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# Data utilization at finnish water and wastewater utilities: Current practices vs. state of the art

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ABSTRACT

This paper analyses the current role of data assets and information systems at water and wastewater utilities in a context where most utilities are small to medium sized. Special focus is put on big data and open data, and existing information systems for their management. Based on a survey and the available literature, we conclude that water utilities could benefit from developing their data assets, and that increasing amounts of data will require utilities build in-house competencies related to management, technology, and security.



## 1. Introduction

The aim of this article is to study the role and usage of different datasets and information systems at water and wastewater utilities in an environment where most utilities are small to medium sized. An emerging literature highlights the potential that these data hold for improving the operation, management, and control of water systems. More efficient use of these data sets would therefore benefit utility operators, owners, and managers as well as policy makers and regulators. However, in many cases there appears to be a gap between the state-of-the-art solutions and the reality at many water utilities. This paper analyses the current status and provides suggestions for improvement.

This study was carried out in Finland, where municipal water and wastewater services are provided by numerous autonomous utilities, which are either municipality owned or small co-operatives. Finland has a population of around 5.5 million people, of which 92% are connected to centralized drinking water supply and 82% to centralized wastewater treatment. Requirements for drinking water and wastewater treatment are rather stringent and thus the quality of the operations and outputs can be considered high. The total number of water or wastewater utilities in the country is more than 1,400, of which around 400 are owned by municipalities and about 900 by cooperatives. The majority of the utilities have fewer than 20,000 customers, while 20 of the largest utilities provide service to some 80% of all customers (Water Association Finland, 2016). The situation is similar to many other European countries, such as Sweden, Austria, and Portugal. Nearly 50,000 water utilities operate in the US, the majority of which serve smaller communities (EPA, 2008).

Currently, network asset data together with water quality measurements at treatment plants (which are required by environmental authorities) and customer information form the core datasets that all utilities have in some format. The format can be digital, but as Grigg (2012) describes, the smallest utilities may only have paper records on their assets. Utility-specific information and control systems in use at water and wastewater utilities cover:

- Customer information systems (CIS)/customer care and billing systems (CC&B), customer relationship management (CRM), for customer care and billing purposes. This is a mandatory system needed for charging on water consumption, wastewater, connection fees and in some cases also stormwater fees.

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- Computerized maintenance management system (CMMS) for maintaining an asset and equipment register and planning and scheduling maintenance activities, often missing from small utilities.
- Geographical information systems (GIS) and network information systems (NIS) for network information management. These are currently used by larger utilities but not by all small utilities (Jordan, 2010; Grigg, 2012).
- Supervisory control and data acquisition systems (SCADA) for receiving data on the networks and the treatment plants.
- Other systems tailored for the sector such as benchmarking and reporting systems.

At present, the extent to which existing datasets and modern information systems are used by Finnish utilities still varies very much. This is reflected by a recent regulation requiring that utilities must have their network datasets in digital format by the end of 2016 in Finland (Act 681/2014 on the Amended Water Services Act 2014).

In the future, the amount of data available can be expected to grow thanks to digitalization. Brynjolfsson and McAfee (2014) suggest that “everything that can be digitized will be digitized and everything that can be automated will be automated“. The ongoing digitalization has been predicted to become as significant a change as industrialization was (Frey and Osborne, 2013). The emergence of inexpensive sensor devices and intelligent communication networks will bring new opportunities to utilities but also new challenges with respect to (among other things) data management. The concept of the Internet of Things (IoT) envisions that objects will collect and exchange data over the Internet, radically increasing the amount of data in many fields, including the water and wastewater sector.

In this article, examples are given based on the literature review on advanced cases of data utilization. The potential and challenges water and wastewater utility managers see in emerging new datasets are studied with a survey. Following the Survey Methods and Survey Results sections, we provide a Needs Assessment focusing on the competencies that will help utilities that wish to benefit from the presumably growing amount of available data. The Discussion section brings the findings together.

## 2. State of the art in data utilization at water and wastewater utilities

### 2.1. Advanced examples presented in the literature

Currently, data is produced mainly from measurements of different physical or chemical attributes of water at different points in the water supply and sewerage supply chain. The new potential data utilization technologies include online water metering, continuous water quality monitoring, leakage and event detection, pipe condition monitoring, real-time modeling of networks, optimization of water and wastewater treatment, and network asset management.

Online water consumption metering is an example of an existing technology not yet widely in use in the water sector. Smart electricity meters are being deployed widely already, while at the same time smart meters for water are not yet installed on such a grand scale (Stewart et al., 2010). Even though there are differences between the water and energy sectors, potential benefits exists for the water sector as well. Beal and Flynn (2015) found evidence that the awareness of the benefits of smart metering is increasing at the utilities in Australia and New Zealand. Smart online meters are able to deliver real-time data and thus help in understanding for water consumption patterns (how much, when, and where water is delivered to the consumer). Water demand estimation through smart meters can be used to optimize demand patterns even when just a part of the consumers are monitored in real-time (Aksela and Aksela, 2011; Gurung et al., 2014). Gurung et al. (2014) found that enhanced modeling and optimization of the water supply network provides financial benefits in terms of avoided system costs. Another benefit of smart meters is the large amount of data points they enable. These data can be used in the same way that network flow and pressure measurements are currently used, such as for leakage detection.

Smart water consumption meters can also provide new kind of services to customers. Britton et al. (2013) showed that smart meters are able to identify post-meter leakage. This information may be of interest to insurance companies in terms of the potential to significantly reduce water damages to property and ensuing insurance compensations. Nguyen et al. (2013) propose a model where water consumption can be measured and analyzed at the household level. The proposed architecture uses data from smart meters and pattern recognition to profile residential water consumption. The algorithms used can detect and categorize events like the use of washing machines, toilets, or showers automatically. Customers can access their water consumption history on a web site and compare their consumption to benchmark information from similar consumers. The detailed history data, trends, and up-to-date information help utilities to plan and manage the networks as well. The analysis of such data could also provide a chance to new services such as closure of connection in case of a leak inside properties. Fischer (2011) studied the overall potential of smart metering. The benefits include more efficient water use and the subsequent reduction in energy and chemicals needed in water and wastewater treatment. Despite the higher initial investment costs, smart meters are expected to prove more cost-effective in the future (Fischer, 2011).

Another relevant domain for utilities is water safety planning. Thompson and Kadiyala (2014) present a continuous monitoring system for water quality. The system is an integrated solution combining sensors and analyzers in the distribution system, data from other sources, such as customer feedback and security monitoring, data analysis, and visualization software. The results of their study show operational enhancements, such as early alerts of pipeline breaks or water quality monitoring trends, which were earlier unavailable. Examples are given of how the system has helped in locating the causes of water quality problems. An additional benefit reported in their study is improved regulatory compliance.

Preventive maintenance is another important utility activity. According to Matsuoka and Muraki (2007) preventive maintenance is the systematic care and protection of equipment and machines and the reliability of the process depends on systematically scheduling. In the most advanced cases, predictive maintenance uses sensor feedback information from equipment to make data-driven decisions, improve quality and production performance, and prevent more expansive repair costs (Fraser, 2014). The maintenance system can also be integrated through a geographical information system (GIS) platform that brings different types of data together based locational components for more efficient management of water, wastewater, and stormwater systems (Shamsi, 2005).

Continuous monitoring is also of high value in the hydraulic operation of water distribution. Many studies have been conducted on event recognition in water supply networks (e.g. Vries et al., 2016; Romano et al., 2014). For example, Romano et al. (2014) portrayed an operational event recognition system which can be used to detect and analyze pipe bursts and leakages with accuracy and reliability. The benefits reported in the study include reduced reaction time to sudden events, the diagnosis of the causes of said events and the prioritization of responses. In a broader context, real-time monitoring can be applied to continuous awareness of the network state. Real-time or dynamic modeling of water distribution networks has been investigated in several studies (e.g. Sunela and Puust, 2015; Boulos et al., 2014; Hutton et al., 2012). Real-time control is a relevant issue in sewer networks as well. Campisano et al. (2013) studied the potential and limitations of existing equipment for real-time control of sewer systems and found that the technologies needed for real-time control are largely there, even though room for improvement was found such areas as water quality measurement.

### 2.2. Big data and open data

Intelligent communication networks with smart meters and sensors produce vast amounts of data in (near) real-time. Mayer-Schönberger and Cukier (2013) introduced the useful term "datafication" to frame the idea of enabling and utilizing detailed information from various sources. Converting available data into a quantified format that can be stored easily can lead to actionable information and thus better decisions through new services, such as predictive analysis.

Datafication results in big datasets or "big data." Various conceptions of big data have been proposed in the literature (Ylijoki and Porras, 2016). Understanding big-data characteristics is essential to building related software solutions. Laney (2001) advanced the 3 V conception of big data: volume, velocity, and variety. Volume refers to increasing amounts of data. Velocity indicates the need to capture and analyze data at high speed in (near) real-time. Variety is related to different types of data, such as transactions, social media posts, and video. Some technology vendors have developed their own conceptions of big data.

A related emerging development is the rise of open datasets. According to the Open data Institute (2016), "open data is data that anyone can access, use or share. When big companies or governments release non-personal data, it enables small businesses, citizens and medical researchers to develop resources which make crucial improvements to their communities." Organizations, particularly governmental and other public actors, are producing and publishing increasing amounts of open data for the public. In the European Union, for example, spatial data is available through the INSPIRE directive (European Parliament and of the Council, 2007). Price information on municipal construction contracts are now made publically available in Finland. Social media channels are also increasing the available data. Utilities use these mostly for customer service and feedback, but they provide potential for data collection as well.

Big data and open data are partially overlapping concepts. Some open-data sources are in effect producing big data. Similarly, some actors publish big data under an open-data license. Examples include the U.S. Energy Information Administration, which currently offers more than 1000 open access data sets and NASA Earth Exchange (NEX), which provides earth science datasets and climate projections. These data are available in various formats.

For the water sector, as in other fields, big data and open data offer many possibilities in terms of asset management and system control as well as new services that can be provided to utilities and their customers. Much of the big data in the water sector is related to piped networks, but water treatment facilities can also produce large amounts of data and these data can be processed in new ways. High-grade monitoring and control of water treatment processes can thus be aspired (Haimi et al., 2013).

For various industries, data-driven organizations appear to have a competitive advantage. (McAfee and Brynjolfsson, 2012). Water and wastewater utilities can similarly benefit from a data-driven approach in measuring and improving decision-making. Even though the water sector is still at the early stages of accumulation, and the data are largely transactional, a number of documented case studies on advanced data utilization are available. In other words, the potential for these and other applications are just beginning to be explored.

## 3. Survey method

In order to map the status of the utilization of existing information systems and datasets at water and wastewater utilities, a survey with special focus on the possibility of integrating open or big data into them was conducted. The survey was designed in cooperation with key actors in the Finnish water sector. The development the survey involved the Finnish Water Utilities Association (FIWA), the Association of Finnish Local and Regional Authorities, the Ministry of Agriculture and Forestry, the Finnish Environment Institute, the consulting company Sito Ltd., and some Finnish water utilities. An online-survey link was sent to 314 water professionals working at Finnish utilities and a total of 150 utilities in February 2015; altogether, a total of 113 completed questionnaires were received.

The aim was to gain insight on current data management practices and preferences in the Finnish water sector. Different groups of professionals may take part in decisions related to data management and information systems at utilities. Because of this, one to three water professionals were selected from each utility (based on utility size) to answer to the survey. The sample covered utilities located all over Finland to ensure good representation of all the types of facilities encountered across the country. The overall response rate to the survey was 36%. Of the respondents, 33% represented top management, while 48% were other utility employees and 19%, were technical experts and maintenance engineers. The average age of the respondents was 52 years.

The survey had 24 questions, six open, of which only some were relevant for the topic of this analysis. The open questions were not mandatory, and the respondent was able to bypass individual questions. Due to this, the number of responses on individual questions varied. The questions of the survey covered different aspects related to data management and policies. These included data usability and system interoperability, license and maintenance agreement policies, current needs for training and know-how on information systems, and anticipated needs for data-related services.

### 3.1. Survey results

The survey results reported here cover three themes based on respondent perceptions about (1) information system capabilities, (2) data utilization for benchmarking, and (3) customer service and public image.

### 3.2. Information system capabilities

At the majority of utilities surveyed, according to the respondents, open data and open interfaces have not been taken into account in the existing information technology (IT) contracts and systems, such as those related to customer information or customer care and billing systems (Fig. 1).

The respondents were of the opinion that expanding existing information systems with open data interfaces or interfaces to other systems is highly expensive. The utilities typically have to order any changes to the systems from a software provider. The survey results support the idea that there is room for improvement

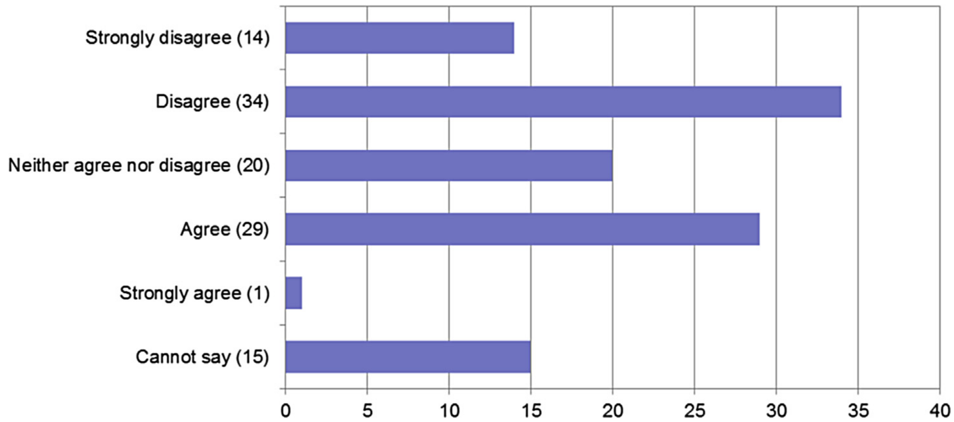


**Fig. 1.** Open data and open interfaces have been taken into account in IT contracts.

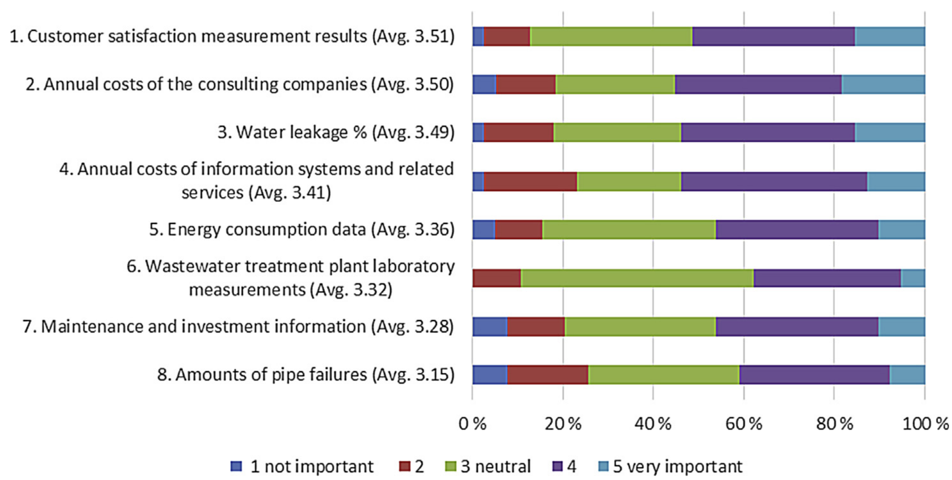


**Fig. 2.** Benchmarking the following information of water utilities can provide additional values for the water business.

in terms of open-data interfaces.

Survey respondents saw several areas where better data availability and better information systems would add value to their business and ease their daily work, including real-time monitoring of the water distribution system and utilization of data collected by smart meters. The potential for user-friendly customer care and billing systems was also mentioned. Respondents also favored getting billing systems into a cloud-based service, which could be accessed irrespective of user location. The respondents wished for an online service to report failures and inform the utility's emergency repair department. Finally, respondents wished to provide better information services and text messaging (SMS) services to customers and utility employees.

### 3.3. Data utilization for benchmarking

Respondents were also asked about the extent to which they use data from a national benchmarking system (named VENLA). The benchmarking system VENLA is provided by the Finnish Water Utilities Association (FIWA) to member utilities. As summarized in Fig. 2, the most important and useful metrics in the benchmarking system for comparing water utilities of similar size were considered to be: (1) the results of customer satisfaction surveys, (2) annual spending on consulting services, (3) operational performance data (namely, leakage levels in the water distribution system and inflow and infiltration levels in the wastewater network), and methods used to reduce leakage and inflow and infiltration.

The current web-based benchmarking system is used by 37% of the water utilities represented in the survey. The system was considered to help in developing targets and collecting information for comparative reports for the staff and the executive board. Among the respondents, 25% felt they had clearly benefited from operational benchmarking while 13% did not appear to take advantage of the benchmarking data.

The survey also explored rights of access to the benchmarking data (Fig. 3). The respondents were of the opinion that the benchmarking results should be shared among various interest groups. Three of the most important groups were considered to be the home organization, governmental authorities, and research organizations and universities.

The responses also revealed that 26% of the respondents reported that their utilities carried out a customer satisfaction survey annually and 19% mentioned that surveys were conducted every two to five years; 45% reported that surveys were not conducted on a regular basis and 10% were not aware of any customer satisfaction surveys.

### 3.4. Customer service and public image

The respondents were of the opinion that interactive online services can encourage citizens to observe and report water leaks or other problems to the water utility. They also estimated that open

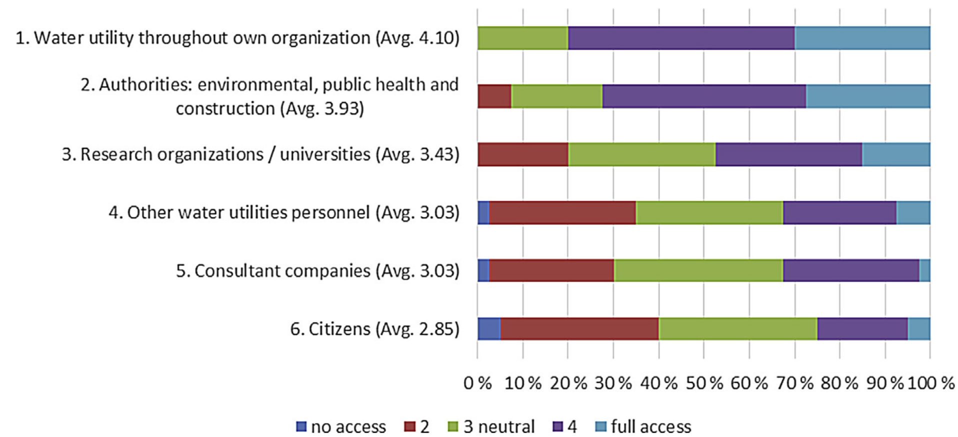


**Fig. 3.** Extents of the rights of different groups to obtain benchmarking data.

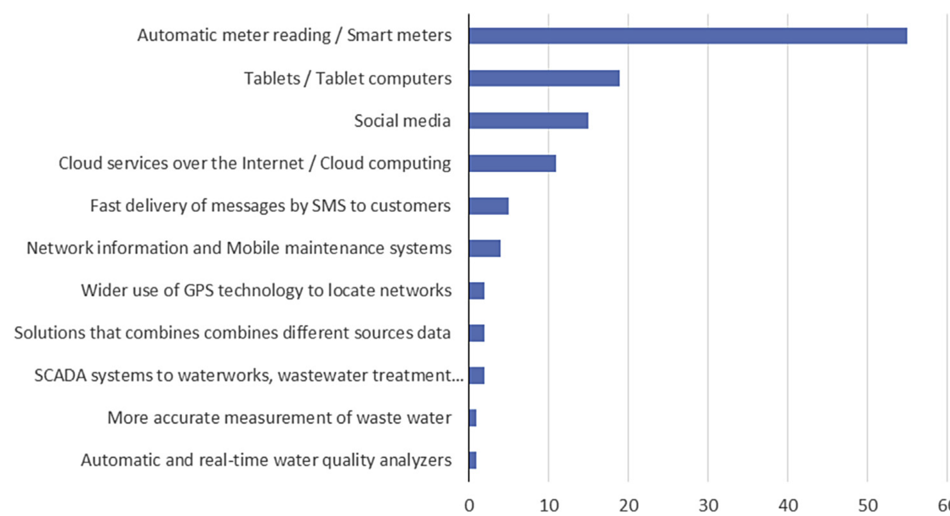


**Fig. 4.** New technological solutions which can be put into operation in the future.

data and transparency would have a positive impact in terms of convincing decision makers to increase investments for network renovations. The respondents thought that, in the coming years, the three most important technological developments will be smart meters and automatic meter reading, wider use of tablet computing by personnel, and more active use of social media (Fig. 4). Respondents expected the use of smart meters to increase progressively as their cost declines. Tablets were considered beneficial in improving for example fieldwork efficiency as they allow network and maintenance data to be entered and viewed in the field. Development of customer communication was considered an important future task. Social media channels (such as Facebook and Twitter) were expected to complement text messaging (SMS) and e-mail communication services. The role of cloud services and cloud computing were expected to play a bigger role in customer care and billing systems. Cloud services were seen to also help facilitate the administration of meetings and preparation of common documents.

In the open questions, survey respondents highlighted some ideas for improvement and future prospects in data management. They saw a need to develop consulting services for competitive tendering and long-term engineering services for automation projects. The respondents wished to outsource the GPS field surveying related to network digitalization and updating of environmental permits. Some respondents also mentioned a need for outsourcing billing and customer services. Automatic computing of non-revenue water (NRW) per network area was also mentioned. According to the results (Fig. 5), representatives of the Finnish water sector believe that more training and mentoring regarding new IT systems and consulting contracts is needed.

## 4. Needs assessment

Based on our survey results as well as the available literature, we can outline the competencies needed in the water sector due to the growing data intensity and emerging analytical opportunities. Building data-intensive capability is not a trivial task. The utilities must integrate existing and new technologies and information systems and deal with vast amounts of data in (near) real-time. This requires investments in information technology and software, as well as employee IT skills. We identify the need for competency in three key areas.

### 4.1. Managerial competency

Data-intensive approaches and decision-making processes offer many new opportunities for water utilities. However, solid leadership is essential if the utility is to succeed in efficiently developing and utilizing big data (Davenport, 2014). Utility managers may need to experiment. Making the most of big data requires a

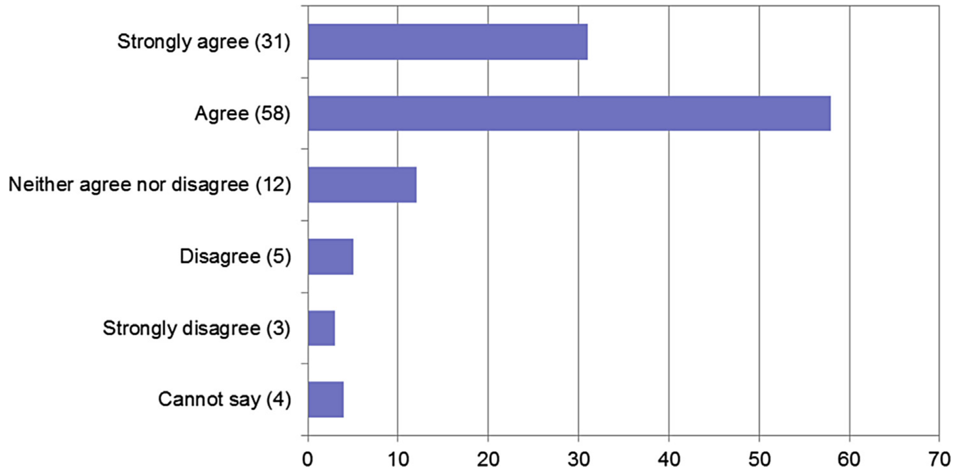


**Fig. 5.** Needs to be obtain more training and mentoring with new IT systems and consulting contracts.

data-driven organizational culture (e.g. Shen and Varvel, 2013; Dutta and Bose, 2015). In addition, utilizing data may require changes in the decision-making processes. Managing these changes requires training in how to collect, store, analyze, and report on data as well as how to use data to make better decisions. As the water sector is still in the early stages of the big data era, it is difficult to calculate the return on investment in information technologies; a less risky approach may be to start small and learn from experience (Mui and Carrol, 2013). Data intensive and agile management approaches require new leadership skills and practices in addition to data management skills. Most Finnish water and wastewater utilities are traditional organizations that are just starting to recognize the potential opportunities associated with open and big data.

### 4.2. Technological competency

In order to improve data management, new technological solutions must be adopted. As the installation base of sensors and smart meters increases, water utilities must deal with vast volumes of (near) real-time data. Current data-management platforms and information systems may require significant changes due to the growing volume, velocity, and variety of geospatial and other data. An analytics platform is required to derive value from the data for utilities and their customers. The results can be presented in a visual and accessible format. All these needs require additional expertise in analytics, software systems, software engineering, and cloud computing. These skills must be developed either inside the utility or acquired from a reliable service provider (Gartner, 2015).

### 4.3. Security competency

Water utilities have so far emphasized care of the physical security of their assets. With smart metering and cloud-based software solutions, utilities must protect themselves and their customers against unauthorized access. Smart metering also gives rise to privacy concerns. McDaniel and McLaughlin (2009) discuss security issues in the context of smart electric grids and their findings apply to the water sector as well. As they point out, vulnerabilities in software are especially attractive to hackers who may try to benefit financially or cause damage by attacking infrastructure control systems. Similarly, privacy safeguards are also needed to avoid the misuse of utility software or allowing data to fall into wrong hands.

## 5. Discussion

The expanded use of intelligent communication networks and social media will increase the availability of data in the water sector and challenge current IT systems. We considered whether water and wastewater utilities are prepared to benefit from this change, given that most are small and have limited resources. The cost of hardware and software presents a barrier to modernizing information systems. Two organizational and operational options may help overcome this barrier. One is for utilities to merge in order to achieve purchasing power. Another is for solution providers to offer services with fees proportional to the number of utility customers.

Our survey of utility respondents shed light on these issues, identifying smart water meters as the most interesting new technological development. Wider use of tablets for field work and more active use of social media were also considered potentially beneficial. Modern cloud computing services were considered promising in the areas of customer care and billing systems. Online services were expected to encourage water customers to report leaks and other failures to the utility. Benchmarking similar sized utilities was considered beneficial especially sharing knowledge about customer satisfaction, annual spending on consulting, and methods for combating leakage in water distribution systems and inflow and infiltration in sewer systems.

The survey results suggest that there is much room for improvement regarding both open data and big data utilization in the water sector, supporting the view that the industry is only beginning to understand the potential that new datasets offer. Many water and wastewater utilities are interested in smart water meters and social media. However, it is apparent that the technology platforms of most Finnish water utilities were not designed for and are not prepared to deal with large amounts of real-time data.

Based on our findings, we encourage small and medium sized utilities to take a more active approach to information management, including IT contracts that enable the development and utilization of big data. Smart meters and two-way online communication services could be offered to customers, including leak detection and usage monitoring (possibly enabling new billable services). In any case, new managerial, technological, and security competencies are needed if utilities are to make good use of the information now available to them.

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