Benchmarking the Process of Physical Water Loss Management

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Abstract
Over the last two decades a rapid development in water loss management has been seen. For practitioners like operators of water utilities it is not easy to decide on the best strategy in water loss management and to choose the best technology. Therefore the tool of process benchmarking facilitates the possibility of comparing operational processes in water loss management and exchanging experiences on basis of performance indicators.

The process benchmarking system for the process of physical water loss management described in this paper enables a systematic quantification of the performance in physical water loss management. Beside economic aspects, technical quality criteria are also assessed. The system was tested in a pilot project in Austria and the field test was very successful.

Introduction
This paper is part of the investigations carried out within a PhD thesis entitled "Process benchmarking in water supply sector: The process of physical water loss management" at the Institute of Urban Water Management of Graz University of Technology in the years 2006 to 2009 (Koelbl 2009).

Water losses from drinking water supply systems are one of the greatest problems worldwide not only regarding supply safety (quantity) but also regarding the provision of safe potable drinking water (quality). Decision makers often tend to try solving the problem by opening up new resources but this is a fight against the symptoms and not against the real causes. Knowledge about water losses and the management of water losses is also still very important if the supply network is in good condition. Water losses are the only measurable indicator for the condition of a pipe network and are, therefore, an important basis for maintenance and rehabilitation planning (Koelbl 2009).

One possibility for assessing the performance in water loss management is to use the management methodology of benchmarking, especially that of process benchmarking. Two existing initiatives on benchmarking the process of water loss management have a strong focus on qualitative comparisons of the process. One is the Canadian benchmarking project (compare Main et al. 2008) and the other one is the Scandinavian 6-Cities project (compare Stahre & Adamson 2002). But, up to now, no systems with systematic quantifications of the performance of the process of physical water loss management have been developed.

A process benchmarking system which would allow the assessment of the performance of water supply utilities in water loss management from an economic point of view as well as from technical quality aspects was developed as part of an OVGW project (Austrian Association for Gas and Water). This paper gives an overview of this approach and describes methodological experiences and some selected results from the first project run in Austria.

OVGW Process Benchmarking System for Physical Water Loss Management
After two corporate benchmarking project runs (Neunteufel et al. 2004 and Theuretz-bacher-Fritz et al. 2006), an initiative on process benchmarking in the Austrian water

supply sector was started in 2007. The OVGW process benchmarking system is not holistic but scrutinises various selected processes out of the whole field of activities of a water supply utility. This is different to the approach of the International Water Association (IWA) within the Manual of Best Practice on Process Benchmarking (Larsson et al. 2002),

One of the processes analysed is physical water loss management. To benchmark this process a vast range of tasks has to be considered. Koelbl (2009) describes the process benchmarking system for physical water loss management in detail.

Larsson et al. (2002) describe a holistic approach of process benchmarking as it is practised, e.g., in the Netherlands. The idea of this system is to carry out comparisons for the whole value chain of a water supply utility with all its processes, beginning with the water abstraction and ending at the sales to customers. This holistic approach with its partitioning in well confined processes is not practicable for process benchmarking water loss management because water loss management is an integrative process that reverts to various tasks of the whole value chain of a water supply utility. Therefore, a selective strategy as practised, e.g., in Australia (Piccinin 2006) or Canada (Main et al. 2008) was chosen.

The challenge in benchmarking the process of physical water loss management is to develop a system which is able to provide comparability between the different techniques applied in water loss management (Figure 1). The performance comparison has to include economic and qualitative aspects of process operation.

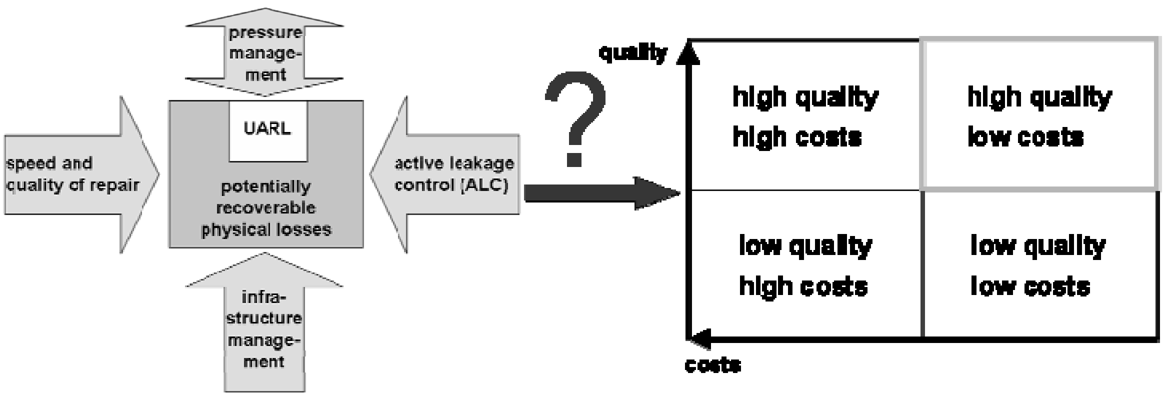

Figure 1: How to benchmark managing of physical water losses

Process Structure

A precondition for a high-quality process benchmarking is a diligent process structure. Thus the process structure of water loss management has to consider the basic methods of water loss management suggested by the IWA Water Loss Task Force (Figure 1, left part). Therefore various sub processes and supporting processes were defined. Figure 2 shows the OVGW process structure with a division into four sub processes:

- Leakage Monitoring
- Leak Detection
- Repair
- Analyses & Planning

Supporting processes are activities which are usually not only carried out for the purpose of water loss management but which have a great influence on the performance of water loss management. The supporting processes can be divided into qualification of staff (intangible asset management) and the infrastructure management (physical asset management).

Because the pressure management philosophy in central Europe, especially in Austria, Germany and Switzerland is clearly different from the IWA philosophy, no single pressure management sub process was defined. In the central European countries mentioned above, pressure reduction under a level of 30 m to 40 m service pressure head is seen as an urgent measure for systems in a poor infrastructure condition and it is seen more as a fight against the symptoms than against the real cause of water losses. Of course, unnecessary high pressures should be avoided even in systems in good condition. Therefore context information about pressure management is considered in the process benchmarking system (as part of infrastructure management supporting process) to improve awareness of optimisation potential due to unnecessary high system pressure (Koelbl 2009).

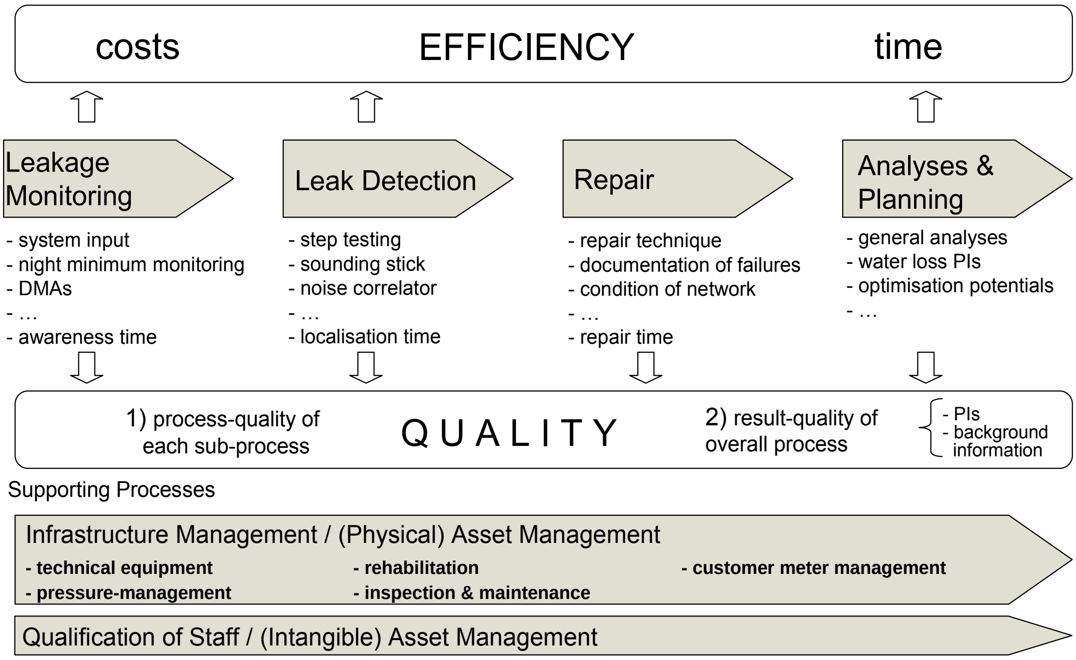

Figure 2: OVGW process structure for physical water loss management (Koelbl 2009)

The process structure stood the Austrian fieldtest. However, some amendments regarding the repair sub process need to be considered. Because this sub process is usually much more cost intensive than the other three sub processes, the results from the overall process would have been distorted if the repair costs had been included. Therefore the repair process should be considered as a part of the infrastructure management supporting process. The repair costs are considered as background information but are not summarised in the overall process costs.

Process Performance Indicator System

A process benchmarking system was developed (Figure 3) on the basis of this process structure. This system consists of a subsystem for data collection (variables, context information) and a subsystem for data evaluation (performance indicators, quality matrix)., The costs and also the hours of work are calculated for both the overall process and the sub processes. Outsourcing (in-house and external) of tasks is also considered and separately visualised. The accuracy was evaluated for all the water flow data.

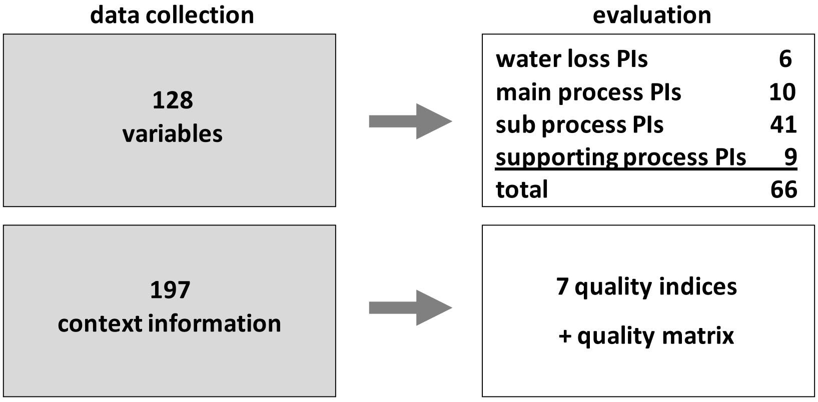

Figure 3: Process performance indicator system (Koelbl 2009)

Quality Matrix and Quality Indices

In order to benchmark both technical and economic aspects, quality criteria for each process step were determined. Therefore a lot of background information about the individual conditions (e.g., structure of the water supply system) and about the differences in the operations had to be gathered. A quality matrix with about 100 single criteria was developed to evaluate the quality of process operation which complements the process performance. Table 1 gives an example of the methodology used for the quality matrix (for complete matrix see Koelbl 2009).

Table 1: Selected part of quality matrix

Process Water Loss Management - Quality Matrix					
Level / Topic / Questions	low 1	2	3	4	high 5
Leakage Monitoring (flow, pressure)					
System Input Metering	Most of our system input is not metered	Not all, but > 50% of our system input is metered	Our system input is metered but we are not sure about the accuracy of these (partly old) meters	Our system input is metered with mechanical and/or magnetic flow meters that are rarely calibrated	Our system input is metered with magnetic flow meters that are regularly calibrated
District Metered Areas (DMAs)	We have no DMAs and have no plans to establish DMAs	We plan to install DMAs and have started to establish the first DMAs	The first DMAs are established and we have already the first results	We have several DMAs and check and analyse inflow data sporadically	We have several DMAs and monitor flow and pressure on a regular basis
Night Minimum Measurements	Up to now we did not make night minimum measurements	The night minimum consumption is metered and analysed sporadically with external instruments	The night minimum consumption is metered daily but evaluated only in larger intervalls (e.g. once in a week or month)	We analyse the night minimum consumption of the whole system every day	We analyse the night minimum consumption of each DMA every day
Process Control System (SCADA)	We do not have a SCADA system	We have started to plan (or install) a SCADA system	We have a SCADA system but not all of our system input meters or zonal meters are implemented	All of our system input meter data or zonal meter data are transmitted to a control room permanently	All of our system input meter data or zonal meter data are transmitted to a control room permanently and there are automatic alarms if limits are exceeded

A quality index for each sub process, each supporting process and for the overall process is calculated on the basis of the performance level of each single criterion in the quality matrix. Therefore the single criteria are weighted within the quality index calculation for the sub or supporting processes (an example is shown in Table 2). The quality indices of sub or supporting processes are used for the calculation of the overall process quality performance. Of course this “overall quality performance” has to be seen critically, because a lot of (sometimes soft) single criteria, which are weighted within the sub quality indices, are behind this value. These sub indices are then weighted for the calculation of the main process quality index. Anyone who has ever worked with weightings knows that weightings are not always 100% objective and others may define other weightings (Koelbl et al. 2009).

Table 2: Quality index of leak detection sub process

A	B	C	D	E	F	G	H
sub or supporting process	Code	Criteria	maximum points for single criteria	weighting within sub or supporting process	max. points of sub or supporting process	reached points	quality index of sub or supporting process
leak detection S211	2.1	general procedure in leak detection (strategy)	4	2	48 Σ (D * E)	No. of points (points of single critera * weighting)	G / F * 100
	2.2	leak location time	4	2			
	2.3	hit rate (success in leak detection)	4	1			
	2.4	accuracy in pinpointing leaks	4	1			
	2.5	documentation of leak detection	4	2			
	2.6	existing leak detection equipment	4	2			
	2.7	routine leak detection at service connections	4	2			

Selected Results

Before discussing some selected results from the first project run in Austria with eleven participating water supply utilities, the main influencing factor and grouping criterion beside the urbanity (rural, small city, large city) are discussed briefly.

Leak Detection Strategies

The leak detection strategy turned out to be the main grouping criterion. Depending on the strategy, the main focus is laid on leakage monitoring or on leak detection. Two different strategies in leak detection can be differentiated:

- leak detection as a routine survey *on a rotational basis* (e.g., annual leak detection campaigns) and without educated guesses (e.g., on basis of DMAs)
- *cause related leak detection,* e.g. on basis of DMAs

Mixed strategies are also common if parts of the network are developed as measuring zones or DMAs (e.g. outskirts, pressure zones).

Water Loss Assessment

One basic aspect of the performance comparison is the assessment of the level of water losses. Figure 4 shows the results for the Infrastructure Leakage Index (ILI). According to the definition of this PI, the ILI should only be calculated for water utilities with more than 3000 service connections. Therefore the utilities with less than 3000 service connections are marked within the figure. The ILI is the preferable performance indicator for a classification of water losses because this PI considers many structural criteria like length of mains, number and length of service connections and the average service pressure. Regarding the generally good Austrian leakage level, the following classification for the ILI's of the OVGW process benchmarking 2007 can be made:

Class C (ILI 4-8), high water losses: utility numbers: 6, 7

Class B (ILI 2-4), medium level of water losses: utility numbers: 2, 4

Class A (ILI <2), low water losses: utility number:s 1, 3, 5, 8, 9, 10, 11

At this point the importance of considering data accuracy of water balance data should also be mentioned (note: min., max. values in Figure 4 represent confidence intervals).

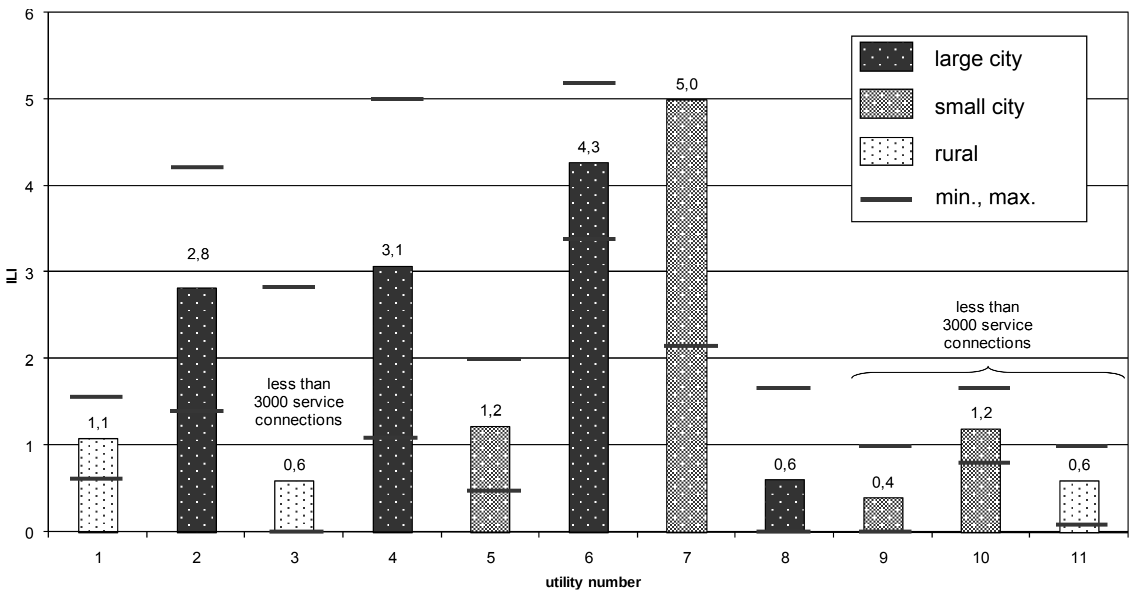

Figure 4: ILI results of OVGW process benchmarking 2007 (Koelbl et al. 2009)

The evaluation of the overall process performance is difficult, due the complex process structure and many different aspects that need to be considered in water loss management. But the comparison of economic and qualitative aspects of single sub processes works well and enables the derivation of concrete measures.

Figure 5 shows the costs of the leakage monitoring sub process and the ILI. The depreciation costs of leakage monitoring systems are considered within these costs. The effort in working hours for leakage monitoring strongly depends on the leakage monitoring systems installed and on the size of the utility. Small utilities with complex systems (e.g. many system input points and several measurement zones) have higher costs per kilometre of distribution mains or per 100 service connections than larger utilities and utilities with less complex systems. Depending on the functionality of the monitoring system (e.g. analysis software), the daily effort in working hours is variable.

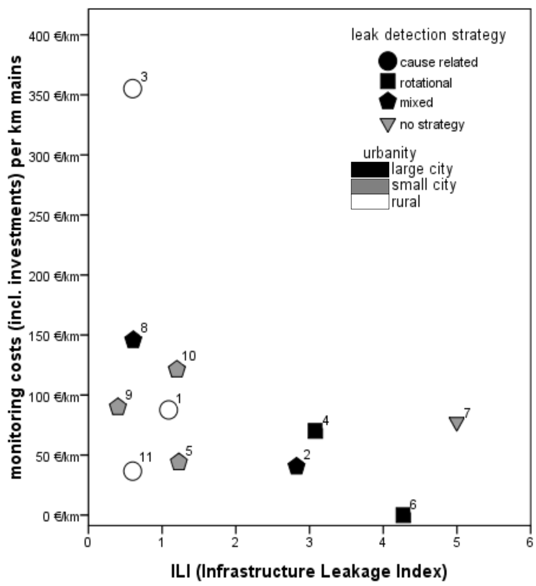

Figure 5: Leakage monitoring costs inclusive investment costs for leakage monitoring systems (results of OVGW process benchmarking 2007, in Koelbl 2009)

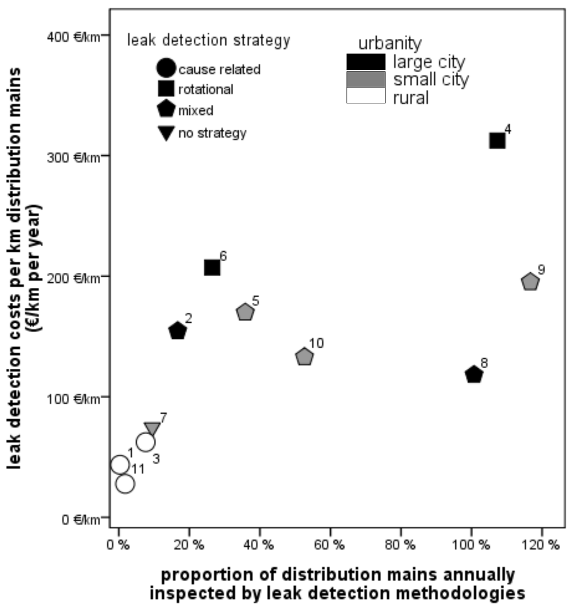

Figure 6: Costs of leak detection and proportion of network and service connections annually inspected by leak detection (results of OVGW process benchmarking 2007, in Koelbl 2009)

The unit of the cost data is € per kilometre of distribution mains per year. The two figures not only give a good overview of the water loss situation and the leak detection strategies (cause related or on rotational basis) but also of the influence of urbanity. We see that the utilities 6 and 7 have higher water losses than the other utilities. One reason could be the almost absence of an effective leakage monitoring at utility 6 and an (up to now) missing strategy in water loss monitoring at utility 7 (Koelbl et al. 2009).

Figure 6 shows how much leak detection is carried out by the water utilities per year (average of the assessment period of three years) and the costs of leak detection per km of mains. The costs related to the amount of leak detection also vary with the leak detection technology used. For example, water utility number 4 has relatively high costs using mainly common sounding methodologies like listening sticks and leak noise correlators. On the other hand, utilities 8 and 9 use noise loggers and have much lower costs for leak detection. Utilities 8 and 9 have a much better performance than utility number 4 when comparing the water loss PIs. Concerning failure rates, the three utilities are in a comparable range of about 15 to 18 failures per 100 km of distribution mains per year. Therefore utilities 8 and 9 have a comparable effort to utility 4 in pinpointing (Koelbl et al. 2009).

Another outcome of this analysis is the fact that those utilities which use DMAs (cause related strategy) have a significantly lower effort in leak detection. Utilities 1, 3 and 11 only do cause related leak detection, which is less (or much less) than 10 % of the distribution mains per year. Therefore the leak detection costs of these utilities are only a 1/4 to 1/3 of the costs of the utilities 2, 5, 6, 8, 9 and 10. Utility 7 has quite low costs because there is a lack of leak detection measures, which becomes clearer when comparing the level of water losses (Koelbl 2009).

Methodological Aspects

The 2007 OVGW process benchmarking field test was very important from the methodological point of view. The most important outcome is that the process benchmarking system developed for the process of physical water loss management works. Following the feedback from the eleven participating water supply utilities, the field test turned out to be more than just a test run. The process benchmarking system fulfilled most of the requirements for such an instrument and, therefore, the benefit for the utilities was satisfactory. But, of course, the field test also provided important information about optimisation potentials of the process benchmarking system itself. Some of these methodological experiences are (Koelbl et al. 2009):

- *Comparability:* It was found that a comparison at the level of sub processes or even at the level of single tasks works well, whereas a performance comparison of the main process of physical water loss management is difficult. Therefore it is very important to consider the frame conditions of the participating companies (e.g. age and physical status of pipes and fittings, level of water losses, general network instrumentation).
- *Process structure:* The necessary adaptation within the process structure (change of leak repair from a sub process to a supporting process) has already been discussed previously. This is necessary as the costs for leak repair are not considered because the costs for leak repair are (in general) several times higher than the costs for the rest of the process of physical water loss management. However, for questions like the long-term economic level of leakage the costs for leak repair and also costs of other supporting processes like rehabilitation have to be taken into account.
- *Investment costs of leakage monitoring systems:* For better comparability of leakage monitoring costs and the total costs of the main process it is necessary to consider the investment costs of leakage monitoring systems (e.g. measurement equipment, SCADA systems), which was not done within the

OVGW 2007 project. The estimation of the portion of investment costs which is related to leakage monitoring is difficult due to the fact that these systems, in general, are not only used for leakage monitoring but also for controlling the water supply system (e.g., control of pumps).

- *Quality matrix:* The experience with this matrix was very positive. Together with the performance indicators, the structured quality matrix enables a good overview of the strengths and weaknesses in process operation and it is easily possible to derive measures for improvement. Within the best in class workshop a comparison of the underlying practices could also be facilitated by the quality matrix.
- *Best-practices workshop:* The workshop was a central part in the field test. In this workshop the results were discussed in detail and the utilities had the opportunity to exchange their experiences. However, due to the many aspects which need to be considered in water loss management, further workshops and/or discussions and analyses, maybe in smaller groups or even bilaterally between two utilities are useful and sometimes necessary to derive concrete measures for improvement and to reach the aim of benchmarking: learning from each other.

Conclusion and Outlook

The first experiences in benchmarking the process of water loss management in Austria are mainly positive. Except for some minor improvements, the process benchmarking system works well. A performance assessment is possible on the basis of the calculated PIs and the well structured quality matrix and measures for improvement can be derived. Another aspect is the use of the performance comparison as a decision support to find the optimal strategy in water loss management for each water supply utility.

But, of course, it is a great challenge to benchmark the complex process of physical water loss management. From time to time adaptations of the process benchmarking system to future innovations and technological developments will be necessary. Another useful aspect, especially for developing countries and systems with bad infrastructure condition, could be the extension and adaptation of the system to the task of pressure management.

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