rate for NPV calculations was set to 3%. A sensitivity analysis was performed to show if a different discount rate would give different results.









DISCUSSION

This cost-benefit analysis was conducted considering only costs and benefits incurred by the utility. Due to the scope of the study, effects on society and the environment were not considered. In an ideal situation, the societal benefit of having fewer water interruptions, the environmental benefits of decreased energy and chemical use, and the environmental cost of greenhouse gas emissions during pipe replacements would also be included.

Furthermore, this paper relied on several assumptions when calculating costs and benefits, many of which came from countries of the Global North. Although all the assumptions were discussed with the Hidrodrini utility and considered reasonable, a more robust study would have actual data from the study area. Another alternative would be to use a Monte-Carlo simulation for sensitivity analysis, not the one-way approach. That would show how sensitive conclusions are to multiple assumptions without having to analyse one assumption at a time.

Some benefits were hard to quantify, such as the knowledge gained by installing and managing DMAs. Although I computed a €500/year knowledge benefit for each additional DMA, I believe that this figure is greater because DMAs enable the detection of illegal connections and metering faults, which account for 75% of water losses in this utility. The real value of this method is yet to be determined as Hidrodrini continues to manage the newly installed 23 DMAs.

CONCLUSIONS

The purpose of this thesis was to find the most cost-effective leakage reduction strategies in the Hidrodrini utility in Kosovo. Cost-benefit analyses of installing and operating DMAs, increasing leak-detection personnel, installing and maintaining PRVs, and replacing aging pipelines showed that the most cost-effective strategy for Hidrodrini is installing and operating 8 additional DMAs.

Increasing leak-detection personnel also had a positive NPV, whereas pipe replacements and PRVs were the least cost-effective methods with negative NPVs. Ideally, Hidrodrini could employ both DMAs and increased leak-detection personnel to reduce leakages to their desired level. However, lack of funding, which is prominent across water utilities in Kosovo, may limit Hidrodrini to only one strategy.

Future research could focus on determining the impact of a pressure decrease on saving water in Kosovo, the number of leaks that an additional worker can identify, the leakage rate of each material, and the advantages of DMA beyond physical losses.

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