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SCADA and Smart Metering systems in water companies. A perspective based on the value creation analysis

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Abstract

Considering the invaluable service provided to the society by the water companies, it is imperative to ensure their sustainability. To achieve this objective, these organizations must be allowed to fulfil their Mission with effectiveness and efficiency. Information Technology (IT) solutions are especially important tools in this pursuit of enhanced performance and those with greater visibility in the water sector are: (1) SCADA systems, for operation and maintenance; (2) Smart Metering systems (SM), mainly focused on sales and Customer Relationship Management (CRM). Traditionally, the analysis of the advantages of these technologies has been based on the enumeration of possible and/or desired technical characteristics and functionalities, and not so much on the analysis of the value created through its impact on organizational processes. This communication presents an analysis of the benefits associated with the use of these technologies, or, more precisely, the value created through them. This analysis is based on the processes and activities they subdivide into, because these activities consume resources, hence generate costs, and it is the optimization of these costs that produces efficiency gains. Additionally, these tools generate useful information capable of creating value for the water company. This approach makes it easier to analyse the cost-benefit outcomes the water company may obtain from these technologies. Benefits for society are also taken into account, particularly water use efficiency, energy efficiency, and reduction of CO_2 emissions. The quantification of these benefits was used to build the two cost-benefit analysis (CBA) models developed to assess the potential advantages for the water companies from implementing SCADA and SM systems.

Keywords: SCADA, Smart Metering, Cost-benefit Analysis, Energy Efficiency, Water Efficiency, CO_2 Emissions

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1. Introduction

Despite their enduring Mission, water companies face important challenges at various levels: the pursuit of universality, continuity and quality of services; the protection of public health and environment, particularly by controlling the pollution caused by human activities and productive sectors; and the sector sustainability, which demands full cost recovery, and the increase of operational effectiveness and efficiency.

In most situations, ensuring the sustainability of the water company will require, in addition to adequate tariffs, a management capable of obtaining better results and reducing inefficiency costs, which are difficult to understand and bear in the current socioeconomic conditions.

Any organization, such as the water companies, depends on a series of organizational processes executed in order to design, produce, deliver and sustain its own products and services. The processes create the results an organization provides to its customers. «Process» is a technical term with a precise definition (Hammer, 2003): *an organised group of related activities that together create a result of value to customers***.**

A process is a group of activities, and these are a combination of tasks. No single task creates the desired result. Value is created by the entire process in which these tasks merge in a systematic way for a clear purpose. Activities in a process aren't random or *ad hoc*: they are interrelated and organized. Irrelevant activities are not included, and the included ones cannot be performed in an arbitrary sequence. We do the right things in the right way every time, to ensure effectiveness and efficiency. All activities in a progress must work together toward a common goal, to create the result the customers care about.

Processes fulfil two fundamental functions in the strategy of an organization: (1) they create and deliver a value proposition for customers; and (2) increase the quality of the products and services, reduce costs (enhancing productivity), and reduce delivery time.

Figure 1 (Temido and Sousa, 2010) represents the primary processes of the value chain of a water company which, as the management central core, constitute the starting point for the materialization of the company's Mission (Value chain, a concept created by Michael Porter (Porter, 1985), *is a set of activities that an organization carries out to create value for its customers*). The objective is to represent the main organizational processes in the value chain and their interactions, which link the identification of the customers' needs – the input –, and the satisfaction of those needs – the output.

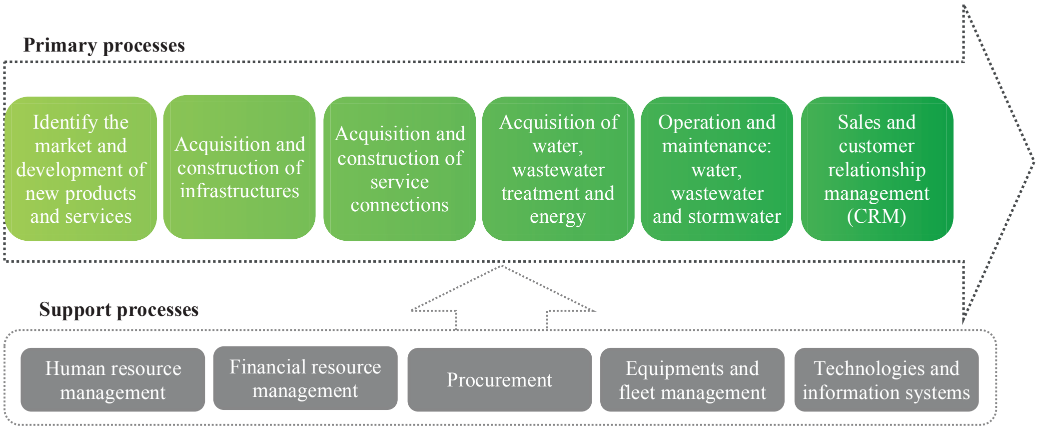

Fig. 1 - Value chain of a water company – primary processes and support processes (Temido and Sousa, 2010)

Besides the primary processes in a water company, related to the creation or transformation of products into services, there are also support processes, whose objective is to support, directly or indirectly, the execution of the primary processes. Among others, the more relevant support processes are: Human Resource Management, Financial Resource Management, Procurement, Equipments and Fleet Management, and IT Systems Management.

Due to their increasing development, IT have assumed an increasing importance in management. There is no management without information, and in the case of the water companies, with geographically dispersed infrastructures (water sources, treatment plants, transmission pipes, tanks and distribution networks), these technologies perform the very important task of providing timely and relevant information for technicians and decision-makers in the various organizational processes, enhancing effectiveness and efficiency.

For the water supply systems companies, the technologies and IT systems that have proved to be the most relevant have been the following: in terms of global (corporate) management - DWS (Document Workflow System); ERP (Enterprise Resource Planning); CRM (Customer Relationship Management); and FMS (Fleet Management System), among others; in terms of technical management, the most prominent are - GIS (Geographical Information System); HMS (Hydraulic Modelling System); SCADA; and SM.

This communication presents an analysis of organizational processes in a water company, and of the activities that constitute them. The objective is to identify cost reductions resulting from the elimination or decrease of these activities, as a consequence of introducing SCADA and SM systems, and to conduct a CBA.

2. Methodology

The project from which this communication emerged can be divided into four main phases:

1. Economic benefits calculation – includes the analysis of the organizational processes of a water company, the activities that constitute them, and the tasks associated. By consuming resources, these tasks produce costs. Thus, the benefits calculation is focused on finding where and how the technologies in consideration might reduce those costs, increasing the efficiency of the company. This procedure made it easier to analyse the benefits obtained from the use of the two IT under analysis – SCADA and SM systems.
2. Economic costs calculation – in this phase, the economic burden a water company will support to implement the mentioned IT was studied (CAPEX), as well as the operation and maintenance costs during the lifespan of those technologies (OPEX).
3. Net economic benefit models for decision support – after studying benefits and costs, in an incremental perspective, considering two scenarios – A (Business as Usual) and B (implementation of the project), two models were created, one for SCADA systems and another for SM systems. Both models rely on formulas of calculation based on the increase of the effectiveness and efficiency obtained in each activity benefiting from the implementation of those IT. These models can be applied to any water company characterized by the adequate input parameters to fill in. Besides the calculation of the net economic benefit for the project lifespan (Net Present Value - NPV), the models analyse other economic indicators, such as the Payback Period (PP) and the Internal Rate of Return (IRR). This model also allows a sensitive analysis by testing the CBA with two additional scenarios, a pessimistic and an optimistic, obtained through an adequate variation of the key variables.
4. Assessment of the impact on environmental sustainability – the models also include, besides the economic dimension (monetary appraisal), an analysis of the impact on the environment resulting from the reduction or elimination of activities in the value chain of a water company (non-monetary appraisal of environmental impact). In environmental terms, the efficiency increase generated by these technologies – SCADA and SM systems – results in a greater efficiency of water resources use, an increase of energy efficiency and a reduction of greenhouse gases emissions (particularly CO_2).

The construction of these models also allowed the identification of the organizational processes in which each technology creates more value. This way, it is possible to identify in each company the processes, and their activities, that may benefit more with the implementation of each one of the technologies.

3. SCADA systems

SCADA is a technology that comprises supervision, control and data acquisition. It enables the remote monitoring and control of the whole system, or parts of it, and processes information to generate alarms, reports, graphs or other outputs essential to operation and maintenance. In water supply systems, SCADA can monitor and control a wide variety of equipments and processes, from the water source to the customer's tap, including transmission pipes, treatment plants, tanks and distribution networks. In the urban water cycle**,** SCADA systems can also be used to monitor and control wastewater and stormwater systems.

3.1. Benefits

The assessment of the benefits arising from the installation of a SCADA system in a water company was based on the analysis of the value chain, including the organizational processes, and their activities, this type of companies perform and on the improvements that this technology may provide. Following this reasoning, some benefits were identified, as well as its origin (the activities that benefit from the technology), generating each benefit for the value chain.

I. Greater effectiveness and efficiency in operation:

One of the activities that achieve greater effectiveness and efficiency in operation is the prevention and detection of failures in the water supply system.

The remote information about the system's working conditions enable the water company to act quickly when problems occur, such as pipe bursts or electrical and mechanical failures. In case these do occur, the water company receives an alarm that offers immediate knowledge of the problem, and useful context information to rapidly locate and repair it. This way, it is possible to reduce the duration of that problem, reducing the consequent service disruption, or even avoiding it.

The fulfilment of service levels, particularly in terms of water quality, flow and pressure, is another source of benefits. By allowing the water company to monitor several parameters in real time, it ensures a greater safety in the quality of the product provided to customers, as well as better service levels. Regarding the water quality monitoring, another advantage emerges: it is possible to optimize the use of chemicals, leading, in certain cases, to a possible reduction.

The information made available by SCADA systems also helps to improve the system operation, namely a better management of the storage capacity, the optimization of the pumping stations operation and pressure management.

By enabling the remote control of valves and pumps, the SCADA systems allow faster responses in emergency situations, such as fires or pipe bursts. Remote control, gathered with the system's monitoring, can also lead to a reduction of human resources and travelling needs, especially those related to the operation of electromechanical equipments.

A SCADA system allows the optimization of the pumping stations operation, reducing energy consumption and related costs. This comes from two different origins: the system monitoring produces useful information to obtain better operation rules aimed at energy efficiency improvement and reduction of the energy bill; the reduction of water losses (to be analysed further on) decreases the volume of water to be pumped, thus leading to lower energy consumption and related costs.

The information provided by the SCADA system generates a decrease in water production (or acquisition). A greater efficiency in terms of active leakage control (ALC) generally leads to less non-planned repairs (bursts in pipes and service connections), responsible for significant flows of water losses, although with short duration. By enabling a faster response, SCADA contributes to reduce the volume of water losses and the duration of possible service disruptions. Additionally, if the water company promotes Infrastructure Asset Management (IAM), the timely rehabilitation/substitution of pipes and service connections also enables the reduction of the number of non-planned repairs. However, IAM requires information about the state of the infrastructures and operational information, and some can be provided by SCADA systems.

By reducing the number of service disruptions, particularly through the reduction of non-planned repairs, faster response in case of bursts or faults, and a better IAM, the volume of water sales increases, particularly due to the reduction of the periods of service disruption.

II. Greater effectiveness and efficiency in maintenance

A second benefit identified concerns the activities of maintenance of the water supply systems. SCADA systems reduce the costs of preventive and corrective maintenance.

By enabling a better knowledge of the electromechanical equipments levels of use, the SCADA systems make it possible to better adjust the needs of preventive maintenance, and consequently reduce potential corrective maintenance costs. The information provided by the SCADA systems also allows the detection of measurement errors and faults in flow meters installed in the water supply systems. It is thus possible to better establish their maintenance needs, decreasing possible data failures due to the faster response.

The availability of remote information about water levels (tanks), flows (pipes), pressures (nodes) and power (pumping stations) allows an early detection of faults, which in many situations may reduce its severity, and consequently imply less corrective maintenance costs.

Effectiveness and efficiency in the operation can also be increased as a consequence of the information the SCADA systems provide to IAM, indirectly influencing the reduction of the number of bursts in pipes and service connections.

III. Reduction of water losses

The information provided by SCADA systems enables the reduction of real losses in water supply systems. This technology allows an efficiency increase in the ALC, due to essentially two reasons: tank's water levels monitoring, which allows the detection of leakage and overflows; and night flow monitoring coupled with step-testing (closing of valves), enabling easier location of leaks. Since any small leak that goes undetected is a potential future large-scale burst, this action ensures, indirectly, a reduction of the amount of water lost. These benefits can be estimated as follows:

$$WLRS = RWLRS \times UCW \times \left[\frac{1-(1+DR)^{-LS}}{DR}\right] \tag{1}$$

$$RWLRS = LOST \times ALOSTS + RRL \times PIALCS \tag{2}$$

where: WLRS - Water losses reduction (€); RWLRS - Real water losses recovered (m^3/year); UCW - Unit cost of water at the system entrance (€/m^3); DR - Discount rate (%/100); LS - Lifespan of SCADA (years); LOST - Leakage and overflows at utility's storage tanks (m^3/year); ALOSTS - Avoidable leakage and overflows at utility's storage tanks (%/100); RRL - Recovered annual real losses by the ALC before SCADA (m^3/year); PIALCS - Productivity increase of the ALC team by flow monitoring from SCADA (%/100).

Additionally, remote information about pressure and tank's water levels enables, directly or indirectly, an increase in the efficiency of pressure management, reducing real losses (in water companies that perform pressure management).

A faster response to non-planned repairs also contributes to reduce water losses. By monitoring the water distribution networks, the SCADA systems allow a faster detection and location of this type of failures, reducing its duration.

If the water company performs IAM, it is possible to reduce the number of non-planned repairs (in pipes and service connections) through its timely rehabilitation/substitution. This is probably one of the most important measures to prevent real losses, and SCADA systems can give an indirect contribute, by providing useful information.

Finally, it should also be pointed that the reduction of real losses, obtained through SCADA systems, also results in the decrease of water abstraction charges (EU Water Framework Directive).

IV. Improvement of sales and CRM

The improvements of effectiveness and efficiency previously mentioned, together with a faster response to non-planned repairs, result in a greater customer satisfaction, which, in turn, leads to the reduction of the number of complaints, particularly regarding service disruptions, water quality and service levels.

V. Deferment, downsizing or elimination of CAPEX in infrastructures

SCADA systems provide reliable information extremely useful to build simulation models of the water supply systems, and these enable the optimization of the expansion and rehabilitation needs, thus reducing the capital expenditure (CAPEX).

The attainment of a good infrastructure implies a continuous effort in assets rehabilitation (replacement, renewal and reinforcement). The information provided by SCADA can be used to optimize the design of assets to be replaced, reducing the CAPEX needs:

$$RCARS = TML \times MRR \times AUIC \times IDEIS \times \left[\frac{1-(1+DR)^{-LS}}{DR}\right] \tag{3}$$

where: *RCARS* - Reduction of CAPEX for assets replacement through design optimization (€); *TML* - Total mains length (km); *MRR* - Mains replacement rate (%/100/year); *AUIC* - Average unit cost of assets replacement (€/km); *IDEIS* - Improved design effectiveness with information from SCADA (-).

By contributing to the reduction of real losses, the SCADA systems optimize the installed capacity enabling the deferment, downsizing or even elimination of CAPEX in the reinforcement of existing infrastructures:

$$DCARS = \frac{CREA}{LA} \times \left[\frac{1-(1+DR)^{-D}}{DR}\right] \tag{4}$$

$$D \approx Round\left(\frac{RWLRS}{AWD \times AGRWD}\right) \tag{5}$$

where: *DCARS* - Deferment of CAPEX for assets reinforcement due to the real losses reduction (€); *CREA* - CAPEX for reinforcement of existing assets (€); *LA* - Lifespan of assets (years); *D* - Deferment (years, ≤ lifespan of SCADA); *RWLRS* - Real water losses recovered (m^3/year); *AWD* - Actual water demand (m^3/year); *AGRWD* - Annual growth rate of water demand (%/100/year).

VI. Improvement of the systems reliability and resilience

In extreme situations, for example in case of natural hazards, by remotely controlling and monitoring in real-time the system operation, the SCADA systems enable a better decision making, providing to the water company the ability to perform faster and better responses. In addition to the main benefits mentioned above, there are others equally important, such as the fulfilment of the targets imposed by the regulation authorities. SCADA systems enable a better operation and maintenance of the water supply systems, a reduction of water losses and a better management of the rehabilitation/substitution needs, resulting in the improvement of the performance indicators used to evaluate the service provided by the water companies.

3.2. Costs

After the calculation of the benefits obtained with the implementation of SCADA systems, the correspondent costs were estimated, namely: project design and management, installation (particularly labour and materials), maintenance and contingencies in the installation phase (unforeseen costs).

3.3. Conclusions

After the completion of the model and its application to several water companies, it can be concluded that the benefits mentioned are contextual (can assume different importance according to the specific characteristics of each water company). Likewise, the CBA can produce different results depending on the level of efficiency already reached by each water company.

A rigorous analysis of the activities that constitute the organizational processes of the value chain of a water company identified economic and environmental benefits, distinguishing them according to the value created.

In the studies already performed, the reduction of water losses (real losses) represent the major benefit obtained with the installation of a SCADA system. The deferment, downsizing or even elimination of the CAPEX in infrastructures, constitutes, likewise, an important part of the total benefit. The greater effectiveness and efficiency in operation can also represent a relevant benefit, particularly in small water companies. The increase of the effectiveness and efficiency in the maintenance, along with the improvement in the CRM, presented modest economic benefits. On the other hand, the improvement of the systems reliability and resilience proved hard to quantify in terms of benefits obtained, and was not estimated in the current model.

4. Smart Metering systems

SM is a particular concept of telemetry whose goal is the remote and automatic collection of data from the customers meters, registering their consumption of water, gas or electricity. Traditional meter reading requires an employee to visit periodically the location of the meter and register its reading. The information gathered is necessary to assess the water volume the customer consumed and is fundamentally used for billing purposes. Due to the large number of meters installed and its geographic distribution, a more frequent reading of those meters is only possible by using telemetry systems. SM also provides real-time knowledge of the working condition of the meters installed, through the communication of alarms and other information about the equipments. The water company can then use this information to optimize processes and improve the services provided to their customers. SM is nowadays a growing trend in the operation of water distribution systems, along with the flow measurement in DMAs and the water consumption of the large customers, for which the volumes of water involved have long since justified the investment in remote metering equipment.

4.1. Benefits

The methodology used to study and quantify the benefits resulting from the installation of a SM system in a water company was similar to that already presented for the SCADA systems. It started by analysing the activities of the organizational processes from the value chain, identifying the tasks in which SM would create value. The elimination or reduction of those tasks was then expressed by equations with parameters customized to any water company. Among the benefits identified, the more important will now be highlighted.

I. Reduction of costs associated to meter reading

Manual meter reading is an activity that traditionally demands several resources: manpower, vehicles, travel expenses and registering equipments (like portable reading terminals). The adoption of new IT solutions, like SM, can automatically and remotely perform this activity, generating direct benefits for the water company and their customers. Due to regular meter readings, the direct economic benefit from SM can be estimated as follows:

$$RCMRM = AUCMR \times NAMR \times RAMR \times \left[\frac{1-(1+DR)^{-LM}}{DR}\right] \tag{6}$$

where: *RCMRM* - Reduction of costs associated to meter readings (€); *AUCMR* - Average unit cost of manual meter readings (€/reading); *NAMR* - Number of annual manual meter readings (-); *RAMR* - Reduction of annual manual meter readings (%/100); *LM* - Lifespan of SM (years).

Another source of benefit is the elimination of readings confirmation due to human error. For a number of reasons, the readings reaching the billing system contain errors, leading to customers' complaints and/or new travels to the readings locations.

The meters are sometimes installed in inaccessible locations, requiring scheduling the visits with the customers in order to enable the readings. If the water company has remote access to the meter reading, this problem vanishes. This can also be positive to the customer: the water company can always use "real-time" consumption for billing purposes, avoiding potential problems due to estimated consumption.

Other tasks are eliminated, such as the management of water meter reading schedules, or the readings reception and introduction in the billing system, since remote readings are automatically placed there, once more benefiting the water companies.

A reduction in the number of work accidents can also be expected, once the employees committed to meter readings are no longer exposed to potential risk situations.

II. Improvement of sales and CRM

SM has a significant impact on the reduction of CRM costs: customer billing claims, due to inaccurate meter readings; and readings confirmation. By performing frequent remote readings, SM enables early detection of customer's excessive consumption (leaks), preventing future complaints. Likewise, by always billing "real-time" consumption, complaints due to estimates above the real consumption disappear, thus reducing re-billing needs.

As the water company can remotely access the meters readings, if the meter remains at the consumption location, making new contracts or ending existing ones can be performed remotely and much faster, and this can be viewed as a new opportunity to improve CRM.

The access to better and more detailed information enables the customer service to provide easier help to the customers. It becomes possible, for example, to make an instantaneous reading of the customer's meter as he is contacting the water company.

III. Reduction of water losses

SM can also contribute significantly to reduce water losses. In the case of apparent losses, this technology proves advantageous in three main aspects: customer metering inaccuracies; unauthorized consumption; and data handling errors. Concerning the errors due to sub-metering, caused by the meters wearing, SM can play an important role, warning the water company if the meter's maximum flow was exceeded. This can damage the meter or make it loose its accuracy, increasing sub-metering. In case of jammed (no metering) or stiff meters (sub-metering), the SM system sends an alarm informing that the equipment is no longer registering consumption or is registering values abnormally inferior to those of the customer's consumption history. Experience suggests that nearly 80% of the causes of measurement errors lie in nearly 20% of the meters. In this context, SM appears as an important technology for the identification of troublesome meters (80/20 rule). Sometimes customers with large meters have consumption patterns that do not fit the meters flow rates range. In these cases the detailed information provided by SM is crucial to identify the situation and enable an adequate sizing of a new meter. The data from SM can also contribute to the detection of unauthorized consumption, another cause of apparent losses. With the detailed information about water consumption, together with the information from the SCADA system, the water company will be able to detect unauthorized uses of water. Another type of illegal practice is customers tampering the meters. In these situations, the SM system immediately generates an alarm warning the water company, and this can significantly reduce the volume of water consumed between the moment in which the tampering occurs (when the meter starts measuring deficiently) and the moment in which normality is restored. Still in the perspective of apparent losses reduction, crossing information about consumption from different utilities (water, gas and electricity) can eventually lead to an easier detection of irregularities.

Regarding real losses, SM can play an important role in increasing the efficiency of ALC. The water consumption monitoring allows the identification of abnormal consumption, which might otherwise be confused with the occurrence of bursts, generating false alarms. In the context of pressure management, by contributing to the water demand management, SM may prove relevant by allowing the reduction to even lower pressure levels, attaining greater reduction of the water losses. Data provided by SM allows the elaboration of more reliable and frequent water balances, contributing to a better definition of management and control methods. The reduction of real losses, besides the direct benefit from the water no longer lost, also leads to a reduction of water abstraction charges (EU Water Framework Directive).

IV. Improvement of water network operation and maintenance and meter management

SM system contributes to improve the operation and maintenance of the water network and the management of the water meters. These systems provide reliable consumption information especially useful for building network simulation models and for meter design purposes. Detailed information about water consumption also enables a greater efficiency in defining meter replacement needs, reducing the number of meters to replace before the legal term is reached. From the whole meters population, only a small fraction, usually corresponding to jammed meters, accounts for a very significant part of the apparent losses. The percentage of stiff meters can also be significant, and similar to the previous one. By assuming the economic lifespan to replace only the jammed and stiff meters (experience indicates that these represent about 20% of the total) and the legal lifespan to replace the remaining (about 80%), if the economic lifespan is lower than the legal lifespan the benefit for the water company can be estimated as follows:

$$RCMM = NWM \times \left(\frac{1}{ELW} - \frac{1}{LLW}\right) \times RWR \times AUCWR \times \left[\frac{1-(1+DR)^{-LM}}{DR}\right] \quad (7)$$

where: $RCMM$ - Reduction of costs of meter management (€); NWM - Number of water meters (-); ELW - Economic lifespan of water meters (years); LLW - Legal lifespan of water meters (years); RWR - Reduction of water meter replacement (experience indicates a value of 80%/100); $AUCWR$ - Average unit cost of water meter replacement (€/meter).

V. Deferment, downsizing or elimination of CAPEX in infrastructures

For water companies that practice IAM, SM can produce considerable benefits, due to the deferment, downsizing or elimination of CAPEX in infrastructures. By enabling water demand management through the reduction of water losses, particularly real losses, and by informing the customers of the occurrence of residential losses, the water companies will be able to defer, downsize or even eliminate CAPEX in infrastructures. Likewise, if the water company gives direct feedback of the customer's water consumption, then he will be able to reduce his consumption and this also contributes to defer, downsize or even eliminate CAPEX in infrastructures.

SM increases the flexibility in tariffs, enabling the water companies to encourage customers to change their habits of consumption (especially in peak hours, seasonal periods or during droughts), mitigating peak demands and reducing the stress over the water distribution network.

Finally, detailed information about consumption enables the building of more reliable decision support models, which are crucial for the adequate management of existing infrastructures and planning of new ones. The possibility of extending the lifespan of the infrastructures, through a better maintenance, particularly in a context in which water consumption tends to decrease, enables a reduction of the CAPEX in infrastructures.

VI. Improvement of the systems reliability and resilience

In situations of water shortages, SM can create conditions for prioritizing water consumption according to contingency plans, for example, assigning priority to consumption in hospitals. Additionally, through the reduction of water losses, by promoting the efficient use of water and the reduction of consumption in peak hours (better water demand management), SM also contributes to increase the network efficiency, improving the systems reliability and resilience.

VII. Value added services

Water companies can also use the SM data to provide value added services to customers interested in accessing detailed information about their water consumption (direct feedback), or receiving alarms warning them about the occurrence of leaks in their residential plumbing. Additionally, insurance companies usually provide solutions to defray material damages in case something unexpected happens that damages the household of the insurance holder or his neighbours. The timely communication of the occurrence of leaks in the customer residential plumbing can mitigate potential damages, reducing the risk associated to the house insurance premium paid by the insurance holder (usually the water company customer).

4.2. Costs

The costs of SM systems were estimated taking into account: project design and management costs, installation costs (particularly labour and materials), maintenance costs and contingencies in the installation phase.

4.3. Conclusions

The model of CBA presented here calculates the total benefit enabled by the installation of a SM system - sum of the economic value created to the water company by each of the benefits. The weight of each benefit is not equally distributed or shared in the same way by different water companies. For the water companies analysed in this study, for validation and testing of the model purposes, among the benefits mentioned, the reduction of costs associated to meter readings should be highlighted, since it leads to the greatest economic value for a SM project. The next most important benefits were the improvement of water network operation and maintenance and meter management (mostly the meter management), the improvement of sales and CRM and the reduction of water losses. However, when comparing the magnitude of these benefits, while the reduction of costs associated to meter readings represents a significant economic benefit, the remaining represent only moderate benefits.

Regarding the improvement of the systems reliability and resilience, although SM systems can offer a relevant economic benefit, as for the SCADA systems, the quantification of this benefit is quite complex, and so it was not considered in the model presented.

The benefit associated to the value added services was not considered also, admitting that it shall only be included if the water company wishes to promote the efficient use of water and consumption reduction, by giving direct feedback to its customers. Since it is each water company's responsibility to analyse the benefits and disadvantages of that option, it was not considered here, even though the model incorporates that functionality.

5. SCADA and SM systems in the value chain of the water companies

After studying the value chain of a water company, the organizational processes that constitute it and the activities where the IT might create value, it can be said that SCADA and SM are technologies with different importance in the various processes of these companies. Both technologies lead to benefits in several processes in a water company. However, analysing the importance of the various benefits generated by SCADA systems, it can be concluded that this technology proves especially relevant in operation and maintenance, followed by CRM. Regarding SM systems, the greatest benefits concern sales and CRM. However, by contributing with relevant information for other organizational processes of the water company, SM proves to be also an important tool for the operation and maintenance of water supply systems. In the cases studied, the IT considered also presented a significant impact in the reduction of the costs related to the CAPEX needs of a water company, particularly in the case of SCADA.

6. Benefits for society

Technologies such as SCADA and SM contribute for a more sustainable use of water and energy, and reduce the stress exerted on the environment, promoting the reduction of CO_2 emissions and other greenhouse gases.

By reducing water losses, water companies reduce the use of water and energy resources. SCADA and SM systems help fighting waste from the water source to the customer’s tap. By providing to the customer detailed information about its consumption (direct feedback), SM can contribute to attain a more efficient water use.

Remote reading (measurement equipments) and control (valves and pumps) contributes to reduce the distances the water company’s employees must travel to make readings, verifications, or other supervising and control routines. Remote execution of these activities enhances environmental sustainability, by reducing greenhouse gas emissions, and also reduce the economic resources necessary to develop the water company’s activities.

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