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REVIEW PAPER

Economic Analysis and Economic Leakage Level in Water Loss Management and Paths for Future Evaluation: A Review

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ABSTRACT: Operational and investment costs increase due to aging of the network, increasing the failure rate, leakage and the water demand, new investments and energy consumption. Several methods and tools with different initial investment and operating costs are proposed for reducing water losses in the related literature. The aim of this study is to make detailed evaluations within the framework of economic components for effective and sustainable water loss management and provide a reference for further studies. The most important advantage is that there has not been a detailed assessment and discussion in this context within the framework of economic analysis and the economic leakage level. The methods and tools for reducing the water losses such as district metered areas, passive leakage control, active leakage control, pressure management, pipe management and network renewal methods, were evaluated economically and discussed. The most important issues in water loss management are the definition of the economic leakage level and the cost components that are the maintenance and break repair, methods applied to detect and control the leaks and automation systems for monitoring, control and data transfer. Moreover, the priority, suitability, applicability and economic impact of the methods should be considered to decide the methods for more efficient use of resources.

Keywords: Economic Analysis, Economic Level of Leakage, Water Distribution System, Water Loss.

1. Introduction

In urban water management, the increasing in failures and leaks, aging of the network, decreasing in useful life, excessive water demand, and insufficient capacity of the existing system increase operational and maintenance costs. In addition, the initial installation and operational and maintenance costs of the methods and tools used for reducing and monitoring the water losses in many utilities also reach significant levels. For this reason, it is crucial to carry out economic analysis and

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elaborate the benefits and cost assessments of the Water Loss Management (WLM) components in terms of effective and sustainable management. In the literature, the cost and benefits and economic effects of the water loss management methods and tools are analyzed and evaluated (Fanner and Lambert, 2009; Lambert et al., 1999). These studies have focused on planning and applying the Pressure Management (PM) (Gomes et al., 2011; Creaco and Walski, 2017), defining the District Metered Areas (DMA) (Ferrari and Savic, 2015; Campbell et al., 2016; di Nardo et al., 2017), planning the Active Leakage Control (ALC) (Lambert et al., 1999; Berardi et al., 2016; Cabral et al., 2019; Lipiwattanakarn et al., 2019), reduction of failure rate, passive leakage control, asset management (Deidda et al., 2014; Farley and Liemberger, 2005; Loganathan et al., 2002; Suribabu and Neelakantan, 2012; Tricarico et al., 2006). Barandouzi and Kerachian (2016) proposed a methodology based on Probabilistic Support Vector Machines (PSVMs) for identifying the contamination source location in WDSs. The efficiency and versatility of the proposed methodology were examined using the available data and information from water distribution network of the City of Arak in the western part of Iran. In general, specific targets are defined for the Non-Revenue Water (NRW) rate and significant investments are made to achieve these targets. However, in many cases, these investments are not economic since they are not supported by Cost-Benefit Analysis (CBA). The main reason can be explained as; water losses are dependent on many factors that are the physical, operational, hydraulic and environmental variables, and the intervention and prevention method is not chosen considering the current conditions of each system. Therefore, the current condition of the system should be considered in the management of the water losses and the Economic Leakage Level (ELL) should be defined for selecting the most appropriate of prevention strategy (Haider et al., 2019; Lambert and Lalonde, 2005; Molinos-Senante et al., 2016). Deidda et al. (2014) define the ELL is that a balance between the costs of water saved and the marginal costs of an additional reduction from leakage. This idea was used for a reference area in order to intervene the system in large WDSs. During the development of the most appropriate renewal strategy to reduce leakage levels in WDSs, a balance should be provided between the ELL, the marginal benefits of saved water and operating/investment costs.

The aim of this study is to make detailed evaluations within the framework of economic components for effective, efficient and sustainable urban water management and prevention activities applied in managing the water losses. The most important advantage of this study is economic assessment of water loss prevention methods which are evaluated and discussed under the ELL concept. For this purpose, the water loss management methods and tools such as ELL calculation, the district metered areas, passive leakage control and network maintenance, ALC, PM, asset management and network renewal, automation systems for monitoring and database, are evaluated economically and discussed by considering the current literature.

2. Economic Components in Water Loss Management

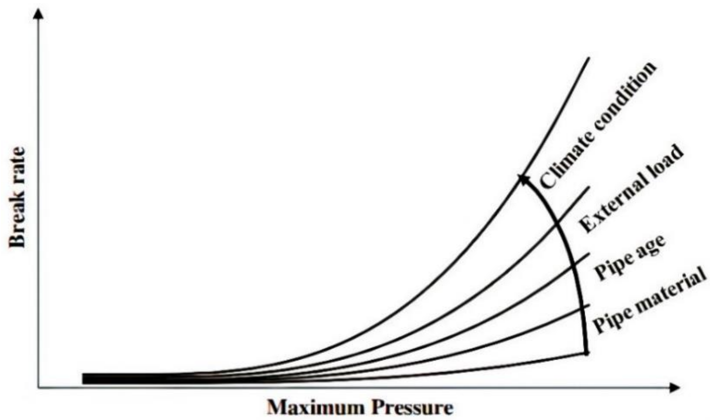
Leakage occurs in water transmission and distribution systems due to physical, environmental, operational and hydraulic factors and indirectly causes significant economic impacts for the utilities. Apparent losses including the volume of unbilled water, constitute the direct loss of revenue for the utilities. The economic impacts of NRW are (Lambert and Lalonde, 2005; May, 1994): i) leakage cost; ii) maintenance and repair costs of failures; iii) energy cost; iv) new resource cost' and v) apparent losses cost. Several methods and tools that are establishment and monitoring of water balance, DMA definition, customer management, PM, Minimum Night Flow (MNF) analysis, factor analysis for failures, asset management, Geographical Information System (GIS), Supervisory Control and Data Acquisition (SCADA), customer management, automation systems, are applied in WLM.

The following issues should be considered in the selection of methods order to use technical, economic and available resources more efficiently; i) priority, suitability, applicability, economic impact of the selected methods; ii) current status of the personnel, economic, technical in the utility; iii) device, automation, data transfer, operational and maintenance cost; and iv) the maintenance costs and expected benefits from the selected methods. Therefore, in this study, detailed analysis and evaluations were made within the framework of economic components for the methods and tools applied in WLM.

2.1. Passive Leakage Control

The pipe breaks density in the system increases due to the decrease in the resistance of pipes against environmental, hydraulic and operational factors (Farley et al., 2008). The increasing in the break rate leads to increasing in the cost of operating, repairing and maintenance. Moreover, the frequency of water interruptions for repairing the pipes increases and customer satisfaction level decreases and the operating conditions of the system deteriorate. Several factors such as fluctuations and variations in operating pressure, pipe age, material fatigue and environmental factors have effect on failure rate (Islam and Babel, 2013). Reducing the failure repairing time and performing repair and maintenance activities in a shorter time and reducing personnel expenses, failure management system and establishing the appropriate teams make significant contributions in order to reduce the leakage costs. Loganathan et al. (2002) defined failure threshold rate for operating the system and the failure management in WDS by considering the costs of the maintenance, repair and renovation and inflation rate.

A significant relationship between pipe diameter and failure threshold value based on cost analysis was defined. Farley and Liemberger (2005) reported that the existing systems in developing countries are weaker in terms of technological and current condition than developed countries and the water loss reduction methods should be developed specifically for the systems. Wang et al. (2009) used the annual break rate as the main criterion for the determination of the current status of the network and proposed that the administrations should evaluate the maintenance, renewal or replacement activities and determine the priority by evaluating the status of the existing pipes with the limited budgets. Tricarico et al. (2006) conducted a cost-based study highlighting hydraulic reliability for the rehabilitation of WDSs where the frequency of failure is high. In this context, a network operating model was proposed based on the lowest cost and maximum benefit approach.



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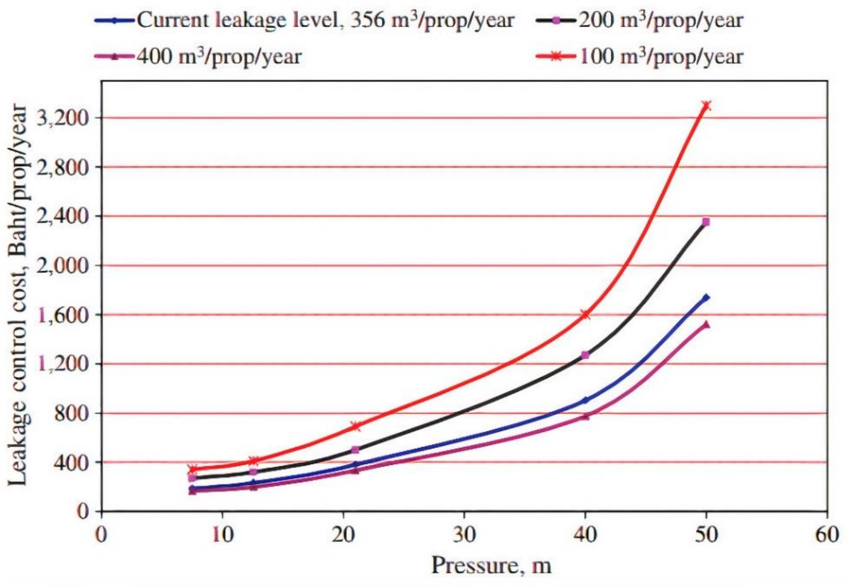

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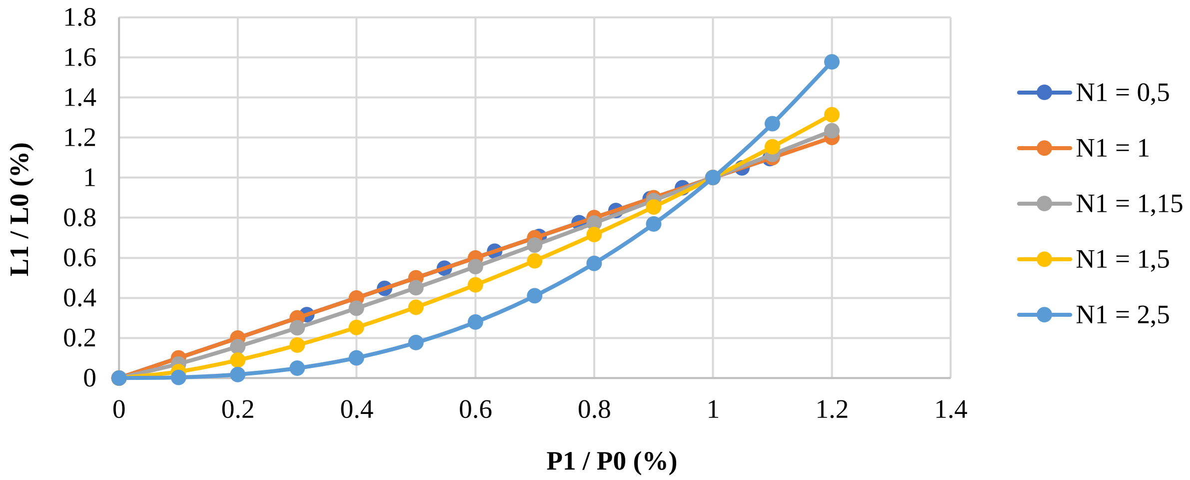

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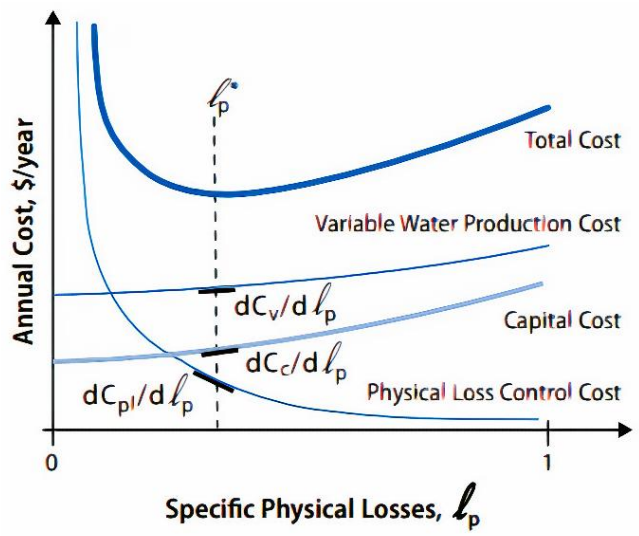

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Fig. 1. a) Hypothetical shapes of break rate functions influenced by factors contributing to pipe breaks (Ghorbanian, Guo and Karney, 2016); b) Cost of active leakage control with pressure for different leakage levels (Islam and Babel, 2013); c) Pressure-leakage relationship for different coefficients N1 (May, 1994); and d) Optimality condition for physical losses (Wyatt, 2010)

Ghorbanian et al. (2016) focused that the pressure, pipe type, pipe age, external load, climatic conditions are effective on the failure rate of the pipe (Figure 1a). Suribabu and Neelakantan (2012) emphasized the necessity for economic analysis during the design and operation of WDSs. A performance-oriented model was developed and proposed by considering the maintenance and repair costs during the useful life of the designed networks. According to Zamenian et al. (2017), the failures in WDSs cause significant water losses as well as significant social, economic and environmental impacts, and have significant impacts on energy consumption and cost, particularly in systems where water is delivered by pumps. For this reason, development of the strategic asset management plans was proposed to determine the potential damage of the pipes, evaluate the current situation, estimate the failure rate and prioritize the regions to be renovated.

2.2. District Metered Areas

Monitoring, controlling and implementing an effective water loss strategy in a large and complex WDS is time-consuming and costly. For this reason, the DMA approach was firstly planned and applied by International Water Association (IWA) in England in 1980. The DMA is a region where boundaries are precisely defined, usually have an inlet and are separated from other regions by isolation valves to control water losses (Farley et al., 2008). The DMA provides important contributions in the successful implementation of tools and methods such as minimum MNF, leak detection, customer management, and passive leakage control to reduce water losses (Gomes et al., 2013). The most appropriate size and number of the DMA should be determined by considering the main length, the number of service connections and making economic analysis (Lambert and Morrison, 1996).

Although the small size of the DMA provides an advantage in terms of managing the water loss components and controlling the system, the costs of the device-equipment, workmanship for isolation and field works and data transfer will increase. On the other hand, in the case of large planning, the investment and operating costs will be reduced while the operational components will be difficult as the size of the system components will increase (Farley et al., 2008). However, the following issues and field works can cause significant costs: i) determination of the number and location for isolation valves and identification of boundaries; and ii) room construction for flow-meter and pressure valves at DMA entrance, purchase and installation of flow-meters and pressure gauges and automation systems.

Gomes et al. (2013) emphasized that economic conditions and assessments are crucial parameters for planning and defining the boundaries of the DMAs in WDSs. In the study, an algorithm was proposed for minimization of the total cost and maximization of the benefit during the creation of DMA. Thus, the ELL is determined for DMA planning and implementation. Ferrari and Savic (2015) proposed that the expected benefits from the DMA (reduction of leakage and failures, reduction of energy and water consumption and efficiency) should be analyzed and evaluated under the economical perspective for planning and implementation DMA. Significant economic benefits in terms of pressure-dependent consumption reduction, failure frequency and leakage reduction was obtained by applying the efficiency analysis for DMA. As a result, the cost-benefit analysis and an economic performance evaluation framework was provided for comparing different DMA schemes and identification of the best solution from different options.

Kanakoudis and Gonelas (2015) expressed that the most important component for reducing the NRW rate is estimation of the ELL which is basically defined based on network conditions, pressure, NRW rate, consumption, water price and water production cost etc. Campbell et al. (2016) analyzed the benefits of the DMA methodology in terms of economic and control capability in WDSs. Genetic algorithm based model was developed and the most suitable options for the practitioner were defined for determination of the usage places and number of isolation valves and flow-meters in the most appropriate way. According to di Nardo et al. (2017), the DMA planning is quite complex and therefore the system should be analyzed in detail in terms of hydraulic, economic and topological aspects. An algorithm was developed by considering the economic and energy components for determining the boundaries of isolated zones and the locations of the devices to measure the hydraulic parameters. The developed algorithm aims for minimization of the operating costs by using the least possible flow-meter and simplifies the calculation of water balance by improving the hydraulic performance.

2.3. Active Leakage Control

In WDSs, the recoverable leakage volume, system operating and water production costs increase due to the awareness, recognizing and locating time the unreported leakages which is a significant part of leaks. The ALC strategy including awareness of these leakages, locating, repairing and preventing activities, plays an important role in reducing the volume of leakage (Lambert and Lalonde, 2005; Farley et al., 2008; Islam and Babel, 2013). However, in order to obtain benefits from the ALC method, it is very important to create isolated zones, monitor the minimum night flow and determine the recoverable leakage volume. In ALC methodology, leak location should be determined with devices and equipment such as ground microphone, regional recorder, and regional correlator. However, the costs of devices and equipment with different characteristics, sensitivities and prices are quite important component (Suribabu and Neelakantan, 2012; Kanakoudis and Gonelas, 2015; Zamenian et al., 2017; Cabral et al., 2019). Lambert et al. (1999) stated that ALC plays an important role in leakage management, and the cost-benefit analysis should be performed for ALC works during the definition of ELL. Li et al. (2015) examined the methods and devices used for detection and location of the leakages, and evaluated the advantages, disadvantages and costs of the methods. The working ranges of the ground microphones with low operating cost are between 200 to 500 m. The accuracy rate of this device is low and the efficiency is dependent on the personnel experience. On the other hand, regional noise logger and correlator equipment has a scanning range of up to 2000 m and automatic detection with high accuracy, whereas these devices cost were high.

Fantozzi (2006) pointed that ALC has an important role in the reduction and control of water losses as a result of technological developments. An approach is proposed by considering the water cost, intervention cost and the natural degradation rate of the network to determine economically the frequency of intervention for ALC method. Islam and Babel (2013) emphasized that the total costs including the system operating and water production should be considered to determine the ELL (Figure 1b). It was argued that the cost of ALC method depends on the duration of the screening and inspection activities which include the cost of inspection activities (leak detection and detection in the field with devices) and the break repair. Berardi et al. (2016) stated the importance of faster detection and repairing of unreported leakages due to the implementation of ALC for reduction of water losses.

It is argued that the implementation of the ALC strategy will reduce the operating costs and potential damage of the failures and leakages and provide the significant benefits. Lipiwattanakarn et al. (2019) analyzed the effects of leakage prevention and reduction on energy and system operating costs. After the repair of the leakages in the DMA, the inlet flow rate was decreased by 9% and the system input energy was reduced by 8% and the efficiency of the system was improved with ALC. Moslehi et al. (2020a) proposed a methodology based on the field data for the short-run economic leakage level with respect to ALC method. The proposed methodology was applied to a large WDS and the short-run ELL was estimated to be 27 m^3/service connection/year based on the current ALC policy and operating pressure.

2.4. Pressure Management

The system operating pressure is an effective parameter in the occurrence of new reported or unreported failures or leakage rate per unit time in existing failures in WDS (Farley et al., 2008). May (1994) developed a function between the leakage and pressure based on direct measurements for pipes with different diameters (Figure 1c). Lambert and Morrison (1996) developed a model, background and burst estimates (BABE) that calculates standard failure frequencies and flow rates for background losses. The fixed and varied area discharge (FAVAD) method was proposed as the most basic and widely used approach that expresses a relationship between leakage flow and failure rate with operating pressure (Lambert et al., 1999). PM contributes significantly to the reduction of leakage volume in existing failures, reduction of the risk of new leaks, extending the economic life of the pipe and reduction of operating and initial investment cost (Fanner and Lambert, 2009). Tabesh et al. (2011) proposed a demand-driven and pressure-based hydraulic design model by using the genetic algorithm. Authors expressed that more realistic data can be obtained by integrating possible leakages into hydraulic systems. However, components that are the room construction, device and equipment selection and placement, and automation system for monitoring the data, constitute significant costs.

Therefore, before applying PM in a system, answering the following questions is very important for system efficiency under the economic aspects (Kanakoudis and Gonelas, 2015): i) Is PM required? Is it applicable? What are the expected benefits?; ii) Is there information about network behavior, customer water demand characteristics? Has the hydraulic model been simulated? and iii) Have the cost components, equipment, installation, workmanship, and field work costs been determined? Has the CBA been performed?

Gomes et al. (2011) stated that the failure frequency and leakages can be reduced by applying PM. Consequently, the water production and transmission costs could be decreased. Moreover, it was determined that effect of PM on decreasing water consumption is very low. Thornton and Lambert (2007) investigated the benefits of PM in WDS. Firstly, pressure zones were established in the network then appropriate PRV was selected. It was stated that if a successful system is installed, the number of failures and instant water loss values will decrease. Creaco and Walski (2017) implemented an active pressure control strategy to reduce leakage and losses and analyzed the economic outcomes by comparing the results of the conventional and remote controlled PRVs. The results showed that active pressure control is not needed in areas where leakage level is low and maintenance and operating costs are low.

The remote controlled pressure control systems are more suitable in complex and large systems. Fontana et al. (2018) proposed a real-time pressure control system for the prevention and reduction of leaks. It was expressed that real-time pressure control provides significant gains in reducing the minimum night flow rate, minimizing pressure fluctuations and regulating pressure. Moslehi et al. (2020b) presented an economic evaluation framework to support the decision-making process relating to alternative PM schemes. The methodology was applied to a DMA by changing the existing fixed–outlet to time-based (TM-PRV) and flow-based modulation.

2.5. Network Renewal and Asset Management

The network renewal method, which creates a very high cost for reduction the water losses, is preferred primarily in many cases. Therefore, in a WDS firstly, the parameters that are current failure rates, the costs of the network operating, maintenance and repair, new water resource and energy and initial investment in current conditions should be considered. Moreover, in case of network renewal, medium and long term operational costs should be also analyzed (Kanakoudis and Gonelas, 2015).

Since the cost of pipe material, workmanship and construction are at very high levels, detailed cost-benefit analysis and alternatives should be evaluated before the network renewal approach. Therefore, ALC and other reduction methods for WLM should be firstly implemented and monitored then priority regions in network renewal should be identified to reduce the initial investment costs (Suribabu and Neelakantan, 2012). Tricarico et al. (2006) proposed two factors that are reducing costs and maximizing hydraulic reliability which should be considered for the design of WDSs. In this context, the reliability of all points in the system to reach expected minimum pressure required to meet every hour of the day, while the amount of unsold water and losses are evaluated economically.

Wu et al. (2010) analyzed the pipe failure records to determine the network leakage rate in WDSs, and presented a curve representing the relationship between pipe ages and leakage amount. The ELL was determined by calculating the optimum replacement period and costs for the pipes. Romaniuk (2016) carried out Monte Carlo simulation for different material and failure records to provide a reference in obtaining maintenance costs. Zangenehmadar and Moselhi (2016) developed a model for estimating the remaining useful life of pipes as well as predicting the degradation rates. According to existing literature studies, generally the concept of useful life for networks is widely studied topic. This concept is quite important in cases where network leakage control cannot be economically managed by network repair, maintenance activities, pressure management or other basic methods. In other words, in cases where the cost spent per unit pipe to operate the network is greater than the cost spent to replace the pipe, it can be evaluated as having completed its useful life for the network. Shahangian et al. (2019) analyzed the effects of flow hydraulics, pipe structure (particularly elastic behavior) and submerged jet on leak behavior based on the numerical and experimental study. The results Showed that the leakage exponent is close to the theoretical value of 0.5, considering the effect of pressure head on leak area behavior.

3. Economic Leakage Level

The methods applied to reduce and control water losses cause direct economic costs for utilities. In order to reduce leakages, four basic methods (PM, asset management, ALC and failure repair speed and quality), which require the detailed information about the current network conditions and technological tools have been used (Lambert et al., 1999). In WDSs, PRV or new water tanks are required for pressure management. The state-of-the-art equipment such as acoustic listening and regional monitoring devices are needed for active leak control. In this case, a new problem arises for utilities is that will there be a financial return to the utility for the expenditures to reduce water loss? In order to answer this question, the utilities should determine the optimal level of leakages based on the current network conditions. The most important issue in WLM and managing leakages is defining the ELL (Islam and Babel, 2013; Haider et al., 2019). For this aim, making a regional based evaluation and considering the current network and economic conditions, local costs, benefits, engineering parameters and other factors rather than universal assumptions will provide a more realistic approach (Deidda et al., 2014). The ELL can be changed with system characteristics such as water production and operating costs, type of transmission (pump-fed and treated or gravity-fed and non-treated). Therefore, the ELL should be calculated by considering the status of the existing network. Since the network conditions will not remain the same during this time, the ELL will also vary. Therefore, deterioration rates in the networks and materials used should be calculated as well as economic changes.

In defining the ELL, firstly, the leakage reduction methods should be well understood and analyzed. Each method will create a cost and benefit due to the current condition and characteristics of the network. Two different approaches were proposed in the literature, namely Short-Run (SRELL) and Long-Run ELL (LRELL). SRELL is considered to be the ELL that should be reached at the current pressure. In the SRELL theory, the ELL is generally evaluated on the whole system. For this reason, making separate calculations for different pressure zones provides an advantage in determining the economic level (Lambert and Lalonde, 2005). On the other hand, the LRELL includes less theoretical assumptions in dealing with leaks and several basic parameters that are the pressure management, network rehabilitation, team number optimization are considered. The LRELL will be more useful for utilities in the framework of long-run planning. In the LRELL methodology, four methods used in leakage management are considered (Lambert and Lalonde 2005).

Rudolph (2008) argued that water losses should be assessed separately for developed and developing countries. It was emphasized that the water loss rate, which is 8% in Germany, can reach up to 90% in developing countries and the main reason for this is the difference between the budgets allocated for water management. The results demonstrated that 30% loss rate is economical in regions where water production and operation costs are low. Moreover, the economic repair level and the point where the lost water value is equal to the detection and repair cost, were was calculated as 6.9 m^3/day/km. Wyatt (2010) defined the ELL as the point where the total amount spent to reduce water loss is equal to the slope of the unit production cost of water (Figure 1d). This optimum point is where the marginal utility of the leak is equal to the marginal costs of detection. For this purpose, three basic calculations were used: i) the cost of leakage directly proportional to the level of leakage; ii) the cost of detecting inversely proportional to the level of leakage; and iii) cost of repair independent of leakage level.

Lambert and Fantozzi (2005) proposed a practical and rapid approach for economic evaluation of financial and physical parameters to develop and implement an ALC strategy. In this context, marginal cost of water, cost of prevention method, leakage rate and related costs are considered. Fanner and Lambert (2009) presented a method for identifying and predicting the ELL by considering the main components of leakages. Islam and Babel (2013) emphasized that the most important component of the leak control strategy is the determination of the ELL which depends on network conditions, operating pressure, marginal water cost and all costs spent for leakage control. Molinos-Senante et al. (2016) envisaged that environmental and resource costs will be evaluated within the ELL. In the determination of the costs, the costs on which many parameters, such as the number of employees called shadow costs, and the number of interventions, are calculated. Considering the aforementioned studies, there is a need to establish a model that can take into account all technical and economic variables for the strategy ~~to~~ should be determined for struggling water losses. As it is known, four basic components such as pressure management, ALC, improving fault repair speed-quality and asset management affect WLM. These four basic structures should be solved simultaneously in problem solving.

4. Conclusions

In this review, detailed literature review was conducted within the framework of economic components for effective, efficient and sustainable urban water management and prevention activities implemented for struggling water losses. Evaluations that can serve as a reference for subsequent studies are made and basically the following basic results are obtained:

- The economic analysis and elaboration of benefit-cost assessments (CBA) for both operational and water loss management (WLM) components of the system are very important for effective, efficient and sustainable management of the system.
- The main cost components that come to the forefront in WLM can be given as follows; the costs of leakage maintenance and repair of reported and unreported leakages, the cost of methods used for detection, control and prevention of unreported leakages, the costs of energy and searching for new water resources, and the cost of automation systems for monitoring, control and transfer of data.
- Deciding on methods for preventing, monitoring and controlling the water losses in order to use more efficiently for economic and infrastructure resources; the priority, suitability, applicability and economic impact of the method should be considered. Furthermore, it was emphasized that factors such as devices, automation systems, data transfer, operation and maintenance cost, expected benefit from the method, operating cost and possible costs on maintenance costs should be taken into consideration.
- The main and service connection failures in water distribution systems (WDSs) have significant social, economic and environmental effects, cause significant water losses and have significant effects on energy consumption especially in pump-fed systems. Therefore, it has come to the fore that it is necessary to determine the damage potential of the pipes, evaluate the current situation, estimate the failure rate, prioritize the regions in rehabilitation and formulate strategic asset management plans.
- The district metered areas (DMA) approach is widely used in water loss management and provides significant gains in the fight against unreported leaks. In addition, it is underlined that it provides important contributions for minimum night flow (MNF), acoustic leak detection, customer management, passive leakage control and other means-methods applied to prevent and reduce water losses. However, in addition to the benefits of the district metered areas, it was reported that system design and field productions constitute significant costs.
- The recoverable leakage volume increases due to awareness and locating periods of the unreported leaks, and system operating and water production costs also increase. It was emphasized that active leakage control (ALC) strategy, which includes awareness of these leaks, locating, repairing and preventing activities, plays an important role in reducing the volume of physical losses. It was reported that the ground microphones were in the range of 200-500 m in the inspection range and the accuracy percentage was low and the efficiency was dependent on the personnel experience, whereas they had a low operating cost. On the other hand, it was emphasized that regional noise logger and noise correlator equipment has a scanning range of up to 2000 m and automatic detection with high accuracy, whereas these devices are costly.
- The system operating pressure is

influential factor in the occurrence of reported or unreported breaks in water distribution systems and in increasing the leakage volume lost per unit time in existing breaks. By applying pressure management schemes, the benefits can be obtained the reduction of leakage volume in existing faults, the reduction of the risk of new failures and new leakages, the reduction of the volume of water consumed per unit and the prolongation of the pipe's economic life.

- Defining the economic leakage level (ELL) is the most important issue in water loss management and fight against leaks. While determining this level, it was emphasized that making a regional based evaluation and taking into consideration the current network condition, economic conditions, local costs, benefits, engineering parameters and other factors rather than universal assumptions will provide a more realistic approach.

As a result, in the light of the examinations and evaluations carried out in detail in the previous parts of the paper, according to indicated literature survey: there are methods with different characteristics and costs in water loss management, the importance of economic analysis in deciding these methods, choosing suitable and applicable method according to the current system conditions and defining the economic leakage level. In the following studies, it is thought that the economic analysis of the economic effects of water loss components, defining the detailed benefit and cost standards for the methods to be applied for the prevention of the components, the determination of the optimum leak level and optimization and the use of mathematical based models will make important contributions in the determination of the economic leakage level.

List of Abbreviations

WLM	Water Loss Management
PM	Pressure Management
DMA	District Metered Areas
ALC	Active Leakage Control
NRW	Non-Revenue Water
CBA	Cost-Benefit Analysis
ELL	Economic Leakage Level
WDS	Water Distribution System
SCADA	Supervisory Control and Data Acquisition
GIS	Geographical Information System
IWA	International Water Association
MNF	Minimum Night Flow
AWWA	American Water Work Association
BABE	Background And Burst Estimates
FAVAD	Fixed And Varied Area Discharge
PRV	Pressure Reduction Valve
TM-PRV	Time-Based Pressure Reduction Valve
LRELL	Long-run Economic Leakage Level
SRELL	Short-run Economic Leakage Level

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