PROJECT DELIVERABLE REPORT

NAIADES

Greening the economy in line with the sustainable development goals

DELIVERABLE 2.1

SMART WATER SERVICES DIGEST AND TREND ANALYSIS

A holistic water ecosystem for digitisation of urban water sector

SC5-11-2018

Digital solutions for water: linking the physical and digital world for water solutions

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1. Summary

This report delves on the trends in the area of smart water services for both residential or commercial consumers across all of physical and digital components, like IT infrastructure layers (e.g. devices, routers, servers, sensors etc.) and decision support tools (e.g. visual analytics, mitigation engines, etc.). It first discusses the ways in which the three use-cases (Alicante, Braila, and Carouge) have been integrating smart water services in their daily activities and offerings, throughout recent history. It will also comment on the vulnerability and threat landscape regarding the realization of the IT use-cases. Secondly, the report will provide a review of advances and innovations that IT partners have been working on the past 5 years. It will focus on the topic of IT Infrastructure layers (devices, routers, servers, sensors, etc.), on Decision Support Tools (visual analytics, mitigation engines, etc.), and Emerging Standards (research directions and commercial offerings). Thirdly, the report provides a very general overview of trends regarding SMART water services technologies. In this overview this report discusses three domains of SMART water services technologies. These are water metering technologies, data platforms and software technologies.

2. Introduction

Although the definition of 'smart city' is still developing, it is agreed among scholars that the major feature of a smart city is the use of information and communication technologies (ICT) (March, Morote, Rico, & Saurí, 2017). ICT-embedded urban systems that use sensors, real-time monitoring, and a digital knowledge-sharing platform facilitate more efficient and effective urban management. According to the literature, some of the "opportunities for IT supporting" within the area of maintenance can be divided into three main groups:

- tools for registration components of the networks and technical facilities (materials, tools) used for maintenance and repair works (i.e. ERP systems),
- tools for monitoring the condition of water supply system (i.e. SCADA systems),
- tools for identification and spatial location of the water supply components (i.e. GIS systems)

This report focuses on the trends in the area of smart water services for both residential or commercial consumers across all of physical and digital components, like IT infrastructure layers (e.g. devices, routers, servers, sensors etc.) and decision support tools (e.g. visual analytics, mitigation engines, etc.). It first discusses the ways in which the three use-cases – Aguas de Alicante, in Alicante (Spain), Compania de Utilitati Publice Dunarea SA, in Braila (Romania), and the city of Carouge: served by the multi-utility company Services Industriels de Genève SIG, Geneva (Switzerland) – have been integrating smart water services in their daily activities and offerings, throughout recent history. It will also comment on the vulnerability and threat landscape regarding the realization of the IT use-cases. It is important to mention that, although the third IT use case is based in the municipality of Carouge (Canton of Geneva, Switzerland) and concerns the irrigation of the city's public gardens, this report focuses on the work of the multi-utility company Services Industriels de Genève. This, because they are the ones that provide the water to the municipality.

This section was carried out hand in hand with representatives of the three use-cases – *Aguas de Alicante*, *Dunarea SA*, and Smart City Carouge. To this extent, they are fully aware of the facts presented here, since they were the ones who provided most of them and this information was also socialized with them in the discussions that took place at the plenary meeting held in January in the city of Alicante.

Secondly, the report will provide a review of advances and innovations that IT partners have been working on over the past 5 years. It will focus on the topic of IT Infrastructure layers (devices, routers, servers, sensors, etc.), on Decision Support Tools (visual analytics, mitigation engines, etc.), and Emerging Standards (research directions and commercial offerings). Finally, the report provides a very general overview of trends regarding SMART water services technologies. In this overview this report discusses three domains of SMART water services technologies. These are water metering technologies, data platforms and software technologies.

In the near future, after the pilots have been implemented in the three selected locations, this report will be valuable for evaluation purposes. Since it describes the ways in which the three use-cases had been integrating smart water services in their daily activities and offerings before the implementation of NAIADES, and it also enumerates the advances and innovations that IT partners have been working on over the past 5 years, **the report can be used evaluate the impacts of the project on the three locations and the collaboration between partners and pilot cases.**

3. Methodology

To write this report, three sources of information were explored. Firstly, two water utilities – *Aguas de Alicante*, in Alicante (Spain) and *Compania de Utilitati Publice Dunarea* SA, in Braila (Romania) were visited. During these visits, different staff members were interviewed, including technical and engineering executives/operators, as well as financial and customer service teams. The data obtained in these interviews was complemented with relevant literature in order to give context to the everyday operation of the utilities. In the case of Carouge, information was obtained through the website of Services Industriels de Genève and through skype interviews with Laurent Horvath, the municipal manager for the Smart City initiative.

Secondly, we conducted a survey with the partners of the NAIADES project. This survey covers advances and innovations that the different organizations have been working on since 2015. The survey was divided into three tables: the first one relates to the topic of IT Infrastructure layers (devices, routers, servers, sensors, etc.). The second table concerns Decision Support Tools (visual analytics, mitigation engines, etc.) and Emerging Standards (research directions and commercial offerings).

Finally, we also did an inventory of SMART water services technologies. This inventory is presented in Annex 1. For this we consulted the corporate websites of different manufacturers for flow monitors, pressure Sensors, leak detection devices, and smart water meter technologies. We also drew from secondary sources, specifically from Waternomics, (2015) (www.waternomics.eu).

4. IT Use-Cases

4.1 Alicante – *Aguas de Alicante*

- There are two devices one mechanical and one electromagnetic to measure the flow for the production of Alicante's groundwater wells. The utility is trying to verify with external ultrasonic meters that both are calibrated and if there is one that is out of calibration, it is repaired or replaced. These measurements are visible in the remote control room. In this area, the utility staff consider it would be desirable to have verifiers that realize that the meters are working well.

- The utility has modelled the drainage network and has also modelled the marine network of coastal waters. These modelling exercises allow the utility to prevent saline intrusions when there is an episode of rains that finally produces a sanitation pumping discharge into the sea. In these cases they create an immediate online alert.

- There is a computerized management system in the laboratory. All technical managers have access to this system and when some quality parameter exceeds the value required by the legislation an alert automatically activates. The company publishes quarterly analyses of water quality, made from water in the network and in the deposits. The citizen can see the analysis of water quality made at the point where he/she resides. The citizen can also request the report of the water that comes out of its household tap. There is also a national coordination system for drinking water: this is an online platform to which the citizens can access and visualize the analyses made in the water.
- There are quality meters in the deposits and at the exit of the deposits and in those strategic points of the network. Recently turbidity meters have been purchased. In Spain there is a sanitation decree that incorporates European parameters. Each company must have a self-control protocol. They do their analysis and any incident is communicated: "*Laboratory equipment is used every so often. There are also field values, in which turbidity, conductivity and residual chlorine are measured continuously. When there is affordable technology to measure organic carbon or to continuously measure trihalomethanes, we could establish it but for now this is done in the laboratory*".
- PH and temperature are also measured in deposit tanks and in network. In the network water pressure is also measured. This is done with very robust equipment, which seldom breaks down. The pressure is monitored with a pressure sensor that is in the field and the main values come by remote control with which you have values at real time: "*What would make this work better would be a reliable, low maintenance chlorine sensor that is not affected by pressure changes and its adjustment easily verified. That is also easy to calibrate*".
- The utility has a control center. Remote reading tele meters are being installed for household consumption and also for the few industrial customers there are in Alicante. They have full

coverage of a radio system in the city with a low power system. They have a number of information and communication technologies to deal with is leaks, asset management, network renewal, and demand prediction.

- The network is divided into *zonas* (zones). They study night-time minimums. Therefore, leak control is very thorough. The utility is able to stop instantaneous leaks of very small flows. This has to do with the fairly dense network of sensors installed throughout the network. To search for leaks a device is located on the sidewalks (in contact with a water rush) and these are left two or three days (to capture night-time values) and if they detect a permanent noise at night they mark it. The next day someone patrols around with a team and records the points where there is noise concentration. At that point another device is introduced that allows to locate the point where the noise is produced. This detects the problematic water rush(s). Technological innovations could make this work more precise: "It would locate leaks exactly, because today, due to the amount of materials that are grouped on the network, the leak has ways to go unnoticed. One factor that must be taken into account is that there is currently a lot of night noise in the city, which makes the job more difficult. If we had a dense network of conductivity meters, perhaps this work would be easier to prioritize and make searches for leaks shorter".

- The utility is not in its 100% in what concerns tele-reading. However, around 90 percent of the users have these meters. This facilitates the control of each zone.

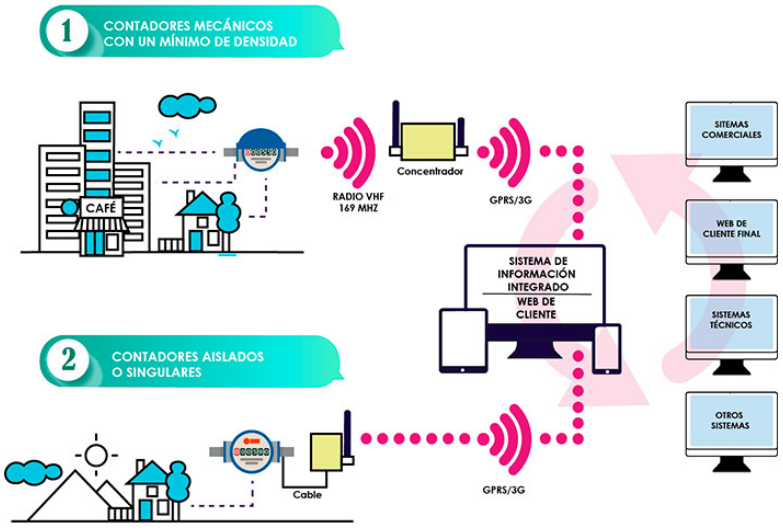


Figure 1. Alicante: Tele-reading system for users (source: Aguas de Alicante, 2020)

- Consumption is recorded with hourly frequency. It is stored in the meter itself and sent approximately once a day. The data is thus produced hourly and sent to the central system is daily. There are macro meters by sector and also throughout the city.

- As for flood prediction, Aguas de Alicante has its own system for predicting rainfall events. Flood risk predictions' information is provided to the police and the municipality. Information is also provided to citizens in real time about infrastructure works and their durations.

- In order to avoid the contamination of seawater, they built a retention tank in the southern part of the city that keeps the water, which evidently, the sewage treatment plant would not be able to treat in case of torrential rain, to avoid an overflow and it would then reach the sea. As the episodes of rain in general are fast/short water it is sent progressively, from the retention tank, to the treatment plant so that everything is treated or reused or sent to the sea but already it has been treated.

- There is another reservoir, exclusively for rainwater in the north, which is an area without slopes. There were many floods in the past because the area has no rapid exit path to the sea. Then they build a drain path that takes water to a park with a storage capacity of 40,000 cubic meters, which allows you them to send the water through a double outlet: either directly to the sea or pump it to the treatment plant to be treated. The exuberant vegetation of this park has brought many new species to inhabit it naturally, as many native bird species have arrived.

Figure 2. Parque La Marjal. Source: Aguas de Alicante, 2020

- The utility wants to advance with sustainable urban drainage solutions to integrate urban drainage systems into the natural drainage systems or a site as efficiently and quickly as possible.

- During the last five years, Aguas de Alicante has worked on 26 innovation projects, covering solutions related to leak detection and location, energy optimization, flood prediction and mitigation, asset management, consumption efficiency, resource reuse, security and health. These are some of the projects:

a) *Augmented reality*: focused on the possibilities offered by the new technologies of Augmented Reality. It developed an application open to the public for communication and monitoring of the evolution of the main works planned / in progress in the city.

b) *The E-Wise platform (Web of information on existing services):* provides information on all the services managed by the utility under the public roads. This way, users can know the services that are in the subsoil avoiding occupational hazards, accidents, cuts in the supplies or defects in existing infrastructure every time a work is carried out on public roads. Updated information of the networks is provided anywhere in Alicante.

c) *Metrawa* (*Decision Support System for the Renewal of Distribution Networks)*: it had the task of optimizing the decision of which networks should be renewed, and which investments should become a priority. It analyzes all the relevant aspects for the replacement of drinking water pipes and their consequences on the level of service required. Metrawa's multiparameter analysis includes aspects such as: structural analysis, based on an aging model of the pipes; hydraulic analysis: suitability of the hydraulic behavior of the network; economic analysis (optimal renewal time versus repair costs); risk analysis, including aspects such as traffic conditions, the impact on subscribers or the existence of sensitive areas. Thus, Metrawa integrates with the Geographic Information System to incorporate its data and provides results that include renewal priorities, expected costs and future evolution of the structural state of the network.

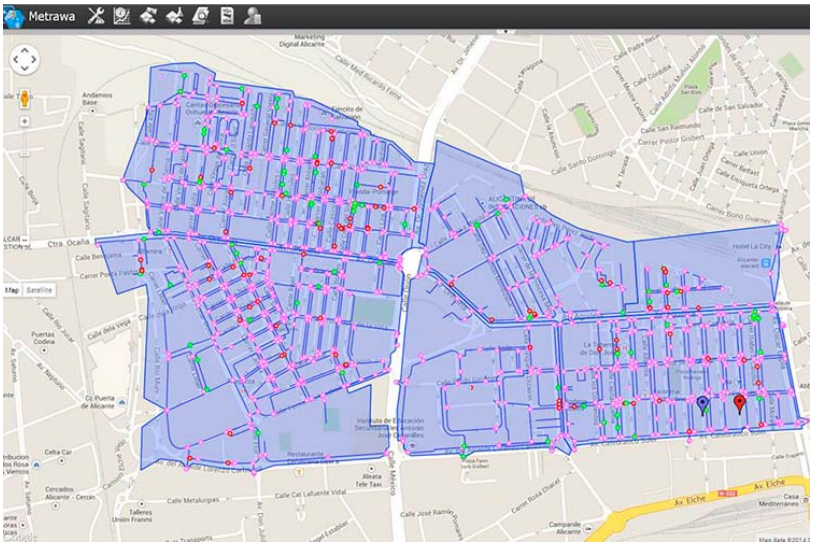


Figure 3. Decision Support System for the Renewal of Distribution Networks, METRAWA.
Source: Aguas de Alicante, 2020

d) *Acoustic Evaluation of the State of Conductions (ePulse):* This project has successfully tested the ePulse technology for the first time in Spain. The system, based on the introduction of an acoustic wave in the pipe section to analyze, allows to obtain a diagnosis of the state of the pipes through the analysis of the speed of propagation of the sound in its walls. The technology has been validated in 21 critical points of the distribution networks of Alicante, with favorable results. In addition, the project has allowed the development of a new calculation algorithm for those cases where the pipes have calcium carbonate inlays. In this way, and thanks to the collaboration between the technicians of Aguas de Alicante and the Canadian company Echologics, it has been possible to calculate not only the level of wear of the materials, but the thickness of these inlays if they exist. Thanks to this innovation, the utility has for the first time a window that allows them to "take an X-ray" of the state of the pipes, without the need to extract samples or do excavations, thus avoiding inconvenience to citizens. The results will be integrated into the METRAWA decision support system of Aguas de Alicante, making it possible to transfer the conclusions of the diagnosis to the entire network.

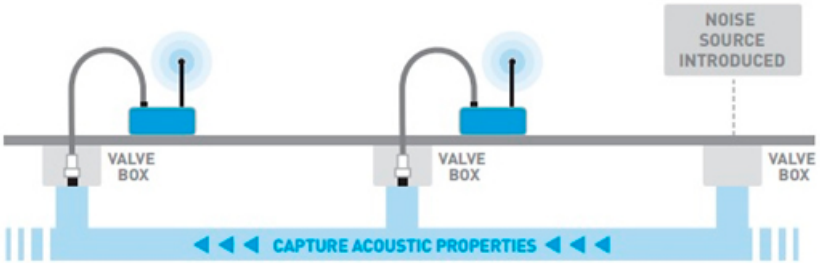


Figure 4. Epulse system. Source: Aguas de Alicante, 2020

e) DAIAD (http://daiad.eu/) was an initiative supported by the Seventh Framework Program of the European Union, carried out together with research centers, NGOs and Greek, Swiss, German and British companies. As a result of the project, the Amphiro b1 device was developed, which was awarded the Innovation Radar Prize award from the European Commission in the "Tech for Society" category. The Amphiro shower monitor, together with the telelecture meter, helped citizens become aware of their water consumption. The device was connected to smartphones and allowed people to keep a record of user consumption (that in turn allowed trends to be identified and comparisons made). Together with the meter, an app and web platform were created for monitoring the consumption of water and energy (hot water) in the home. In addition, a study of the effect on consumption of different information and awareness strategies was carried out through the app. This project had the voluntary participation of more than one hundred homes in Alicante that tested the system for a year, and with the collaboration of several NGOs in Alicante.

Figure 5. DAIAD. Shower water consumption app. Source: Aguas de Alicante, 2020

f) ARA System: conditions of stagnation and anaerobiosis can develop on water stored in the open air. In addition, in the summer, reservoirs can be affected by the sudden death of the ichthyofauna due to high temperatures or by the existence of organic matter,. To prevent these situations, a simple, effective and energy efficient aeration device was developed that helps maintain adequate sanitation conditions in these waters.

Figure 6. ARA System. Source: Aguas de Alicante, 2020

g) iDROSMARTWELL: To promote the efficient production of groundwater, save on operation and maintenance costs, and make the supply and the conservation of the environment compatible, the utility, in collaboration with *Suez Advanced Solutions*, has developed an expert and advanced system that allows a continuous audit of the efficiency of the well, and a complete analysis of the operation of the assembly formed by pumping and aquifer. This intelligent system is capable of calculating efficiency indicators, maximizes the performance of the installation (hydraulic and electrical) and foresees problems that may affect water production. IDroSmartwell is a tool that provides complete and accurate information on the control of water bodies; allows the operation control thanks to the calculation of a large number of hydraulic and electrical parameters, the management of these by means of an operator panel and the possibility of automating and controlling the installation remotely; and reduces costs by decreasing breakdown rates and monitoring efficiency ratios.

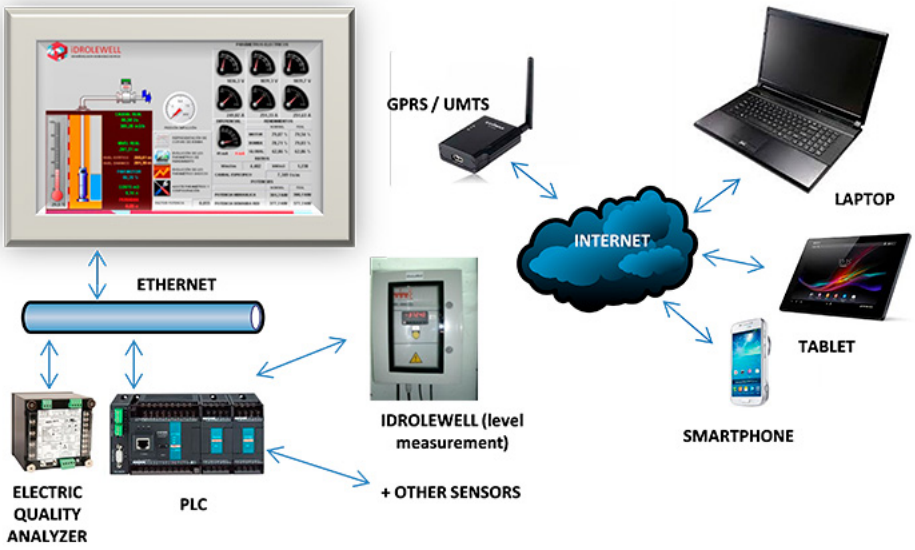


Figure 7. iDROSMARTWELL. Source: Aguas de Alicante, 2020

4.2 Brăila - SC Compania de Utilitati Publice Dunarea SA Brăila

- On average Dunarea extracts from the Danube 1,666 m3 of water per hour. Utility staff measures this inflow with SONOFLO ultrasonic flowmeters. They report the overall water network inflow through a SCADA transmission schedule.

- In what concerns pressure, if the flow is low they do not have any difficulties and are available of meeting all national performance indicators. With high water demand they sometimes can offer the right pressure in the pumps. This is for the regional area supply. The station that supplies the rural towns was financed by European funds in 2007-2013 and it designed for an average annual consumptions. However the capacity of the infrastructure is not meeting its actual demand.

- To monitor warnings/events on faults (leakages, bursts) and unusual water consumption they do a thorough network inspection and rely on the damages reported by dispatchers. They have historical values of consumption per sector and they monitor if this value goes above average (above a threshold calculated on the basis of historical data) and then detect a possible leakage. They are monitoring the nightly consumption from midnight to 6 a.m. The water that is consumed on that time is classified as technical losses. They are currently monitoring pressure in 40 points of the city. They use the SCADA sensors in these points. In the future they would like to organize all city neighborhoods into *sectors* (street metered areas) that can be supervised. Today the sectors in

the city centered are well monitored: they have micro-meters and they compare this consumption with internal consumption. They want to expand this system to monitor other parts of Brăila. They want to expand the technology that they have already.

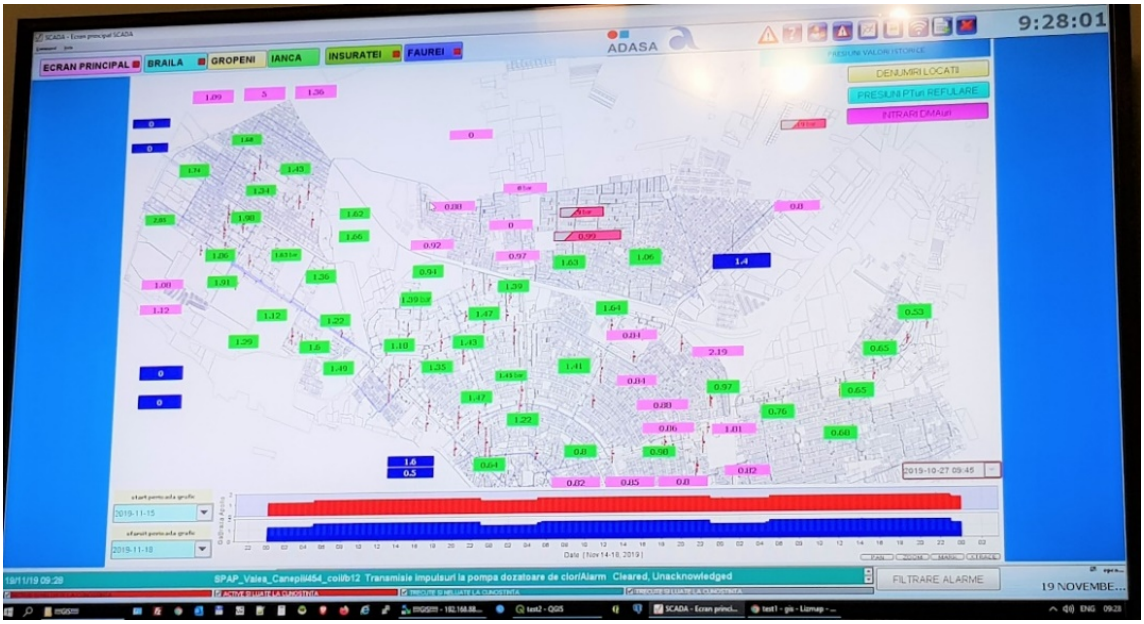


Figure 8. City of Brăila : Pink (metered/delimitated sectors), Blue (main pumping points of water into Brăila), green (pressure stations inside sectors and all over Brăila). Source: Dunarea 2019.

- In the future they would like to organize all city neighborhoods into sectors (street metered areas) that can be supervised. Today the sectors in the city center are well monitored: they have micro-meters and they compare this consumption with internal consumption. They want to expand this system to monitor other parts of Brăila. They want to expand the technology that they have already.

- To modernise the current water infrastructure, the utility has also decided to install Itron's Flodis/Flostar M meter equipped with smart radio modules, to replace the utility's lower precision meters. With the support of local Itron partner Vestra (Elsaco Group), these meters will be deployed for residential, commercial and industrial customers.

- Mobile data collection allows the utility to reduce meter reading time and cost, and avoid manual reading mistakes. Smart meters store and transmit enhanced, advanced data.

- In Brăila 80 percent of the consumers already have smart meters. Next year they will have a full coverage of smart meters to record real time consumption. They are also going to implement metering with daily sending the data so they can see leakages on daily basis. They have special meters for big consumers to monitor all atypical consumption.

- They have two drinking-water plants. They monitor water treatment processes with semi-automated monitoring and qualified personnel. They have a regional SCADA system and an individual local SCADA system supervised by the operators locally. To make sure the water leaving the treatment facility complies with national and international water quality guidelines and standards, they do daily and hourly monitoring of chemical and biological parameters. They have their own laboratory accredited by the Romanian water regulator.

4.3 Carouge – Services Industriels de Genève SIG

- As a metropolitan region, which includes Carouge, Geneva has plans to become a "smart city". SIG defines this as "a city capable of offering its residents a high quality of life with minimal resource consumption, thanks to an intelligent combination of infrastructures and technological innovation". The utility advertises that it "intends to become the preferred partner for the development of smart cantons, cities and municipalities in Geneva". Some of the concrete projects that the utility is developing are:

- éco21: Through its eco21 program, SIG plays a role in assisting with user control with residents in order to help them achieve the environmental objectives of their neighbourhood or canton. The "eco-housing" programme entails visits from experts to help residents to make good use of the energy facilities available, creating exchanges that promote integration within neighbourhoods. In addition, Activéco habitat, a personalized online service, informs households about their consumption levels and gives them advice on how to consume less and better.

- App GIS and me: SIG makes available to its individual customers the free mobile application SIG et Moi, an app intended to simplify their lives: personalized invoice notifications, of the date of passage of the index reader, possibility of transmitting online statements of meters, monitor real time consumption, curbing consumption advice, etc. The application also makes it possible to manage online the procedures relating to a move in or move out in the canton.

- GéniLac: This system has been able to take advantage of the lake's water to cool and heat homes and business buildings. The principle is simple: in summer, the water collected at a depth of 45 meters, cools the buildings via a network of sub-lake conduits. In winter, heat pumps can be added to the system to heat buildings. This feat of innovation is accompanied by a control system that automatically optimizes its operation in real time according to the needs of buildings, which reduces thermal losses by more than 10%.

Figure 9. GéniLac. Source:

- SmartVisio: SIG offers its business and property management customers an intelligent solution for greater efficiency. The Smart Visio multi-fluid online platform supports them in the daily monitoring of their different energy/water/heat consumptions and control their costs.

5. Vulnerability and threat landscape regarding the realization of the IT use-cases

5.1 Alicante

Alicante experienced economic prosperity throughout the late 1990s and early 2000s, characterized among other things by a construction-boom. The economic crisis that affected Spain from 2008 was felt in the city through the decline in construction and an increase on unemployment. Currently, although the country has recovered, the city experiences high levels of inequality as high-end tourism coexists with still significant unemployment rates and with dynamics of migration across the Mediterranean. Thus, the city's GINI coefficient which quantifies income inequality levels (0 in case of perfect equity and 100 in case of perfect inequality) is 35,5 – five points above the national one.

> In the case of Alicante, housing ranged from old, deteriorated homes of unimaginable extremes, with minimal facilities, sometimes shared by immigrants or inhabitants with a reduced economic capacity, with very high levels of unemployment, in areas that have been significantly affected by the current economic crisis, through to splendid mansions in the areas where the higher-income population resides (Morote, Hernández, & Rico, 2016, p. 7)

Therefore in this city, which already uses many existent smart technologies, one of the biggest challenges/threats comes from inequality. Despite the existence of block tariffs and of some social funds (collected from the profit made by the utility) to alleviate debt and the weight of tariff payment among low-income households, smart technologies should not broaden the inequalities:

> "Affordability of water (and also of energy) will likely be a major challenge for cities in the developed world and may involve growing social and economic inequities. Thus it is urgent that moves towards sustainable uses of water in cities fully incorporate notions of water justice, so that the conservation burden does not fall disproportionally on the more vulnerable" (Saurí, 2019, p. 13).

It is worth mentioning that, since the year 2000, there has been a general decrease in water consumption. Aguas de Alicante has good network efficiency. Water loss is less than 10 percent, counting both physical and commercial losses. This, together with citizen awareness and the use of reclaimed water, has led to the persistent reduction of consumption of drinking water per capita in the city in the last 20 years. The total amount water supplied to the city has been reduced despite the fact that the city has grown.

However, this decrease has been more significant in high/middle income detached houses and apartment blocks (located across the city's northern sector) than in low income households (located mostly in the urban core). This, according to the interviews and relevant literature, can be due to the acquisition of domestic appliances that are more water-efficient (March et al., 2017; Morote et al., 2016). Therefore, rather than smart technologies that will indicate their consumption in real time, low income households in Alicante, may require subsidies for the purchase of new appliances that consume less water.

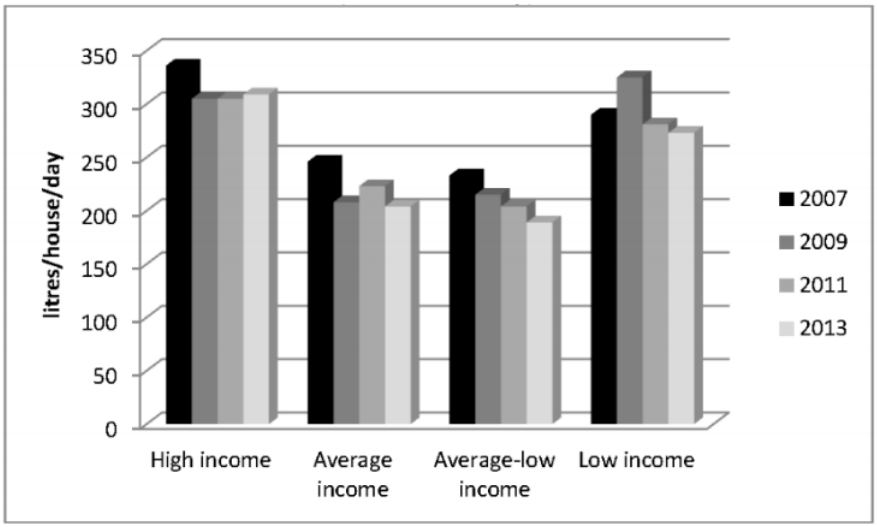


Figure 10. Household consumption in Alicante. Source: (March et al., 2017)

5.2 Romania

There is a Romanian popular saying: "nothing takes longer than a blind man's journey to the city of Brăila". This popular saying summarizes, in a way, the situation of Brăila, as a municipality isolated from the capital of the country and from the largest production centres due, among other things, to the absence of fast roads and nearby airports. Paradoxically, the city is at the same time situated on the banks of the Danube River and during the past it served as an important port and a node for the shipping industry.

After Romania's 1989 revolution, communist regimes felt and industries were privatized. In this vein, the deindustrialisation of Eastern European countries took place much more abruptly than in Western countries and it stretched over a longer period (Bănică, Istrate, & Muntele, 2017). The reduction in production capacities led to the dismissal of a significant part of the labour force in the late 1990s and as a consequence, municipalities like Brăila showed low levels of development in the public infrastructure, environmental pollution, and low attractiveness for investment (National Institute of Statistics, 2016). In this context the overall population of the city has lost about 20.000 inhabitants in the last 20 years and the age distribution pyramid is showing also a trend of aging in the remaining citizens.

During the last decades the utility has received multiple funds from the European Union, such as the Investment Programme which aimed to extend and rehabilitate the water and wastewater infrastructure. The utility is trying to plan ahead on ways to operate with their own funds once the European funding ceases. One of their vulnerabilities is that the average total of monthly water consumption has decreased drastically as a consequence of economic stagnation and migration to the bigger cities or to northern Europe. Utility staff also mentions that the decrease of water consumption also has to do with the aging of the population, as they have noticed that sectors of the city with older population tend to consume less water.

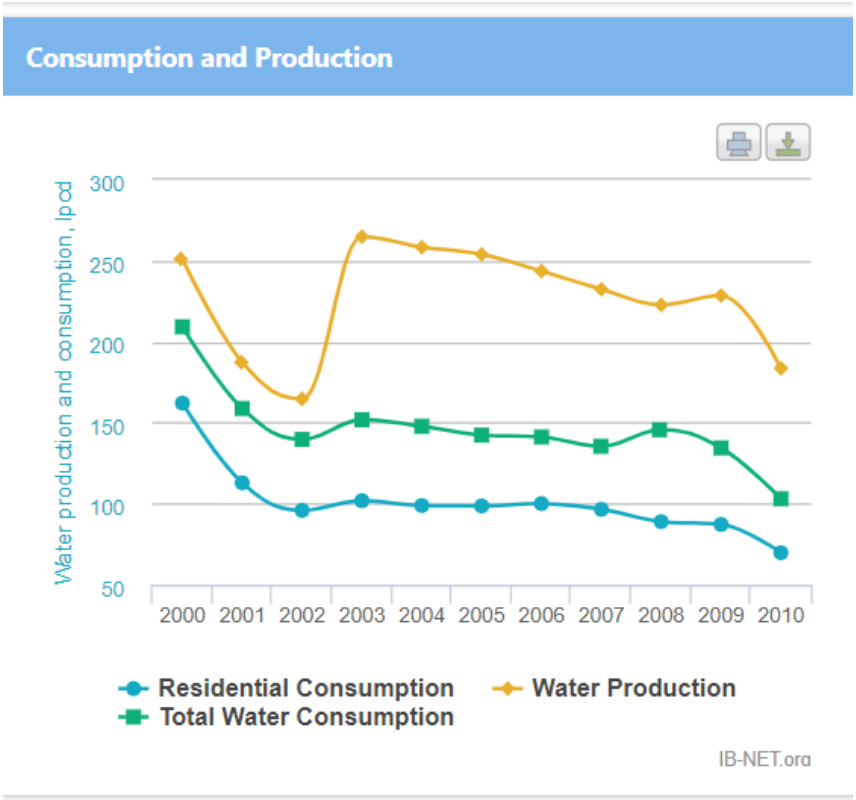


Figure 11. Household consumption in Braila. Source: Dunarea, 2019.

There is a high level of debt among domestic clients in general. By November 2019 (in the date of the visit to the utility), 836 clients had been notified of imminent disconnection. The biggest consumer in the city today is the supermarket Carrefour. Therefore today services are more important than industry. Full cost-recovery is achieved with most efficiency in the services sector. There are some industries that have accumulated debts.

In conclusion, challenges and vulnerabilities are related do with the fact that a number of the population is unemployed and that middle and low income households affected by unemployment are accumulating debt. Another challenge might come then has to do with the shrinking of the city's population due to accelerated de-industrialization.

5.3 Carouge

Carouge is a growing city. Historically industrial, the city has now become also service oriented as multiple fashion boutiques and gadget shops have opened. It receives an important number of tourists during the summer: The city is growing, we went from 20.000 inhabitants to 30.000, and there are now lots of new apartment buildings.

In order to support a strong citizen demand, the municipality, in partnership with the group of environmental activists created 180 garden boxes at different points in the city.

Figure 12. Public gardens: plant and vegetable boxes, Carouge. Source: Municipality of Carouge, 2019.

Everyone can grow and harvest freely and without registration the plants and vegetables of their choice, in an ecological way. All expenses for the boxes are taken from taxes. The City of Carouge provides the water in trucks with cisterns. Workers from the city go to each of the 180 vegetables/flowers, boxes: *"They have to water them manually, they do not have pipes or automatically systems because these are artificial boxes"*.

The water comes from the multi-utility company SIG. It is treated water and charged by the number of thousand litters. They pay for supply and also treatment. These activities are supervised by the One *Departement de la Voirie* (department of roads). This department is in charge of cleaning the streets, removing solid water and watering all public gardens and boxes between 1 or 2 times per week. If it is extremely warm, they have to water them more. The activity is not only time consuming for the city workers but also water inefficient. However, the municipality is proud of the garden boxes program and wants to continue expanding it since it is highly regarded by the population. For this it will be useful to count on technological solutions that can help same money and time.

There are not any visible vulnerabilities in Carouge. It is a growing and very prosperous city in need of smart technologies to manage its decorative irrigation. The city's main concern is to continue with the "vegetable boxes" program, as it fosters trust and integration among residents.

6. Trends and Advances Survey Task 2.1

As part of task T2.1 we are documenting the current trends and advances in in the area of SMART water services for both residential and commercial users. One of the methods we use to identify the trends and advances of SMART water services is to survey the partners of the NAIADES project. In the two tables below, we would like you to indicate what advances and innovations your organization has been working on the past 5 years. The first table relates to the topic of IT Infrastructure layers (devices, routers, servers, sensors, etc.). The second table concerns Decision Support Tools (visual analytics, mitigation engines, etc.) and Emerging Standards (research directions and commercial offerings). If a particular table/row or cell is not applicable for your organization you can just leave it blank.

6.1 Partner: SIMAVI/SIVECO

6.1.1 Table 1: IT Infrastructure Layer

IT Infrastructure Layers	**Digital components**	**Physical components**	**Additional Comments/Images or other information**
Devices	-	-	-
Routers			
Servers		3 servers: - 2 web base - 1 Data base Oracle	First 3 servers mentioned before are for app MyApa, mentioned below. Oracle is for SIVECO Business Analyzer
Sensors			
Other…			

6.1.2 Table 2: Decision Support Tools and Emerging Standards

Topic/Theme	Trends and Advances	Additional Comments/Images or other information
on Support Tools Visual analytics	NA	NA
Mitigation engines	NA	/NA
Other…	2 app: *MyAPA* – application developed for water companies, web based in which the consumer fills the water consumption , pays the bills, gets notification. *SIVECO Business Analyzer* – app that monitors and correlates all levels of activity within a company, allowing for analytical and synthetic real time data processing.	
Emerging Standards Research Directions		

Commercial Offerings		
Other…		

6.2 Partner: EURECAT

6.2.1 Table 1: IT Infrastructure Layer

IT Infrastructure Layers	**Digital components**	**Physical components**	**Additional Comments/Images or other information**
Devices			
Routers			
Servers			
Sensors			
Other…			

6.2.2 Table 2: Decision Support Tools and Emerging Standards

Topic/Theme	**Trends and Advances**	**Additional Comments/Images or other information**

on Support Tools Visual analytics		
Mitigation engines	(1) Risk assessment framework to define a strategic action from risks.	(1) A Risk assessment framework able to explore risk and the corresponding mitigation actions.
Other…	(1) DSS for managing water distribution and large scale (2) A DSS to manage resources at global scale (3) Bathing and Quality DSS (4) Water quality early-warning systems	(1) A DSS comprising Case-based reasoning to plan urban water distribution (pump scheduling) based on the prediction of the demand consumption. (2) Rule based reasoning to manage resources at large scale (from abstraction to the final consumption). (3) A DSS aimed at determining water quality in beaches while reducing CSO spills in waste-water networks. (4) A semantic enriched engine to detect water quality events on real-time. It permits to detect alerts on real-time to reduce the impacts of critical events over the network.
Emerging Standards Research Directions	(1) SAREF-WATR	(1) In order to cross-domain exchange information, there is a trend on using and adopting SAREF framework to bring semantic interoperability at cross-domain.

Commercial Offerings	(1) WaterML2.0 (2) INSPIRE (3) NGSI-LD	(1) A data exchange model used for digital services in water domain. They elaborated a semantic framework to support the data interaction between systems. (2) INSPIRE data format for exchange gepgraphic information. (3) NGSI-LD offers a context-broker specifications to integrate data inside FIWARE.
Other…		

6.3 Partner: ICCS

6.3.1 Table 3: IT Infrastructure Layer

IT Infrastructure Layers	**Digital components**	**Physical components**	**Additional Comments/Images or other information**
Devices	N/A	N/A	N/A
Routers	N/A	N/A	N/A
Servers	N/A	N/A	N/A
Sensors	N/A	N/A	N/A
Other…			

6.3.2 Table 4: Decision Support Tools and Emerging Standards

Topic/Theme	Trends and Advances	Additional Comments/Images or other information
on Support Tools Behavioural Change Support Systems, Persuasive Technologies and Water Consumption Awareness	Increased efforts towards environmental sustainability are focused on demand side policies, seeking to affect the choices of individual consumers so that a 'reasonable' use of resources is reached, through the use of so-called persuasive technology (Schiefelbein et al., 2019). The latter refers to the application of psychological principles of persuasion to interactive media, with the aim to change users' attitudes and behaviors and maintain this change over time. Most persuasive technologies in the area of water conservation are largely limited to sensing and feedback at the point-of-consumption and to simple ambient displays, in the context of HCI research, with the practical limitation that the costs of purchasing and installing such devices citywide seem formidable. Some recent works approach persuasive technologies from a web-based application angle, by integrating data from sensors and providing feedback, visual analytics on water consumption, dashboards and decision support systems for water saving. However, the ability of massive	Related work of ICCS has been published e.g. at (Magoutas et al., 2015). Magoutas, B., Papageorgiu, N., Misichroni, F., & Mentzas, G. (2015). Watercity: triggering residential water conservation through social persuasive technology. In *E-proceedings of the 36th IAHR World Congress* (pp. 1-4).

	real-time social sharing and comparison made available through social media and social networking, is a rather underexplored aspect. In the last years ICCS has been working on the design and development of innovative web-based persuasive technology that aggregates social motivation, visual analytics and other persuasive strategies by exploiting social media, with the aim to promote engagement and enhance user participation in water conservation activities. See: Schiefelbein, U. H., Pereira, W. B., de Souza, R. L., Lima, J. C. D., & da Rocha, C. C. (2019). The Use of Persuasive Strategies in Systems to Achieve Sustainability in the Fields of Energy and Water: A Systematic Review.	
Mitigation engines	N/A	
Other…		
Emerging Standards Research Directions	N/A	N/A

Commercial Offerings	N/A	N/A
Other…		

6.4 Partner: AIMEN

6.4.1 Table 5: IT Infrastructure Layer

IT Infrastructure Layers	**Digital components**	**Physical components**	**Additional Comments/Images or other information**
Devices			
Routers			
Servers			
Sensors		• VFA sensor (for anaerobic digestion monitoring) • Cyanobacteria sensor (for wastewater treatment systems) • Organic compounds sensor (for fermentation)	• See PAVITR project www.pavitr.net • See INCOVER project https://incover-project.eu/ • See THRISENS project (regional)

		• Trihalomethanes sensors • Micropollutants sensor (diuron as example) • Fiber optic sensors for temperature and strain measurement in harsh conditions	• See ACACIA project (regional)
Other…	AI Models to obtain THM from TOC and other water parameters. Tree monitoring through hyperspectral imaging AI monitoring and control of industrial processes, zero defect		• See THRISENS project (regional) • See SILVA project (regional)

6.4.2 Table 6: Decision Support Tools and Emerging Standards

Topic/Theme	**Trends and Advances**	**Additional Comments/Images or other information**

Decision Support Tools Visual analytics		
Mitigation engines		
Other…	• INCOVER DDS for recovery technologies selection in WW • PAVITR DSS for water management technologies selection	• See INCOVER project https://incover-project.eu/ • See PAVITR project www.pavitr.net
Emerging Standards Research Directions	• Smart water projects • Sensors for water management • Digital Twins (sensorization, IoT, AI modelling) • Hyperspectral imaging for water reservoir and plants monitoring; irrigation scheduling. • AI for production management, defects detection, predictive	• See INTEGRADDE project http://www.integraddeproject.eu/ • See VINIoT project http://viniot.eu/

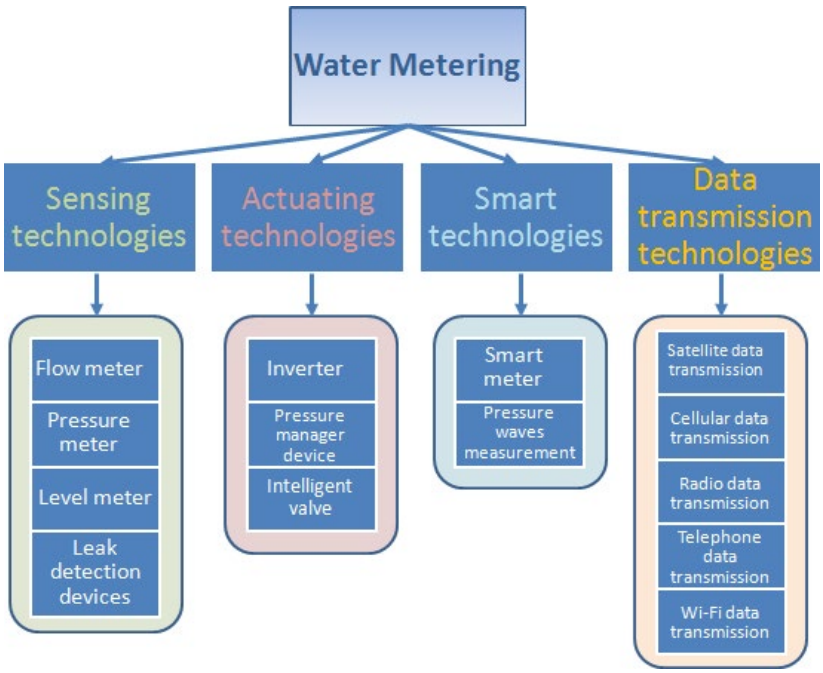
	maintenance, root cause analysis.	
Commercial Offerings		
Other…		

7. ANNEX 1: Inventory of SMART water services technologies[1]

In this section we provide an overview of trends regarding SMART water services technologies. In this overview this chapter discusses three domains of SMART water services technologies. These are water metering technologies, data platforms and software technologies.

7.1 Metering technologies

In the domain of SMART metering technologies different technologies can be distinguished. For water metering we distinguish sensing technologies, actuating technologies, smart technologies and data transmission technologies.



7.2 Sensing technologies

Sensing technologies concern measurement techniques concerning flow, pressure and leakage detection.

7.2.1 Flow measurement

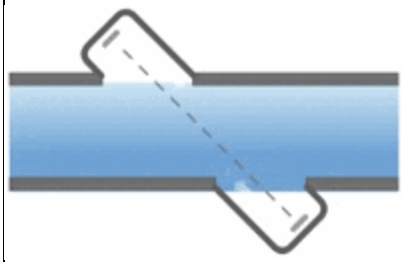
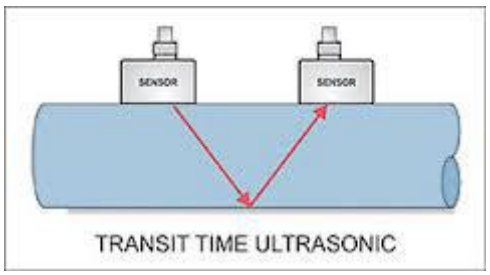
Most flow measurement instruments determine the flow rate based on measurements of the liquid's

[1] This inventory is largely based on Waternomics, 2015.

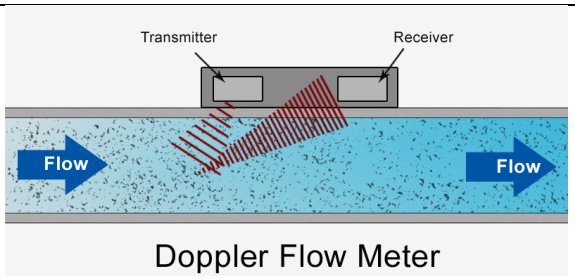
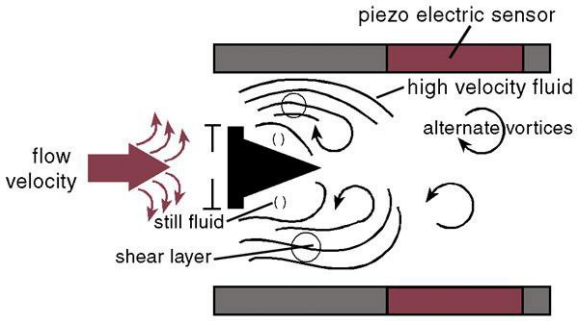
velocity or the change in kinetic energy. Various flow meters are available for closed-pipe systems. Broadly speaking, these flow meters can be placed in different categories, such as (1) differential pressure measurement, (2) positive displacement, (3) velocity measurement, and (4) mass meters.

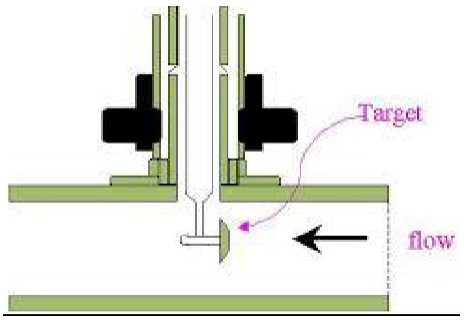
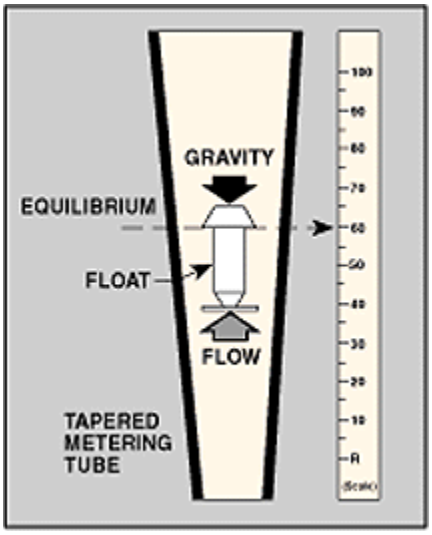
Often used in the water sector are Electromagnetic, Ultrasonic and Turbine flow meters. These have good accuracy, low maintenance, can perform repeatable measurements, and are reliable in demanding conditions. The suitability for the different meter types depends strongly on their use (and the nature of the liquid that is being transported).

Table 7: Metering to measure the flow in a closed network based on velocity method[2]

	Figure	Description
Ultrasonic flow meters	  Ultrasonic flow meter 	Ultrasonic flow meters include Doppler and transit time flow meters. Both utilize ultrasound to make measurements and can be non-invasive. Transit time flow meter: Two transmitters/receivers (transceivers) are located on each side of the pipe. The transmitters send ultrasonic from one side to the other. The average fluid velocity is calculated from the differences in proportional frequency Doppler Effect Flow meter: measurement of particles in the fluid based on ultrasonic sound waves. The velocity is measured based on the ultrasonic source, the fluid carrier and the receiver. This method is not suitable for clear liquid as it is highly dependent of the properties of the fluid it can only be used for applications that do not require high accuracy.

[2] Adopted from www.greyline.com and www.flowmeters.com. Accessed February 3, 2020.

	 Doppler Flow Meter	
Electro-magnetic Flow Meter		These meters measure using a magnetic field applied to the metering tube. The magnetic flow meter requires a conducting fluid and a non-conducting pipe liner. Magnetic flow meters have no moving parts and are particularly suitable for measurement of dirty or corrosive liquids (electrically conductive).
Vortex Flow Meter		Vortex meters make use of a natural phenomenon that occurs when a liquid flows around a bluff object. Eddies or vortices are shed alternately downstream of the object. The frequency of the vortex shedding is directly proportional to the velocity of the liquid flowing past the bluff object. The three necessary components of a vortex flow meter are a bluff body mounted in the flow meter bore, a sensor to detect the presence of the vortex and generate an electrical impulse, and a signal amplification circuit (Waternomics, 2015).

Target Flow Meter		"Target meters sense and measure forces caused by liquid impacting on a target or disk suspended in the liquid stream. A direct indication of the liquid flow rate is achieved by measuring the force exerted on the target. […]. More sophisticated versions use a precision, low-level force transducer sensing element. The force on the target caused by the liquid flow is sensed by a strain gage. Target meters are useful for measuring flows of dirty or corrosive liquids." (http://www.omega.nl/techref/flowcontrol.html)
Variable Area Flow Meter or Rotameter		"The variable area flow meter consists of a vertically oriented glass (or plastic) tapered tube with a larger inside diameter at the top, and a metering float which is free to move within the tube. Fluid flow causes the float to rise in the tube as the upward pressure differential and buoyancy of the fluid overcome the effect of gravity. […]. The height of the float is an indication of the flow rate." (http://www.maxmachinery.com)

As mentioned earlier different meters are suitable for different situations depending on the purpose of their use and the nature of the liquid that is being transported. In the table below different characteristics of the meters are described.

Table 8: Characteristics of selected flow meters

	Field of application	Maintenance	Price[3]

[3] The price range can depend strongly on the size of the pipes in which the meter is used to measure the flow.

Electro-magnetic flow meter	measure flow rates in pipes, when the fluid is water or other conductive fluid	low	€ 400 – 1000
Ultrasonic flow meter	Widely used to measure flow rates in pipes, when the fluid is water, oil of other fluids.	low	€ 100 – 5000
Vortex flow meter	The vortex flow meter is used for liquids and gas applications	low	€ 100 – 4000
Target flow meter	The target flow meter is used for corrosive liquids, gas and water applications	low	€ 200 – 3500
Variable area flow meter	The variable area flow meter is used for air and water applications	low	€ 200 – 1500

Source: Waternomics, 2015

In the case of monitoring flows in water networks, the flow meter needs to adhere to a number of requirements. These requirements include 1) robustness and reliability in order to reduce maintenance, 2) electrical output signal for remote control, 3) wide range of applicability on pipes of different diameters, 4) bi-directionality and 5) small concentrated pressure drops. The meters which best adhere to these criteria are the electromagnetic meter and the ultrasonic meter. These advantages and disadvantages of these two meters are elaborated upon below.

Table 9: Advantages and disadvantages of ultrasonic flow meters

Advantages	Disadvantages
Non-intrusive measurement	The measurement fluid must be clear
Wide range of measurement options	Not suitable for fluid with high temperatures
Price is independent of the size of the pipes	Configuration with external transducers require periodic calibration
Easy installation	Require straight sections upstream and downstream piping, respectively N=20 time diameter upstream and N=5 times diameter downstream
Bidirectional flow measurement	

Source: Waternomics, 2015

Table 10: Advantages and disadvantages of electromagnetic meters

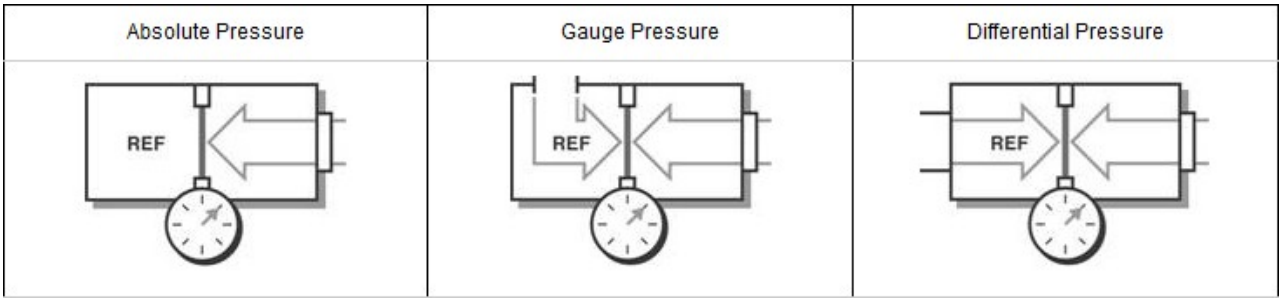
Advantages	Disadvantages

Fixed measuring device	The measurement fluid must be conductive
	Intrusive measurement
	High price, particularly for large diameter pipes (D>500 mm)
Suitable for wastewater, corrosive fluids	Configuration requires periodic calibration
No load loss	Not suitable for fluid with high temperatures
Measurement independent of the flow regime	Not suitable for gas or less conductive fluids

7.2.2 Pressure measurement

Pressure is defined as force per unit area that a fluid exerts on its surroundings. There are three methods for measuring pressure: (1) absolute, (2) gauge, and (3) differential. Absolute pressure is referenced to the pressure in a vacuum, whereas gauge and differential pressures are referenced to another pressure such as the ambient atmospheric pressure or pressure in an adjacent vessel (http://www.ni.com).

Figure 1: Pressure Sensor Diagrams for Different Measurement Methods

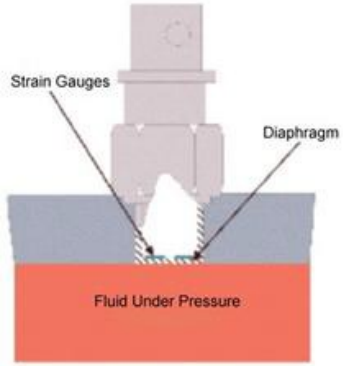
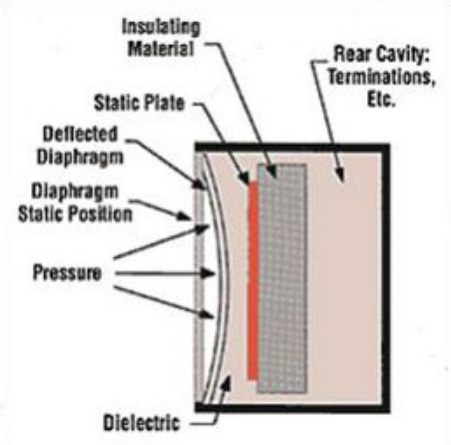
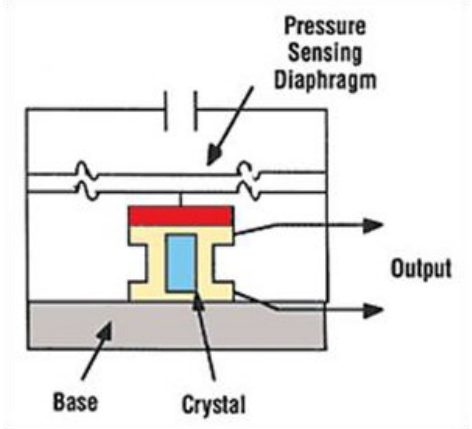


Source: http://www.ni.com

Absolute pressure measurement is suitable for measuring atmospheric pressure. Gauge and differential pressure measurement measure relative to a chosen reference pressure (e.g. atmospheric pressure). In this way the effect of the dynamic reference pressure is excluded (Waternomics, 2015).

Differential pressure measurement is similar to gauge pressure. However, the reference is another pressure point in the system rather than ambient pressure. Common pressure sensor types include 1) wheatstone bridge-based sensors, 2) capacitive sensors and 3) piezoelectric sensors. Generally pressure sensors have an elastic element installed inside. The deformation of this elastic element under the action of the water pressure provides the pressure measurement signal. So the pressure is measured by converting the physical phenomenon to an intermediate form, such as displacement, which can be measured by a transducer (www.ni.com).

Table 11: Differential pressure sensors

	Figures	Description
Wheatstone bridge based sensors		"Bridge sensors are used for high- and low-pressure applications, and can measure absolute, gauge, or differential pressure. Bridge-based sensors use a strain gage to detect the deformity of a diaphragm subjected to the applied pressure" (www/ni.com).
Capacitive Pressure Sensors		"A variable capacitance pressure transducer has a capacitive plate (diaphragm), and another capacitive plate (electrode) fixed to an unpressurized surface, with a gap of a certain distance between the diaphragm and the electrode. A change in pressure will widen or narrow the gap between the two plates, which varies the capacitance. This change in capacitance is then converted into a usable signal" (https://www.drurylandetheatre.com/capacitive-pressure-transducer/)
Piezo-electric Pressure Sensors		Piezoelectric sensors rely on quartz crystals. Electrodes transfer a charge from the crystals to an amplifier built into the sensor. These crystals generate an electrical charge when they are strained (www.ni.com).

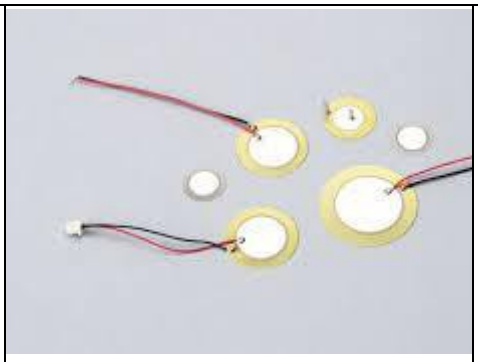
The choice of the pressure sensor to be used in the water sector will depend on the specific application. Generally it is preferable to use electric type pressure sensors because they allow for data logging and remote access to measure data, and thus particularly suitable for use in water network monitoring systems.

7.2.3 Leak detection through microphones

Physical water losses occur as a combination the condition of the physical infrastructure and pressure management. Leak location practices and techniques have advanced rapidly in the last few years. A detection method that has been increasing over the past years is the use of microphones to detect leaks. Three different microphones are discussed in the table below.

Table 12: Microphones used for leak detection

	Figures	Description
Electret microphone		"An Electret microphone is a type of condenser microphone that comes with a permanent charge built into it. All microphones need a pair of charged plates (positive and negative plates) in order to function and record sound. General condenser microphones do not come precharged but need an external voltage to charge the microphone's diaphragm for the microphone to operate. Electret microphones, however, come with a permanent built-in charge. One disadvantage of electret microphones is that its performance decreases over the years; as time passes, the charge on the electret is lost" (http://www.learningaboutelectronics.com/Articles/Electret-microphones).

Piezo sensors		A contact microphone, otherwise known as a pickup or a piezo, is a form of microphone designed to sense audio vibrations through solid objects. Unlike normal air microphones, contact mics are almost completely insensitive to air vibrations but transduce only structure-borne sound. Often used as acoustic leakage probes. (Waternomics, 2015)
Clip-On Contact Microphone		Contact microphones are normally used in musical instruments (brass instrument, a violin a guitar, etc). The microphone uses a piezo element to directly capture the vibrations and send them to tuner. An advantage of these mics is that they can fit to different sizes of pipes (Waternomics, 2015).

7.2.4 Smart water meter technologies

Any device that collects and transmits real-time data can be classified as a smart device. In a smart grid system parameters (such as flow and pressure) would be collected, stored, and transmitted to a computer by the meter itself. Smart water meters have a number of advantages. First, they are easy to use in meter shafts and moist environments where data transmission prevents manual data readings. Second, they are likely to be more accurate due to the use of ultrasonic or other technologies. Third, several kinds of wireless remote reading can be applied (automatic and integrated in a radio network). Fourth, the electronic display can also provide information about sensed irregularities. Smart water meters come in a variety of shapes and sizes and can be used for residential water metering as well as bulk water metering. In addition to measuring water flows they can also be used for gathering additional data such as water temperature[4].

[4] https://www.kwrwater.nl/en/actueel/slimme-watermeters-helpen-drinkwatertemperaturen-in-kaart-te-brengen/. Accessed February, 2020.

	
Kamstrup FlowIQ 2200 Source: www.kamstrup.com	Lorenz Water Meter Source: https://www.lorenz-meters.de/

7.3 Data Transmission and Power[25]

After collection, data needs to be transmitted to a centralized location for further monitoring and analysis. Given the disadvantages of direct line transmission and using broadband from water customers to transmit data (Waternomics, 2015) wireless data transmission is an attractive approach for water utilities. A variety of wireless technologies and protocols can be used depending on the requirements of the particular system, utility and end users. This includes mobile broadband, wireless broadband (Wi-Fi), personal area networks (device-to- device transmission), and satellite communication (Waternomics, 2015).

Things that need to be taken into consideration when developing these systems are: regularity in spacing of smart meters in order to boost reach, availability of a wireless protocol specifically designed to capture the meter signals, availability and connectivity to power sources for the devices.

Table 13: Data transmission systems[5]

	Figure	Description

[5] Based on http://www.globalw.com/support/remote.html. Accessed January, 2020.

Satellite data transmission		The satellite data transmission method was designed for remote water monitoring systems in areas where power is not available, there are no telephone lines, cellular coverage is non-existent, and far enough away from the data collection point that a radio system is impractical. In these environments the satellite data transmission system can gather remote system data and transmit it to a database where it can be viewed from any computer that has connection to the Internet.
Cellular data transmission		Remote water monitoring systems that use cellular data transmission require sites that are well covered by cellular transmission towers. These remote water monitoring system sites will generally be closer to developed areas as a result of this requirement. Cellular data transmission methods will allow for more rapid data transmission from your remote water monitoring site, however an appropriate cellular plan with a local service provider is required. It is also essential that the cellular system be set up to transmit according to the transmission guidelines of the country the remote water monitoring system is located in.
Radio transmission data		Radio systems are used for relatively short-range transmission of remote water monitoring system data. The advantage of radio systems is that one receiver can collect data from a large number of remote water monitoring systems. This allows centrally located base stations or mobile platforms that can move within range of the remote water monitoring stations to gather data without actually visiting the site. An additional advantage is that there are no additional fees with a radio system.
Telephone modem data transmission		Telephone modem data transmission systems are used with remote water monitoring systems that are near telephone lines. Typically this type of system is used where the remote water monitoring systems are near unmanned buildings such as small dams or gauging stations. This type of system has the lowest investment of all the remote water monitoring system data

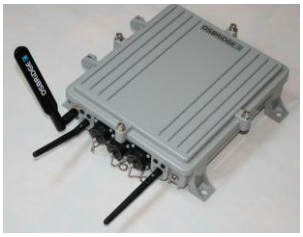
		transmission methods if the telephone lines already exist at the monitoring site.
Wi-Fi transmission data	 	IEEE 802.11 (Wi-Fi) is the most widely used wireless communication technology. The Wi-Fi data transmission system is capable of sending data packets through user datagram protocol (UDP) to a computer with Wi-Fi capability. It is possible to build a data transmission module using inexpensive and simple components. This provides a simple and inexpensive design of data transmission for use in areas like real-time measuring and monitoring when combined with a sensing system.

Table 14: Advantages and disadvantages of different data transmission technologies

	Suitable for difficult area	**Suitable for residential & developed areas**	**Additional fee needed**	**Cellular transmission tower are needed**	**Telephone line needed**	**Costs**
Satellite data transmission	x	x				high
Cellular data transmission	x	x	x	x		medium
Radio data transmission	x	x				medium
Telephone modem data transmission		x	x		x	low
Wi-Fi transmission data		x	x			medium

7.4 Data Platforms

Data platforms centrally collect, integrate, and analyse water consumption data from various sites. The platform also facilitates integration of contextual data for front-end applications and analytics. Ideally, data platforms need to 1) facilitate linkage between data entities across heterogeneous data sources, 2) enable real-time data processing and analytics, and 3) reduce the need for on-site data storage.

7.4.1 Processing Real-time Events

Recently there has been a realization among researchers and practitioners that a new class of information processing systems is needed. The new class, or paradigm, has been motivated by a plethora of distributed applications that require on-the-flow and low latency processing of information items. The application domains features include, for example, spatial-temporal correlation, event sequencing, out of order events, homogeneous aggregation, derived events, event enrichment, outlier handling, early filtering, mobility of event source, mobility of event subscriber, etc. The concepts of timeliness and in-flow processing have been expressed in the literature using various terms such as low latency, high throughput, low delay, volume, and real-time processing. The new paradigm is called vent processing or alternatively stream processing.

Table 15: Comparison of selected real-time data processing technologies

Requirement	Apache Spark	Apache Storm	DRUID	Collider
Real-time data / events	+	+	+	
Real-time Analytics	+		+	
Heterogeneity of Sensor Data				+
Enrichment of Sensor Data				+

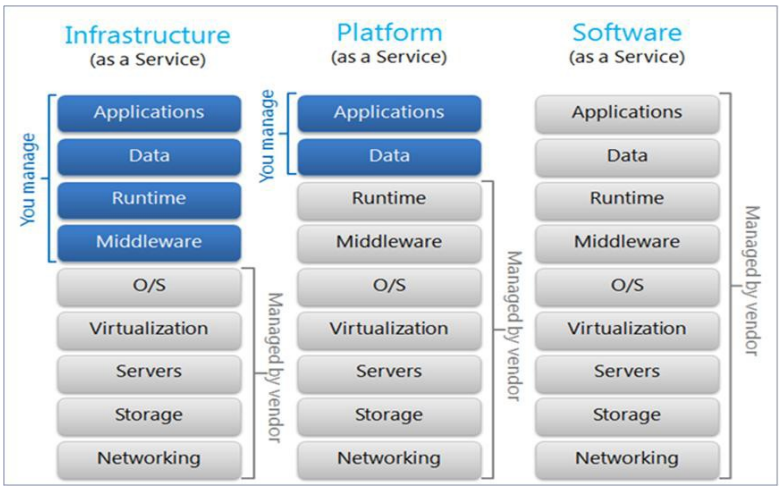
Source: Waternomics, 2015

2.1.1 Cloud Infrastructure

Cloud data storage platforms reduce costs and improve efficiency of data collection and storage. Cloud storage infrastructure means that there is a reduced requirement for on-site data collection and storage facilities, thus reducing capital costs for hardware, as well as ongoing maintenance costs. In essence, there are three models for outsourcing data and applications in the cloud, known as cloud service models: 1) Software as a Service (SaaS), 2) Platform as a Service (PaaS) and 3) Infrastructure as a Service (IaaS). Each of these models provide varying levels of service to the

customer, allowing transfer of management of particular aspects of the service to the vendor.

Figure 2: Cloud Service Models



Source: Alioto, 2010

7.5 Software

This section presents software technologies related both to water information platforms and software components.

7.5.1 Water information platforms and applications

Table 10 summarises selected water information platforms, applications and solutions.

Table 16: Overview water information platforms[6]

Name	Target	Features	Key technologies	
	Facilitate communication of water utilities with customers	• Personalized home water reports to help consumers manage water consumption more efficiently • Customer portal for more detailed analysis of consumers' water use and water-saving	• Data analytics • SaaS model • Cloud computing • Web technologies for UI	• Specifically targeting water utilities and domestic consumers enhancing their communication. • Missing specialization for businesses and large

[6] Based on Waternomics, 2015

		recommendations • Utility dashboard for staff to access visually insightful analytics, reporting and customer relationship tools	• Behavioural change methods	enterprises internal water management • Difficult to be adopted for public spaces • It does not allow access to data to third parties for additional applications
	Facilitates water leakage detection in water networks and mainly target water utilities	• Water network management • Leakage detection • Fault detection • Bursts detection • Actionable alerts and reports about leaks, bursts and inefficiencies and network events • Real-time alerts and dashboard	• Cloud computing • Linked data • Web technologies for UI • Various types of alerts (email, SMS, etc.) • SaaS model	• Targeted to water utilities and network management issues • Missing domestic and large enterprise users • Missing behavioural change tactics
	A set of solutions targeting water utilities for efficient water network management	• Pipeline monitoring • Tackling pressure transients • Burst detection • Alerts with SMS, emails etc. • Real-time monitoring • Configurable dashboards	• Smart sensors • Web technologies for UI • Various types of alerts (email, SMS, etc.) • SaaS model	• Targeting network management for utilities and enterprises • Missing behavioural change tactics • Missing domestic users • Not allowing access to third parties for external applications.

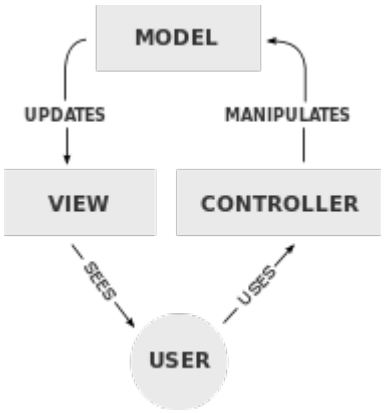
	A set of controllers , sensor and software for irrigation scheduling	• Web based application for real- time monitoring • Site-specific weather data gathered and used for adjusting scheduling of irrigation • Water use monitoring, analysis and diagnostics • Simulation of water conservation plans • Benchmarking water conservation plans implemented	• Sensors and remote controllers • Web technologies for UI • SaaS model	• Targeting agricultural uses of water with irrigation planning • Missing behavioural change tactics • Not allowing access and expansion through third party applications
	Irrigation planning and monitoring	• Irrigation scheduling • Pump control • Flow meter monitoring • Field monitoring • Weather forecast to help irrigation planning • Team management • Task and operations management	• Sensors and remote controllers • Cloud computing • Web technologies for UI • SaaS model	• Targeting agricultural uses of water with irrigation planning • Missing behavioural change tactics • Not allowing access and expansion through third party applications

7.5.2 Back-end web application development frameworks

Back-end web application frameworks are development frameworks for developing the core part of web applications dealing with data modelling and handling according to users actions. Most back-end applications utilize some cloud computing infrastructure (either a data storage mechanism and/or as an application hosting mechanism). Such frameworks provide a specific set of tools to organize data according to the business rules of applications and connect them (data) with appropriate interaction events that happen in the user interface. One of the most popular patterns for organizing the functionality of such a framework is the Model-View-Controller (MVC) pattern. The main component of the MVC pattern is the model which captures the behavior of the application in terms of its problem domain, independent of the user interface. The model manages the data, logic and rules of the application. A view can be any output representation of information, such as a chart or a diagram. The pattern allows for multiple views of the same information to be available, such as a bar chart for

management and a tabular view for accountants. The third component of the MVC pattern, the controller, accepts input and converts it to commands for the model or view. So it initiates actions on the model which in turn output a specific view to the user.

Figure 3: Typical structure of components in the MVC pattern



The following table outlines a selection of MVC web application frameworks that are quite popular.

Table 17: Selected back-end web application frameworks

Name	ASP.NET MVC	CakePHP	Zend Framework	Spring	UltraCore
Language	ASP.NET	PHP	PHP	Java	Java
ORM	Supports ORM with Data Annotations used in definition of data models. Entity Framework also helps in creating model classes based on an existing database or create a database based on an existing data model developed on ASP.NET MVC	The CakePHP ORM borrows ideas and concepts from both ActiveRecord and Datamapper patterns. It aims to create a hybrid implementation that combines aspects of both patterns to create	ORM in Zend Framework is achieved by implementing the Table and Row data gateway patterns through the Zend_Db_Table and Zend_Db_Table _Row patterns. It also uses	Spring allows to use a variety of Java libraries to achieve the object-relation mapping. Two of the most commonly used are Hibernate and iBatis	UltraCore has its own built in ORM library, which allows for easy automatic mapping of objects to tables, based on MDA (Model Driven Architecture) meta data tools

		a fast,simple to use ORM.	Doctrine as an Object-Relational Mapper.		that are defined for the Data
Templates	ASP.NET MVC can import templates using Master Pages and Razor Views in order to help developers build applications with already existing and pre-developed templates. It also by default imports the Bootstrap front-end development framework as a default theming mechanism for new applications.	The view layer in CakePHP can be made up of a number of different parts. Each part has different uses: • views • elements • layouts • helpers • cells It also support the development of plugins to cooperate with front-end development frameworks such as Bootstrap and the template engine Twig.	Templates are supported through the Zend_View class. Zend_View allows developers to use PHP as their template language, or create instances of other template systems and manipulate them within their view script. This way Zend Framework ensures extensibility allowing the usage of other temple engines in combination with it.	Spring allows templating in two ways. By using custom JSP tags which exist as Java classes or JSP snippets and provide a basic facility to encapsulate and reuse parts of JSP pages (headers, footers, etc.). By using template engines like Commons Tiles, Velocity and Thymeleaf, etc.	UltraCore supports web templating, which allows for designers to independently create designs that are later at runtime injected with live UltraCOre components.

Scaffolding	Provides scaffolding for building views and controllers for CRUD functions of entities in the data model. Scaffolding also supports the creation of CRUD functionality for developing a REST API for the data model.	CakePHP provides scaffolding features to create prototypes of applications with code generated from the framework itself.	A scaffolding mechanism is not provided by default within Zend Framework.	Spring supports scaffolding through external tools and libraries such as MyEclipse IDE from Genuitec or Spring Roo, Grails etc.	UltraCore has built in designer tool that can generate complete functioning modules (CRUD) from database tables, or generate smaller application parts. Also the GUI can be designed with a drag and drop designer.
Validation	Validation can be achieved using DataAnnotations and metadata in the data model. Validation (wherever possible)is being implemented at client side with the use of data-variables on html5 elements.	Validation via Contexts (Table (DAO), Entity (VO) & Controller) CSRF Protection Supports	Zand has a set of validators implemented for various types of data allowing the implementation of custom validators and their customization and translation of error messages	Spring allow for other libraries such as Commons Validator and Bean Validation to support validation functionalities	A complete validation library is available, that works with MetaData definitions, so that the validation rules can be inspected both in the Frontend and the Backend, supporting a unified data model without breaks between layers

Other features		Mobile Agent Detection			Integration with UltraTelecom, allowing for multichannel application access, e.g. via email, telephone,sms, etc.

7.5.3 Front-end web application development frameworks

Most existing software presents information on a variety of devices using web interfaces. In some cases there are also additional mobile applications accompanying the solutions. Front-end web application development frameworks provide a set of user interface elements using CSS and JavaScript technologies. Developers using such frameworks can use them to easily develop the front-end of a web application using a specific consistent and in some cases widely used design language that it is easy for the users to understand and use. Moreover such frameworks are also usually taking care of compatibility issues with mobile devices employing responsive web technologies.

For the choice of a technology in the area of front-end development frameworks the richness in supported components and responsive design is a crucial one together with support of web browsers. Moreover, modularity and the learning curve for each of these frameworks play a significant role as well. The learning curve is largely affected by the use of semantic class names and the community activity.

Table 18: Comparison of selected front-end web development frameworks

Name	**Bootstrap (v.3.3.1)**	**Foundation (v.5)**	**Semantic UI (v.1.2.0)**
Link	http://getbootstrap.com/	http://foundation.zurb.com/	http://semantic-ui.com/
Licence	MIT	MIT	MIT
Browser compatibility	IE8 and higher, Chrome (latest), Safari (latest), Firefox (latest), Opera (latest)	IE9 and higher, Chrome (latest), Safari (latest), Firefox (latest), Opera (latest)	IE9 and higher, Chrome (latest), Safari 6 and higher, Firefox (latest), Opera 12 and higher
Customization and theming	Compiled through SASS and LESS CSS engines Allows for customization on download by customizing	Compiled through SASS CSS engines Allows for customization on download by customizing over a set of variables (limited)	Compiled through LESS CSS engines 9 out of the box themes

	over a large set of variables	Foundation for apps offers a few themes customized for specific types of apps	ready to be used
Responsive grid support	Mobile first design approach. Includes responsive grid elements with fluid and fixed width of the grid and also includes helper classes that can be shown or hidden for specific devices.	Mobile first design approach. Includes responsive grid elements but with fixed width only and includes helper classes that can be shown or hidden for specific devices.	Mobile first design approach. Fluid and fixed width grid are supported with options for user defined rows and helper classes for showing and hiding content on specific devices.
Components	Apart from basic typography and helper utilities there are also 21 components and 12 jQuery plugins for interaction effects	About 35 components apart from typography and helper classes.	More than 50 UI components including typography elements and helper classes.
Modularity	Modularity supported by selecting which components to include in the download before downloading	Modularity supported by selecting which components to include in the download before downloading	Modularity supported by downloading separate files for each component
Semantic class names	No	Yes	Yes
Unique features	• Unique elements include: o Badges o Media objects o Wells o Scrollpsy o Carousel o Affix	• Unique elements include: o Joyride o Magellan site navigation bar o Pricing tables o Orientation detection visibility classes o Range sliders o Equalizer to keep equal height columns in one row	• User defined API to connect with states and behaviour of components. • Includes form validation behaviours • Unique elements include: o Loaders o Reveal images o Step o Card o Feed o Item (News or

			sales item) o Statistic o Rating o Shape o Transition

7.5.4 Mobile app development platforms and technologies

One of the most important factors for mobile apps development is the purpose and the target of the application. If the application requires using specific mobile devices characteristics (such as mobile phones sensors) then an approach closer to native and hybrid app development might be more suitable. If not then responsive web apps may be a better choice. Following that, the next important aspect is the effort needed for the development and maintenance of the code base in combination with the range of devices supported by each platform.

Table 19: Comparison of application development platforms

Category	Platform	Description	Technologies	Advantages	Disadvantages
Web applications	Web	Web applications for mobile devices are actually typical web applications which run on any mobile device through a web browser program provided by the mobile devices. Technologies of responsive web design are typically used to enable better presentation and layout of the application for a mobile device. The main benefit of a web application is that it is independent of mobile device	HTML, CSS and Javascript	Potentially all devices supported independent of platform. The application can potentially run on any mobile device.	Difficult or no access to mobile specific features and sensors is hardware (gyroscope, accelerometer, notifications, etc.)

		platform or vendor.			
Native applications	Android	Native applications are developed for a specific mobile devices platform and depend highly on the characteristics and development environments provided and supported by each platform. The Android platform covers the range of devices using the Android operating system. However, this range is not limited to mobile devices only, it currently also includes other devices such as TVs and set-top boxes. Android is provided by Google and currently runs on	Java	Easier access to mobile specific features and hardware (gyroscope, accelerometer, notifications, etc)	Different code base for each platform Increased resources for maintenance Fragmentation in devices, OS versions and capabilities

		devices from a large set of vendors. Applications for Android are provided mainly by google play and a variety of other market places.			
	iOS	This platform covers devices of Apple such as iPhones and iPads. Recently iOS has presented a new programming language for their applications called Swift while also continue to support development in Objective C. Development for iOS also requires Apple computers to be used for the development and publishing of them. Applications are made available through the Apple Appstore	Objective C or Swift		
	Windows	The platform covers mobile devices from a variety of vendors using the Microsoft's			

		Windows Phone OS. Main vendor of windows phone devices is Nokia which is currently bought by Microsoft.			
Hybrid application development	Platform is a combination of native platforms with web	A variety of tools support the development of mobile applications using a common programming language for all device platforms. Developers can then develop applications using this language (usually JavaScript) and export the application in installation packages for a variety of supported mobile platforms. A similar approach is also based on developing mobile applications that use heavily webview elements that display parts of a web page as parts of the user interface of the application	A combination of Native and Web technologies	Easier access to mobile specific features and hardware (gyroscope, accelerometer, notifications, etc) Main core of the application remains the same for all platforms Easier maintenance of code base.	Sill some parts fo the code base are different depending on the platform, but this is reduced comparing to native apps

7.5.5 Charting technologies

An important part of application development is the presentation of information to end-users in easily accessible manner. Chart-type outputs of various types can be employed to achieve this and therefore charting libraries for web applications are a crucial part of application development. There is a wide variety of libraries for producing graphs. However, the selection of a library should combine both the ability for rapid prototype development and enable scalability and extensibility to newer custom charts that might be developed.

For the choice in charting technologies the type of licence is a very important factor. The license determines the customisation and further development of new chart types.

Table 20: Comparison of charting technologies (JavaScript)

Name	Google charts	D3.js	C3.js	Chart.js
Link	https://developers.google.com/ chart/	http://d3js.org/	http://c3js.org/	http://www.chartjs.org/
Licence	Terms of Service provided	BSD	MIT	MIT
Available graph gallery	Area, Bars, Bubble, Calendar, Candlestick, Column, Diff, Gauge, Geo, Histograms, Lin, Maps, Org, Pie, Sankey, Scatter, Stepped Area, Table, timelines, Tree map, Trendlines, Word trees.	Box plots, Bubble, Bullet, Calendar, Chord, Dendogram, Bars, Stacked bars, Circle packing, Steamgraph, Treemap, Sunburstm Voronoi diagram, Symbol map, Zoomable pack, Collapsible force layout, Sankey, etc. There is an extensive library of complex charts that is constantly populated by the developers' community. https://github.com/mbostock/d3/wiki/Gallery	Line, Timeseries, Spline, Multiple line, Area, Line with regions, Step, Stacked area, Bar, Stacked bar, Scatter, Pie, Donut, Gauge, Combination, etc. The library supports a wide variety of graphs based on the D3.js library, thus it is also extensible using the D3.js library.	Line, Bar, Radara, Polar Area, Pie and Donut etc. Provides support for extending and developing custom graphs

Interactivity	Supported through specific events provided for each chart type.	Extensive support for interactivity since developers can use any standards HTML based events to provide interactivity with charts	Provides some interactivity with some supported events (e.g. sub charts, zoom, etc.) but it is also extensible since it is based on D3.js library.	Provides support for building interactivity into graphs but not as easy and extensible as with D3.js based charts.
API Usability and complexity	Quite friendly and easy to develop graphs API which supports data binding with specific data related objects and JSON as input for graphs	Depending on the graph selected API can be quite easy or difficult to use. Many of the already provided graphs have friendly APIs but the library provides a good support for extending or developing new graphs with their own custom API's. Therefore flexibility comes at the expense of more work needed to develop new graph types and APIs	Provides a quite developer friendly API for updating graphs presentation and data. It is mainly based on JSON that describes the properties for the graph and the data and thus it can be considered as a good starting point for developing more graphs if needed.	Quite friendly API based also on JSON for formatting. However, it might be a limiting fir developing more complex features and interactivity on the graphs.

2.1.2 Notification and alerting technologies

Alerts and notifications can be implemented using a variety of technologies. For the notification and alerting technologies the choice is a matter of case-by-case analysis. The most important factor in choosing an option is the urgency of the notification in combination with the obtrusiveness of each technology.

Table 21: Comparison of alerting and notification technologies

Name	Email	SMS	Push Notifications	Call centres

Description	Users are notified by receiving an email	Users are notified by receiving an sms	Users can be notified either by a mobile app that receives the notification and displays it or by web apps	User receives a call by a call centre
Obtrusiveness	Low	High	Mild	High
Important points	• Urgent notifications might be lost if users do not check emails often • Good for informational – not urgent notifications and advices • Also good for newsletter functionality	• Urgent notification will not be lost often. • To be used only for extra critical notifications and alerts	• Urgent notifications might be unnoticed on time of arrival • Possibility for customization of how the alert/notification will respond to actions • Allows for notifications that can prompt for an action	• Urgent notification will probably not get lost. • To be used only for extra critical notifications and alerts • Might require special infrastructure

7.5.6 Web service technologies

Between the dataspace and applications there is a set of services responsible for providing the appropriate information requested from the applications and vice versa. A Web service is a method of communication between two electronic devices over a network. The W3C (World Wide Web Consortium) defines a Web service generally as: "software system designed to support interoperable machine-to-machine interaction over a network."[7]. The choice of web services technology is dependent on the back-end technology selected and the support is allows for each of the technologies. Moreover it is also a matter of what kind of technologies is mostly used and preferred by third parties since the critical role of web services is the connection of the other data layer with applications.

[7] http://www.w3.org/TR/2004/NOTE-ws-gloss-20040211/#webservice

Table 22: Comparison of web service types

Name	RESTful APIs	SOAP	RPC
Description	REST (Representational State Transfer) is an architectural style that can is also applied for web services. HTTP based RESTful APIs are defined with these aspects: • base URI, such as http://example.com/resources/ • an Internet media type for the data. This is often JSON but can be any other valid Internet media type (e.g. XML, Atom, microformats, images, etc.) • standard HTTP methods (e.g., GET, PUT, POST, or DELETE) • hypertext links to reference state • hypertext links to reference related resources.	SOAP web services are based on a "contract" between a service provider and the consumer which describes the rules of communication between them. These "contracts" are described using WSDL (Web Service Description Language) and through a directory called UDDI (Universal Description, Discovery and Integration) clients can identify which software system should be contacted for which type of data. So when one software system needs one particular report/data, it would go to the UDDI and find out which other system it can contact for receiving that data. Once the software system finds out which other system it should contact, it would then contact that system using a special protocol called SOAP (Simple Object Access Protocol). The service provider system would first of all validate the data request by referring to the WSDL file, and then process the request and send the data under the SOAP protocol.	XML-RPC works by sending a HTTP request to a server implementing the protocol. The client in that case is typically software wanting to call a single method of a remote system. Multiple input parameters can be passed to the remote method, one return value is returned. The parameter types allow nesting of parameters into maps and lists, thus larger structures can be transported. Therefore XML- RPC can be used to transport objects or structures both as input and as output parameters. JSON-RPC is similar to XML-RPC but uses JSON instead of XML for exchange of data and communication with the service provider. XML-RPC later evolved to SOAP.

Advantages	• More flexible and simple interface for API development and consumption • Less bandwidth usage is possible • Security can be left to network administration • Less client side complexity	• Contract based • Standards based • Strongly typed • Support from a wide variety of libraries for client side development	• Simple to implement • Simple to consume (results come either in XML or JSON)
Disadvantages	• Loosely typed • Not good handling of attachments. • Not many libraries supporting easy client side development	• Security is debatable • More bandwidth possibly required • Complex to implement and consume by third parties	• No contracts or standards based • More bandwidth possibly required • Older technique which evolved to SOAP

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