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Developing appropriate performance indicators for urban water distribution systems evaluation at Mediterranean countries

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Abstract: As water bodies are being severely stressed due to climate change conditions and growing populations, special attention must be given to areas experiencing water scarcity problems. The Mediterranean area countries are suffering from water scarcity problems jeopardizing the sustainability of the local ecosystems. At the same time, more than 50% of the urban water being supplied in these countries, is being lost through leaks and breaks occurring in the water distribution systems mainly due to lack of efficient water losses reduction strategies. In order to guarantee sufficient quantities of good quality water, water utilities must apply water auditing and water losses control methods. International Water Association (IWA) developed a WB assessment methodology based on a very detailed handbook including 170 water system PIs, based on 232 system variables that need to be regularly monitored. Trying to implement the IWA methodology many practical problems appeared regarding unreliable or even lacking data, local conditions and characteristics. The present paper presents the methodology used to develop new PIs based on the special conditions of the Mediterranean area. The PIs are divided in three groups, regarding the way they are being formed: a) existing ones; b) derived by existing ones properly modified to address special issues; c) new ones developed based on the concept introduced by the IWA, covering additional topics. This whole attempt is elaborated via the on-going project named WATERLOSS-Management of water losses in a drinking water supply system (Project 2G-MED09-445).

Key words: Flood hazard, embankment dam, dam failure, inundation area, floodwave routing, breach formation

1. INTRODUCTION

The Mediterranean countries water resources are increasingly stressed, due to climate change and growing water demand. Water scarcity is one of the major problems the Mediterranean countries are facing. Moreover urban water supply systems suffer from high Non Revenue Water (NRW) values mainly due to breaks and leaks. In some cases NRW values are higher than 50% of the water volume entering the system. Thus, water utilities must become highly efficient throughout the entire water supply process in order to guarantee sufficient quantities of good quality water. Within the specific geographic and climatic context of the Mediterranean area, particular attention needs to be paid to water resources, aiming to safeguard a sustainable water supply in a period of climate change. A recent Word Bank study (Liemberger et al., 2007) showed that more than 45 bio m^3 of water are being lost through leakage corresponding to 35% of the total water supplied. If half of this water volume was saved, 200 mil. people would have access to safe water without any further investment. NRW has also economic effects because the utilities are losing revenues. Worldwide NRW lost is roughly estimated to 10 bio Euros (Liemberger et al., 2007). There is the environmental aspect as well. Water losses imply carbon dioxide and other gas emissions since the water volume being lost has been pumped, treated, distributed and leaked. Water losses related carbon dioxide emissions are even more when desalination is used. Thus, NRW has its own carbon footprint as well.

Water utilities can reduce the large volumes of treated water being lost, by employing improved methods for water auditing and losses control. Associations such as IWA and AWWA have suggested water audit tools and methodologies to assess the water supply systems (WSS). These methodologies include Water Balance (WB) assessments and databases of Performance Indicators (PIs). Specifically the IWA has proposed a WB and a database of 170 PIs based on 232 variables that have to be measured in the water supply system. Although the core idea of each methodology is based on the typical super-market concept (buy only what you really need and fits best), it neglects practical problems arising during its application (e.g. unreliable or even lacking data; local conditions). Till now, an integrated approach is lacking, that will utilize quantified and balanced Performance Indicators (PIs) to account for regional specific conditions and an optimization routine to rank the actions that could be applied by water utilities. This prioritized list of measures should be adapted to local conditions pointing out benefits and revenues from the implementation of the approach, balancing the required investments, considering the income return to end-users and water utilities due to water losses reduction.

2. IWA WB AND PIS

IWA developed a WSS water balance (WB) assessment methodology, including the International Standard IWA WB (Figure 1) and a set of 170 PIs (Table 1) (Lambert, 2002; Alegre et al., 2006) based on 232 variables that need to be regularly monitored.

Water losses represent a big amount of water being lost due to real and apparent losses in water supply systems (WSS). Real losses represent the physical water losses due to leakage on supply mains; treatment plants; distribution mains; storage tanks (and overflows); and service connections up to the water meter. Apparent losses on the other hand represent the unauthorized use due to water theft, illegal use; meter/metering inaccuracies (misread meters; incorrect estimates for stopped meters; adjustments to initial meter readings; improper calculations; computer programming errors; systematic errors due to under/over-registration of meters).

Although the whole idea of IWA methodology is based on the typical super-market concept, it neglects practical problems water utilities are facing during its implementation. The first one has to do with the PIs selection process. IWA PIs range from simple ones, offering a general management overview of the network's operation in terms of efficiency/effectiveness, to detailed ones that deal with specific elements of operational practices. Although PIs have been highly acknowledged as a very efficient tool, discussions on their appropriateness recently emerged (Table 2) (Liemberger, Brothers et al., 2007). The water utility should study and prioritize its needs regarding the WSS evaluation process. IWA proposes a basic methodology to select the appropriate PIs (Alegre et al., 2006) (Figure 2).

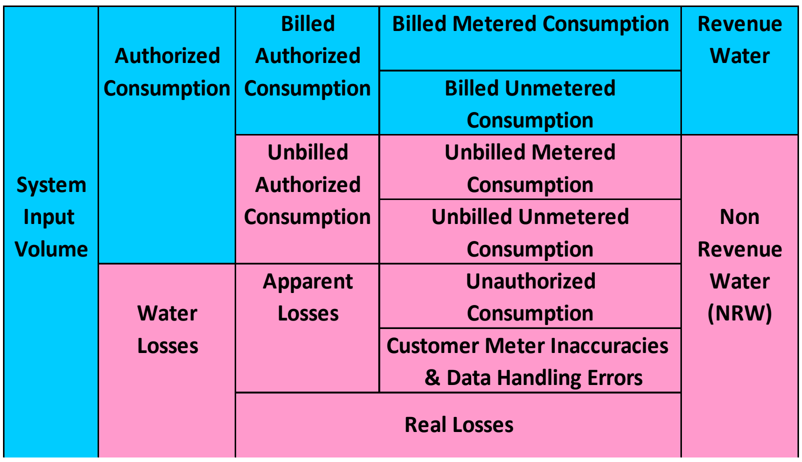

Figure 1. The International Standard IWA WB

Table 1. The 170 IWA PIs (Alegre et al., 2006)

PIs / Number		PIs / Number		PIs / Number	
Water Resources (WR)	**4**	**Operational (Op)**	**44**	**Financial (Fi)**	**47**
Personnel (Pe)	**26**	Inspection & maintenance of physical assets	6	Revenues	3
Total Personnel	2	Instrumentation calibration	5	Costs	3
Personnel per main function	7	Vehicle availability	1	Composition of running costs per type of costs	5
Technical services personnel per activity	6	Electrical & signal transmission equipment inspection	3	Composition of running costs per technical function activity	6
Personnel qualification	3	Mains/valves/service connections rehabilitation	3	Composition of capital costs	2
Personnel training	3	Inspection & maintenance of physical assets	2	Investment	3
Personnel helath & safety	4	Pumps rehabilitation	2	Average water charges	2
Overtime work	1	Operational Water Losses	7	Efficiency	9
Quality of Service (QS)	**34**	Failure	6	Leverage	2
Service coverage	5	Water metering	4	Liquidity	1
Public taps & standpipes	4	Water Quality monitoring	5	Profitability	4
Pressure & continuity of supply	8	**Physical (Ph)**	**15**	Economic Water Losses	2
Quality of supplied water	5	Treatment & Storage	3	Composition of running costs per main function of water undertaking	5
Customer complaints	9	Pumping	4		
Service connections & meter installation & repair	3	Transmission & distribution	2		
		Meters	4		
		Automation & control	2		

Table 2: Comments on the appropriateness of the different PI expressions (Liemberger, Brothers, et al., 2007)

PI	Group	Measure	Condition	Comment
Non-Revenue Water	Financial	Volume of NRW as % SIV		influenced by non-fixed parameters
		NRW % by cost		more appropriate
		NRW in litres/connection/day		
		NRW in m3/km mains/year		
Apparent Losses	Operational	Volume of AL as % SIV		poor indicator
		Volume of AL as % Water Billed		poor indicator
		m3/service connection/day		more appropriate
		litres/service connection/day		more appropriate
		litres/metered property/day		more appropriate
		% of water supplied		more appropriate
		% of authorised consumption		more appropriate
Real Losses	Operational	Volume of Real Losses as % SIV		influenced byconsumption
		per billed account or per property		multiple properties
		litres/service connection/day	service connections>20/km mains	more appropriate
		m3/km mains/day	service connections<20/km mains	more appropriate
		litres/service connection/day when pressurised	intermittent supply	intermittent supply
Water Losses	Operational	m3/service connection / year		
UARL		m^3/km of mains/day/metre of pressure		depends on service connections
		in litres/service connection/day/metre of pressure	service connections>20/km mains	more appropriate

Another problem faced during a WSS evaluation process is the data reliability and availability. This is a common problem faced by water utilities. A case study in Sao Paolo (Paracampos & Thornton, 2002) showed that the quality of the necessary data and their collection techniques adopted are both crucial, for the calculation of the PIs levels. Many researchers agree on the reliability and accuracy of data being an important issue when the WSS is being evaluated (Kolbl et al., 2007; Pearson, 2009; Morrison, 2002; Kanakoudis & Tsitsifli, 2010a; Tsitsifli & Kanakoudis, 2009). Tsitsifli and Kanakoudis (2009) faced the problem of missing data during the WSS evaluation process in the case studies of Larisa, Kos and Veria cities (Greece). They solved this problem by making assumptions based on the available relative literature and performing sensitivity analysis to check the impact of these assumptions on the PIs levels.

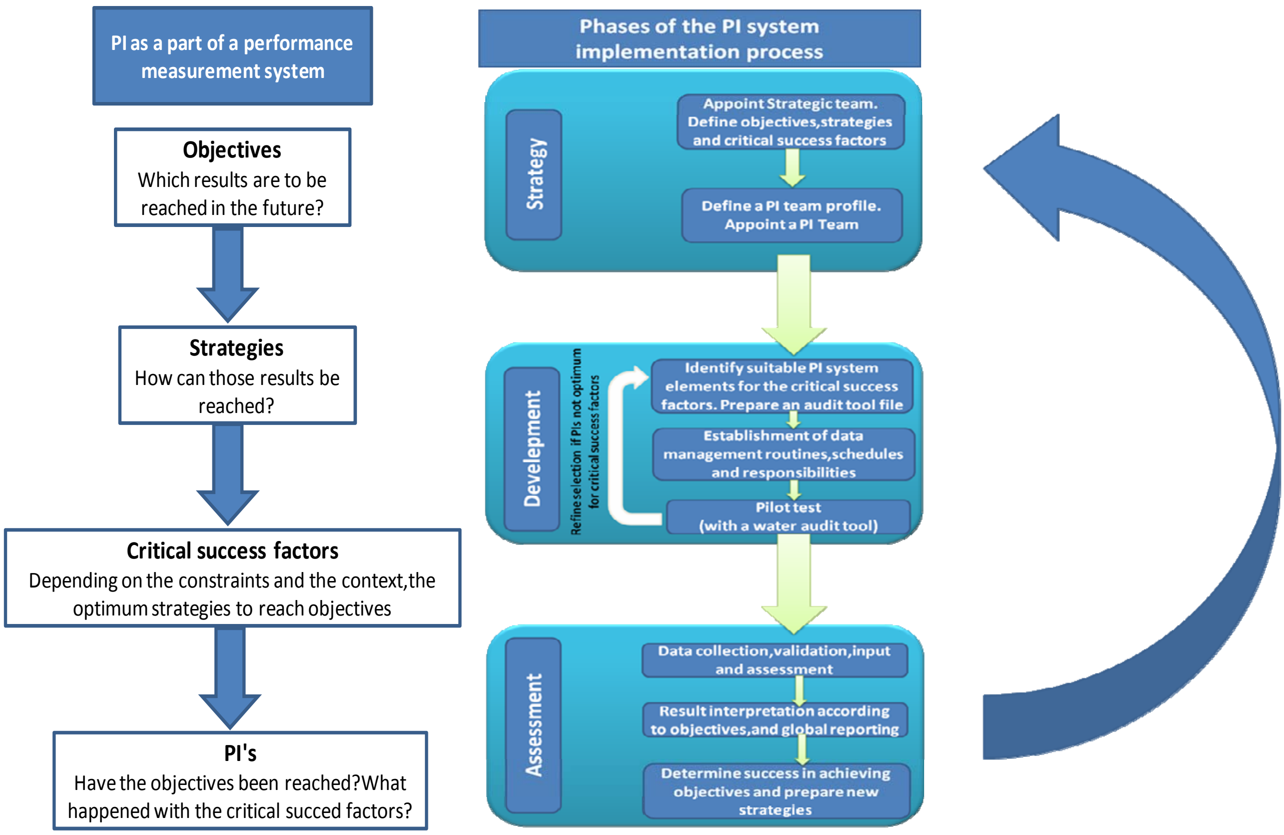

Figure 2: IWA basic methodology to select the appropriate PIs (Alegre et al., 2006)

Kanakoudis and Tsitsifli (2010b) identified another obstacle in performing the IWA WB to Greek WSS. This obstacle has to do with the water billing policy water utilities are implementing. Most Greek water utilities apply inclining water rates that also include a fixed rate. That means that there is a minimum water volume being charged to the users even if they have not actually consumed this water. This minimum water volume threshold is called minimum charge. Other water utilities charge all their customers a fixed price for offering them the possibility to have access to water (opportunity cost). The utilities add the cost of the water consumed by each customer to the fixed price. Both policies have to do with the minimum charge. The water meters recordings must be considered to estimate the metered and billed water volume. The extra water volume charged but not consumed (Minimum Charge Difference – MCD) should be considered as real losses providing revenues to the water utility. This practice met in Greece resulted to the proposal of a modified WB (Kanakoudis & Tsitsifli, 2010b) (Figure 3) taking into account the 1st WB modification proposed by McKenzie et al. (2007).

Such local conditions and characteristics could be met during the WSS evaluation process in different regions. A full PIs database should include more PIs related to special conditions in the Mediterranean.

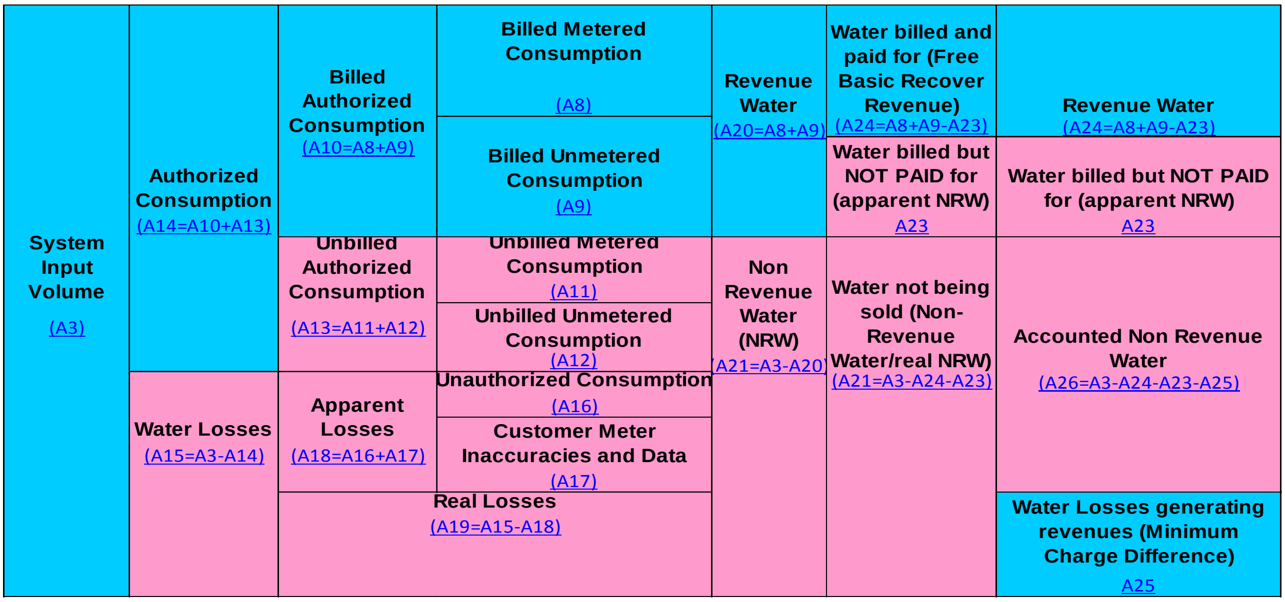

Figure 3: The proposed modified WB including the McKenzie et al. (2007) modification

3. NEW PROPOSED PIS: METHODOLOGY

The present paper presents the methodology used to develop new PIs based on the special conditions of the Mediterranean area including social factors, health factors, water quality problems, environmental factors etc. These new PIs along with some existing ones form a crucial database within an integrated methodology for the reduction of the NRW values. The PIs are divided in three groups, regarding the way they are being formed: a) existing ones being widely used by the Water Utilities in the Mediterranean area; b) derived by existing ones properly modified to address special issues as the water losses per pipe material or diameter and new ones to address social, environmental, health factors etc.; c) new ones developed based on the concept introduced by the IWA, covering additional topics (e.g. energy use and conservation). This whole attempt is elaborated via the on-going project named WATERLOSS-Management of water losses in a drinking water supply system (Project 2G-MED09-445).

The methodology used to select the existing PIs used by water utilities in the Mediterranean included a survey. The survey included a questionnaire distributed to the water utilities associated to the 9 WATERLOSS partners (Table 3 shows the partners, their cities and countries). The questionnaires consisted of five sections. The question to be answered was: “the following indicators or parameters offer a valuable tool to manage water losses in a drinking water supply system”. The people who answered these questions used a ranking system of a 6-point scale from strong disagreement to strong agreement. Section A included the 170 IWA PIs, section B included proposed social, operational, safety and environmental indicators. Section C included indicators regarding the organization performance, section D included suggestions to be made by the respondents and section E included some general information regarding the respondent’s position, experience, education, age etc. A task group was performed within the WATERLOSS partners that had to evaluate the answers.

(a) Existing PIs being widely used by the Water Utilities in the Mediterranean area.

The task group identified 75 out of 170 IWA PIs that the partners wanted/wished to estimate now or in the near future. Table 4 shows the selected IWA PIs, prioritized in 3 groups. The group of the 75 IWA PIs includes 3 out of 4 Water Resources PIs; 2 out of 15 Personnel PIs; 6 out of 26 Physical PIs; 25 out of 44 Operational PIs; 23 out of 34 Quality of Service PIs; and 16 out of 47 Financial PIs. The task group identified the priority list of these 75 IWA PIs categorizing them in 3 levels of priority (priority 1 being the highest level of priority).

Table 3: WATERLOSS partners, their cities and their countries

Partner's No	Partner's full NAME	Partner's City	Partner's Country
LP=PP1	Aristotle University of Thessaloniki	Thessaloniki	Greece
PP2	Conseil Général des Pyrénées Orientales	Perpignan	France
PP3	Water Board of Nicosia	Nicosia	Cyprus
PP4	Regional Development Centre	Slovenia	
PP5	Metropolitan Area of Barcelona	Barcelona	Spain
PP6			
	Kozani Municipal Water & Sewerage Utility	Kozani	Greece
PP7	Autorità di Bacino dei Fiumi Liri-Garigliano-Volturno		
PP8	University of Ljubljana-Faculty for Civil & Geodetic Engineering	Ljubliana	Slovenia
PP9	Department of Herault	Herault	France

(b) Derived PIs by existing ones properly modified to address special issues.

After the selection of the 75 IWA PIs, the task group identified PIs derived from the existing IWA ones, properly modified to address special issues. Such issues are the water and real losses per pipe material or diameter and new ones to address social, environmental, health factors etc. Thus the task group concluded in 11 new PIs. Table 5 shows these 11 indicators, their proposed meanings and their measure. The proposed ALI indicator has been proposed by IWA Apparent Loss Team (Rizzo et al., 2007) but it is not one of the 170 IWA PIs yet. The task group adopted this indicator. The list of the 11 proposed PIs includes mainly operational PIs regarding real losses, apparent losses, water losses and NRW. The denominators are different since the task group wants to investigate the impact of pipe material and diameter in the real losses values. The task group investigates as well the impact of roof tanks and their volume in the apparent losses values. NRW index is being investigated on the basis of number of connections or the length of mains. Finally the last indicator estimates the mains failures per type of main. It is evident from the international literature that the factors taken into account by the task group affect the different types of water losses.

(c) New PIs developed based on the concept introduced by the IWA, covering additional topics.

Finally the partners and the task group ended up to 30 new PIs covering topics such as energy consumption, carbon footprint etc. Two of these PIs have been suggested by Cabrera et al. (2010) during their effort estimating energy losses in the water distribution networks. It is the first time that water losses related energy loss is being addressed. MCD is used to create new indicators regarding real losses and the number of connections. Other proposed indicators show the impact of variables such as pipe age, pipe roughness coefficient, operating pressure etc., to real losses values. Other PIs express the customers' satisfaction and others are related to the water meters and their operational status. The partners' proposals have also been considered. Table 7 shows the list of the 30 new proposed PIs, their meanings and the units they are measured in.

Out of this effort, new and existing variables are needed. At least 22 new variables are needed for the estimation of all the 41 new PIs (11 derived from existing ones and 30 new ones) (Table 6).

Table 4: 75 IWA selected PIs and their priority list

IWA Pis							
existing	selected				48	16	11
170	75			PERFORMANCE INDICATORS	PRIORITY 1	PRIORITY 2	PRIORITY
4	3	Water Resour-ces Perfor-mance	WR	Inefficiency of use or water resources	1		
			WR	Water resources availability	1		
			WR	Own water resources availability	1		
15	2	Pers-onnel	Pe1	Employees per connection			1
			Pe2	Employees per water produced			1
26	6	Physical Performance	Ph2	Raw water storage capacity	1		
			Ph3	Transmission and distribution storage capacity	1		
			Ph5	Standardised energy consumption		1	
			Ph7	Energy recovery		1	
			Ph1	Customer meter density			1
			Ph1	Metered customers			1
44	25	Operational Performance	Op3	Network inspection	1		
			Op4	Leakage control	1		
			Op5	Active leakage control repairs		1	
			Op7	System flow meters calibration			1
			Op8	Meter replacement	1		
			Op1	Vehicle availability			1
			Op1	Mains rehabilitation	1		
			Op1	Mains renovation		1	
			Op1	Mains replacement	1		
			Op1	Replaced valves	1		
			Op2	Service connection rehabilitation	1		
			Op2	Water losses per connection	1		
			Op2	Water losses per mains length	1		
			Op2	Apparent losses	1		
			Op2	Apparent losses per system input volume		1	
			Op2	Real losses per connection	1		
			Op2	Real losses per mains length	1		
			Op2	Infrastructure Leakage Index (ILI)	1		
			Op3	Pump failures	1		
			Op3	Mains failures	1		
			Op3	Service connection failures	1		
			Op3	Customer reading efficiency		1	
			Op3	Residential customer reading efficiency		1	
			Op3	Operational meters		1	
			Op3	Unmetered water		1	
34	23	Quality of service Performance	QS1	Households and businesses supply coverage		1	
			QS2	Buildings supply coverage		1	
			QS3	Population coverage	1		
			QS4	Population coverage with service connections	1		
			QS1	Pressure of supply adequacy	1		
			QS1	Continuity of supply	1		
			QS1	Water interruptions	1		
			QS1	Interruptions per connection	1		
			QS1	Days with restrictions to water service	1		
			QS2	Microbiological tests compliance	1		
			QS2	Physical-chemical tests compliance	1		
			QS2	New connection efficiency		1	
			QS2	Time to install a customer meter		1	
			QS2	Connection repair time	1		
			QS2	Service complaints per connection	1		
			QS2	Service complaints per customer	1		
			QS2	Pressure complaints	1		
			QS2	Continuity complaints	1		
			QS3	Water quality complaints	1		
			QS3	Interruption complaints	1		
			QS3	Billing complaints and queries		1	
			QS3	Other complaints and queries			1
			QS3	Response to written complaints			1
47	16	Economic & Financial Performance	Fi1	Unit revenue	1		
			Fi2	Sales revenues	1		
			Fi4	Unit total costs	1		
			Fi5	Unit running costs	1		
			Fi9	Imported (raw and treated) water costs	1		
			Fi1	Electrical energy costs	1		
			Fi2	Unit investment			1
			Fi2	Investments for new assets and reinforcement of			1
			Fi2	Investments for asset replacement and renovation			1
			Fi2	Average water charges for direct consumption	1		
			Fi2	Average water charges for exported water		1	
			Fi3	Total cost coverage ratio	1		
			Fi3	Operating cost coverage ratio	1		
			Fi3	Delay in accounts receivable		1	
			Fi4	Non-revenue water by volume	1		
			Fi4	Non-revenue water by cost	1		

Table 5: WATERLOSS proposed PIs derived from existing ones

Existing Pis (different denominator)			Comments
Real Losses per pipe material	Real Losses / pipes length of the same material	m^3/km	
Real Losses per pipe diameter	Real Losses / pipes length of the same diameter	m^3/km	
Real Losses per pipe material & diameter	Real Losses / pipes length of the same diameter and material	m^3/km	
Apparent Losses per roof tank	Apparent Losses / number of roof tanks	m^3	
Apparent Losses per roof tank volume	(Apparent Losses / roof tanks volume)*100	%	
Apparent Losses per connection	(Apparent Losses*1000) / (number of service connections*assessment period)	lt/connection/ day	
ALI	Apparent Losses value / 5% of Water Sales		Proposed by IWA but not an IWA indicator yet
Water Losses per water resources	(Water Losses / Water abstracted from the same water resource)*100	%	
NRW per connection	(NRW*1000) / (number of service connections * assessment period)	lt/connection/ day	
NRW per mains length	NRW / mains length	m^3/km mains/year	
Mains failures per type of main	[(Number of failures of the same material of mains during the assessment period x 365) / assessment period] / same material of mains length] x 100		

Table 6: WATERLOSS new proposed variables

New Suggested Variables	
Average operating network pressure	(m)
Minimum operating network pressure	(m)
Maximum operating network pressure	(m)
Pipes length of the same material	(km)
Pipes length of the same diameter	(km)
Pipes length of the same material and diameter	(km)
Roof tanks number	
Water volume abstract from the same water resource	(m^3)
Pipes length with the same age	(km)
Roughness coefficient	
Water use (residential, commercial, industrial)	(m^3)
Average building height	(m)
Energy used	(KWh)
Flow meters replaced	(no.)
Residential consumption	(m^3)
Commercial consumption	(m^3)
Cost to safeguard water supply	(€)
Domestic water meters aged less than 5 years	(no.)
Domestic water meters aged between 5 -10 years old	(no.)
Time to respond to repair leaage events	(hours)
total number of repairs occurred	(no.)
Number of failures of mains of the same material	(no.)

Table 7: WATERLOSS new proposed PIs

New Suggested PIs			Comments
Real Losses per pipe age	Real Losses / pipe length with the same age	m^3/km	
Real Losses per roughness coefficient	Real Losses / roughness coefficient		
Water Losses % water use (domestic, industrial, commerial)	(Water Losses / water use)*100	%	
Water Losses per buildings height	Water Losses / average buildings height	m^3/m	
MCD per Real Losses	(MCD / Real Losses)*100	%	
MCD per connection	MCD / number of connections / assessment period (days)	m^3 /con-nection/day	
Real Losses - pressure	Real Losses / average operating pressure	m^3/m	
Apparent Losses per water meters	Apparent Losses / number of water meters	m^3	
Accounted for NRW per NRW	(Accounted for NRW / NRW)*100	%	
Inhabitants per water meter	Number of inhabitants / number of water meters	Inh/wm	
Energy per volume	Energy used (KWh) / System Input Volume (m3)	KWh/m^3	
Energy costs per volume	Energy cost (€) / System Input Volume (m3)	€/m^3	depends on the cosφ vector
Leakage energy or Energy loss due to leakage (sum of the leaks-related energy loss and additional energy required to overcome leakage)	(difference between the actual energy dissipated in friction losses and the value of friction losses in a leak-free network)		Proposed by Cabrera et al., 2010
Standards compliance	(energy delivered to users / minimum required useful energy)*100	%	
Meter replacement	(flow meters replaced/ per total number of flow meters)*100	%	
Residential Consumption size	(Residential Consumption / of total consumption)*100	%	
Commercial Consumption size	(Commercial Consumption / of total consumption)*100	%	
willingness to pay index (consumer's sensitivity to issues of water shortage and drought)	cost to safeguard water supply/authorised consumption during the assessment period	EUR/m3	
Low pressure-related complaints rate	(No of water pressure-related complaints/total No of complaints)*100	%	may also take the form of any kind of complaint
Low pressure-related complaints per service	No of water pressure-related complaints/No of water meters		may also take the form related to the number of connections
Grade of consumer's satisfaction	(satisfied customers/total population served)*100	%	may also take the form related to the number of connections
Tap water Grade of satisfation	(satisfied customers drinking tal water/total population served)*100	%	may also take the form related to the number of connections
Water taste Grade of satisfaction	(customers affected by the taste and chlorination of potable water/total population served)*100	%	may also take the form related to the number of connections
Grade of employees valuation of customer's satisfaction	Grade of employees valuation of customer's satisfaction		
Assessment of failures according to type of material and fittings in mains and service connections	failure rates (for each type of failure) in No of failures/total No of devices		
Under 5 years old Domestic water meters rate	(domestic water meters aged less than 5 years old/ total water meters)*100	%	
5 to 10 years old Domestic water meters rate	(domestic water meters aged less than 5 -10 years old/ total water meters)*100	%	
Elasticity of Losses related to operating pressure	water saved (difference in water losses excluding theft and reading errors) per m of reduced pressure	m3/m	Effect of network pressure reduction in reducing water losses
Elasticity of failures occurrence rate related to the operating pressure	No of failures prevented per m of reduced pressure	failures/m	Effect of network pressure reduction in reducing the number of mains and connection failures events
Number of days to respond to repair leakage events	Total No of days to respond to repair leakage events/total number of repairs occurred	days/repairs	

4. CONCLUSIONS

The present paper presents the development process of the appropriate PIs used to evaluate the performance of water supply systems. The whole process of developing PIs is part of an on-going project named WATERLOSS-Management of water losses in a drinking water supply system (Project 2G-MED09-445). The basis for the PIs development has been the International WB and the PIs proposed by IWA. The IWA International WB has been modified (Kanakoudis & Tsitsifli, 2010) to fit in the Mediterranean cases. The use of the MCD has been proposed. Based on this proposed modified IWA WB a task group formed within the partners of the WATERLOSS project to use existing PIs and develop new ones. The whole attempt was based on a survey performed within water utilities related to the WATERLOSS project. The respondents evaluated the use of the 170 existing IWA PIs and proposed new PIs to address specific local problems faced in the their water networks. The final out come includes 75 out of the 170 existing IWA PIs prioritized in 3 categories according to their significance. A group of 11 PIs has been set up including PIs derived from existing ones with different denominators. Finally a group of 30 new PIs has been proposed by the partners and the task group. A group of new variables needed to estimate these PIs has been set up. Most of the existing IWA variables are also used. A total database of 116 existing and new PIs will be used in the decision support system (DSS) being concluded within the project. The DSS will use the PIs database and weighting factors to choose the most cost-effective NRW reduction measures. This will be the final outcome of the WATERLOSS project concluded in May 2013.

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REFERENCES

Alegre, H., Baptista, J.M., Cabrera, E. Jr., Cubillo, F., Duarte, P., Hirner, W., Merkel, W., Parena, R. 2006. *Performance Indicators for Water Supply Services*. 2nd ed. IWAp, London.

Cabrera E.M., Pardo M.A., Cobacho R., Cabrera E.Jr. 2010. Energy Audit of Water Networks. Water Resources Planning & Management, ASCE, 136(6), 669-677.

Kanakoudis, V., Tsitsifli, S., 2010a. Results of an urban water distribution network performance evaluation attempt in Greece. Urban Water, 7(5), 267-285.

Kanakoudis, V., Tsitsifli, S., 2010b. Water volume vs. revenues oriented water balance calculation for urban water networks: the "Minimum Charge Difference" component makes a difference! *IWA Int. Conf. 'WaterLoss 2010',* Sao Paolo, Brazil.

Kolbl, J., Theuretzbacher-Fritz, H., Neunteufel, R., Perfler, R., Gangl, G., Kainz, H. and Haberl, R., 2007. Experiences with WaterLoss Pis in the Austrian Benchamrking Project. *IWA Int. Conf. 'Water Loss 2007'*, Bucharest, Bucharest, Romania, 1:176-187.

Lambert, A.O., 2002. International report: water losses management and techniques. *Water Supply,* 2(4), 1-20.

Liemberger, R., Brothers, K., Lambert, A., McKenzie, R., Rizzo, A., Waldron, T., 2007. Water Loss Performance Indicators. *IWA Int.Conf. 'WaterLoss' 2007*, Bucharest, Romania, 1:148-160

Liemberger, R., Kingdom, W.D., Marin, P., 2007. Performance based Non-Revenue Water Reduction Contracts. *IWA Int. Conf. 'WaterLoss 2007'*, Bucharest, Romania, 3: 655-664.

Morrison, J.A.E., 2002. Practical Application of Component Analysis of leakage Using Babe Principles. *IWA Int. Conf. 'Leakage Management 2002'*, Lemesos, Cyprus, 254-266.

McKenzie, R., Seago, C., Liemberger R., 2007. Benchmarking of Losses from potable water reticulation systems-results of IWA Task Team. *IWA Int. Conf. 'WaterLoss 2007'*, Bucharest, Romania, 1:161-175.

Paracampos, F., Thornton, J., 2002. SABESP's (Sao Paolo Water and Sanitation Company) experience in applying the IWA water loss indicators-a field experience. *IWA Int. Conf. 'Leakage Management 2002',* Lemesos, Cyprus, 143-157.

Pearson, D., 2009. Developing a Non-Revenue Water Reduction Strategy with Inadequate Data. *IWA Int. Conf. 'WaterLoss 2009'*, Cape Town, South Africa, 6-12.

Rizzo, A., Vermersch, M., Galea St. John, S., Micallef, G., Pace, R. 2007. Apparent water loss control: the way forward. *Water21, IWA Publishing*, August 2007, 9.4, 45-47

Tsitsifli, S., Kanakoudis, V., 2009. Evaluating the performance of an urban water distribution network: tips and tricks for troubleshooting. *EWRA 6th Int. Conf.*, Lemessos, Cyprus, 419-426.