# Incentive to reduce water loss for urban water utilities: A cost minimization approach

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**Abstract**

In this paper, we focus on the issue of water loss caused by leakage from obsolete water network pipes. Investment on water infrastrucutre have been experiencing an all-time low in the U.S. and many other developed OECD countries. Regardless the ownership type of the utility, costly investments are naturally left out. We develop in this theoretical paper, a static cost minimization problem of a water utility that is faced with a constraint to reduce water loss. As predicted, by imposing a limitation on water loss, pipe replacement is necessary. Moreover, even under a static model, it is indeed cost efficient for the water utility to replace pipes and reduce water loss.

## 1 Context and Motivation

Water infrastrucutre around the world is facing an age of replacement. For example in France, the renewal needs amount to 1.5 billion euros per year[Salvetti, 2013]. The immediate consequence of obsolete water infrastructure is water leakage, which accounts for the majority of water lost in developed countries. Water loss is not only a matter of environmental degradation, it exacerbates the concern on future water sustainability in urban areas. As potable water is heavily underpriced, there is a vast degree of public negligence towards the value of water. Hence, in light of political popularity, governments engage less in costly actions that might lead to increased water prices in the short run with benefits only revealed in the very long run. Therefore, naturally investments will be "biased towards shorter-term gains" [Spiller and Savedoff, 1999]. In the U.S. "for decades, these systems - some built around the time of the Civil War - have been ignored by politicians and residents accustomed to paying almost nothing for water delivery" [Duhigg, 2010].

Moreover, water loss leads to economic, financial and health concerns. Economically speaking, water that is lost through poorly maintained pipes are extractions of water resources that is directly put to waste, exploiting precious water resources. In financial terms, water loss is the amount of water that is not serviced to the customer; hence a loss of potential revenue. Moreover, "leaky pipes are known for increasing pumping energy [...] and can increase the risk of compromised water quality by allowing intrusion of polluted groundwater" [Colombo and Karney, 2002]. The increase in cost by increasing water input into the service network is the "marginal cost associated with drilling, consisting mostly of energy and treatment cost" [Garcia and Thomas, 2001]. This wasted energy has further consequences on the environment associated with the emission of CO2 and greenhouse gases due to energy production and consumption.

Since the introduction of the European Water Framework Directive, all member states are urged to achive several targets such as full cost recovery in the very near future. Such a directive incentivises firms to engage in pipe replacement investments. The issue is that such an obligation will appear as cost inefficient to firms due to increased costs today with benefits that would appear in the long run. We argue in this paper that in terms of cost efficiency, pipe replacement should be initiated as soon as possible.

A study has shown the positive benefits of reducing water loss on the cost of the firms[Martins et al., 2012]. According to their empirical results, the marginal cost of producing water loss is greater than the marginal cost of producing water supplied. Water loss has come up in several empirical studies on the performance of water utilities; however, with little attention. The literature focuses mainly on the effects of ownership type and cost structures.

Our paper takes the first step to formalizing the significance of water loss and the need for pipe replacement in a theoretical model. We set up a static cost minimization problem with a constraint on water loss. The results show that even under a static model, the quantity of pipe replacement is positive and indeed cost efficient to the firm. We distinguish two optimal levels of investment in pipe replacement according to the endogeneity of the quantity demanded.

# 2 Methodology

We set up a static cost minimization problem where the firm minimizes the costs of supplying water to the urban population. The firm is subject to a production constraint which is defined by the difference of water input minus the amount of water lost through leakage. The amount of water loss is defined by a function that is denoted by $\alpha\left(\overline{K}\right)$ which depends on the quantity of replaced pipes. The greater the investment in pipe replacement the closer $\alpha\left(\overline{K}\right)$ is to zero.

Our first model is faced with an exogenous quantity demanded. In other words, the amount of investment does not reflect on the price of water charged to customers and hence does not alter the quantity demanded. The second model is set up with an endogenous quantity demanded. In other words, the cost of investment is reflected on the price of water charged to customers and hence according to the elasticity of demand, quantity demanded can change.

This endogenity allows the quantity demanded to decrease as investment in pipe replacement increases. This second model tries to represent the notion of "full cost recovery".

The optimal quantities of investment are not clearly comparable at this stage as their difference depends on the exogenous parameters; the cost of water input, the cost of invesment (new capital), the exogenous quantity demanded and the elasticites. By calibrating these parameters, we could conclude whether investment in pipe replaement is greater under exogenous quantity demanded or endogenous quantity demanded. This result is crucial for evaluating the effect of "full cost recovery" on the investment decision of the firm.

# 3 Results

According to the comparative statics of both models, when the cost of water input reflects the scarcity of water (its true value), investment in pipe replacement is favored. In the case where demand increases, instead of an increase in the water input, investment in pipe replacement is favored to reduce water loss. Investment in pipe replacement only declines when facing rising investment costs. This has a policy implication; instead of subsidizing the water tariff charged by customers, investment costs should be lightened for the firms to be incentivized to invest in pipe replacement.

Moreover, this model shows that the marginal cost of production declines as water loss diminishes; hence even under a static cost minimization, it is cost efficient for the firm to invest in pipe replacement for future gains in the cost of production.

# 4 Conclusion

Our paper will add a new dimension to the issue of water loss in the literature of integrated urban planning. Water loss is not just an enivronmental concern; it leads to all aspects of economic, financial and social consequences. In the exisitng literature, water loss issues appear only in empirical studies. It has never been formulated in a theortical economic model. The results from our model have potential implications on policy implementation for water utility management. Reducing water loss does not only have positive externalities to the environment and public health, it is indeed cost efficient to the water utilities as long as their cost of investment does not discourage their incentives to invest.

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