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Abstract (for dissemination)	This report presents the main trends and challenges that need to be addressed in the future development of the ICT for water management sector. Three case studies of smart water technology implementation in Malta, Singapore and South Korea are also presented to validate the needs and challenges for successful implementation of Smart Water solutions. Lastly, a set of recommendations on the adoption, implementation, and operating and maintenance of Smart Water Technology and a checklist tool for Smart Water Implementation is provided. This report concludes with an action plan for the next 5 years.
Key words	Roadmap, SMART Water, ICT

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List of Acronyms

A/M	Asset Management
BP	Business Process
BU	Business Unit
DSS	Decision Support System
DW	Drinking Water
DWNM	Drinking Water Network Management
DWTP	Drinking Water Treatment Plant
ICT	Information and Communication Technologies.
IS	Information System
IS/IT	Information System / Information Technology
IS/IT	Information System / Information Technology
IT	Information Technology
MDM	Meter Data Management
SSI	Small Scale Implementation
SWG	Smart Water Grid
SWM	Smart Water Management
SWNM	Storm Water Network Management
W/M	Work Management
WssTP	Water Supply and Sanitation Technology Platform
WW	Waste Water
WWNM	Waste Water Network Management
WWTP	Waste Water Treatment Plant

Executive Summary

This report is part of WIDEST (www.widest.eu), a H2020 funded project – Coordination and Support Action (Ref. Number 642423). Deliverable "D3.3 Report on Overall Roadmap" focuses on the presenting the overall roadmap. The objectives are to assimilate information across the three topical roadmaps in WP2 ("Semantic Interoperability and Ontologies", "Smart City Connection" and "Smart Water Grids") to provide advice about effective implementation of the holistic approach and specific analyses and recommendations for policy makers and other readers.

This document presents the main trends and challenges that need to be addressed in the future development of the ICT for water management sector. They are:

- Standardization and Communication Protocols
- Big Data and Data Analytics
- Systems for Smart Water Management
- Geographic Information Management
- Smart Sensors Technology

Three case studies of smart water technology implementation in Malta, Singapore and South Korea where they demonstrated that Big Data and Data Analytics, interoperability between different systems and tools and geographical intelligence are required for successful implementation of smart water solutions.

The document concludes with a set of recommendations classified into three categories: namely the adoption, implementation, and operating and maintenance of Smart Water Technology and a checklist tool for Smart Water Implementation, developed by WIDEST, to provide utilities a look at their commitment level towards smart water solution implementations. The document concludes with an action plan with the following recommended activities:

- Development of semantics tools to properly contextualize the business processes in the water domain
- Development of cross-domains data sharing (Water-Energy Nexus)
- Development and support for pilot projects
- Development of performance benchmarking
- Development of systems standards for cities and communities
- Development of Open Data initiative for free flow and easy access of data
- Provide review analysis and guidelines for the ICT solutions and systems in SWG

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1. Introduction

More than 1.8 billion people worldwide will be living in areas of water scarcity where more than two thirds of the world's population will face water-stressed conditions in the next decade. This future water shortage requires immediate action on development of resources, reduction of demand and higher efficiency in treatment and transmission. In addition, future flood risk management requires immediate action in risk assessment, defence and alleviation systems, forecasting and warning systems and institutional and governance measures. Over recent years, technology has developed greatly and has matured with mass production to allow a wider uptake of methods and devices. After the development phase, technology is now entering an application and implementation phase that is targeting several fields including environment. A relevant example is given by the European Union who has defined a major priority for the next 20 years on "ICT for sustainable growth" with the ambition to lead innovation at the worldwide scale. In such context, ICT refers to technologies that provide access to information through telecommunications. It is similar to Information Technology (IT), but focuses primarily on communication technologies. This includes the Internet, wireless networks, cell phones, and other communication mediums. The current situation in the water domain is characterised by a low level of maturity concerning standardization of ICT solutions and business processes. The massive and rapid spread of communicating devices within the Society and their application to the industrial sectors is not coordinated. The only relevant angle for the development of these technologies (M2M) within the water domain has to be based on the identification of the benefit provided in each business process by the introduction of the new solutions.

Right now, smart technologies provide the right opportunity to address these water challenges. According to a research commissioned by Sensus (2012), water utilities can save up to $12.5 billion annually by utilizing smart water networks from a combination of the following:

- Improve leakage and pressure management (up to $4.6 billion annually)
- Smart network operation and management (up to $2.1 billion annually)
- Smart monitoring and sensing (up to $600 million annually)
- Strategic prioritization and allocation of capital expenditures (up to $5.2 billion annually)

However, there exist challenges to implementing smart technologies. Among these changes there are:

- High economic cost (low-to-average investment cost – profit benefits ratio)
- Lack of funding, political and regulatory support
- Lack of standardization (product and services are too fragmented)

This document will present the different challenges and provide solutions and recommendations on how to bring Smart Water Technologies into the focus of the stakeholders.

In section 2, definitions on the water businesses process for urban water uses will be presented. This will be useful for the analysis of the trends and limitations in smart water management in the following sections.

In section 3 and 4, the trend, limitations and challenges that need to be addressed in the future development of the ICT for water management sector are identified. They includes:

- Standardization and Communication Protocols
- Big Data and Data Analytics
- Systems for Smart Water Management
- Geographic Information Management
- Smart Sensors Technology

Section 5 will present three case studies of smart water technology implementation in Malta, Singapore and South Korea where Big Data and Data Analytics, interoperability between different systems and tools and geographical intelligence are shown to play a crucial role for the successful implementation of smart water solutions.

In Section 6, a set of recommendations are presented in three categories: the adoption, implementation, and operating and maintenance of Smart Water Technology together with a checklist tool for Smart Water Implementation, developed by WIDEST, which provide utilities a quick evaluation of their commitment level towards smart water solution implementations.

Lastly, the document concludes with an action plan with the following recommended activities:

- Development of semantics tools to properly contextualize the business processes in the water domain
- Development of cross-domains data sharing (Water-Energy Nexus)
- Development and support for pilot projects
- Development of performance benchmarking
- Development of systems standards for cities and communities
- Development of Open Data initiative for free flow and easy access of data
- Provide review analysis and guidelines for the ICT solutions and systems in SWG

2. Definitions

In this section, the water cycle is defined as comprising of three domains: Water Uses, Natural Hazards Mitigation and Protection of Natural Environment. The water business processes in the urban water use (a sub-domain in Water Uses) will be identified and defined for the analysis of the trends and limitations in smart water management.

2.1 Water Business Processes

A business process is a collection of related, structured activities or tasks that produce a specific service or product (serve a particular goal) for a particular customer or customers. It implies a strong emphasis on how the work is done within an organization, in contrast to a product's focus on what. A process is thus a specific ordering of work activities across time and place, with a beginning, an end, and clearly defined inputs and outputs: a structure for action. Some processes result in a product or service that is received by an organization's external customer. These are called primary processes. Other processes produce products that are invisible to the external customer but essential to the effective management of the business. These ones are called support processes

In keywords, a BP:

1. Has a Goal
2. Has specific inputs
3. Has specific outputs
4. Uses resources
5. Has a number of activities that are performed in some order
6. May affect more than one organizational unit.(Horizontal organizational impact)
7. Creates value of some kind for the customer. (The customer may be internal or external)

2.2 Water Cycle

The water cycle can be divided in three domains that are associated to specific activities and business processes[1]:

- Protection of natural environment and ecosystems;
- Natural hazards mitigation and disaster prevention;
- Water uses.

[1] http://cdn.intechopen.com/pdfs/22755/InTech-Ict_for_water_efficiency.pdf

The first domain considers all actions needed to assess and advice on the environmental impacts of development proposals and projects related to specific water uses. Results are used by regulatory services. The domain covers also all conservation actions of water related ecosystems.

The second domain is focused on water related natural hazards mitigation actions. Floods, water-borne and vector disease outbreaks, droughts, landslide and avalanche events and famine are the processes covered by this domain. Every year, disasters related to meteorological, hydrological and climate hazards cause significant loss of life, and set back economic and social development by years. The disaster is defined as a serious disruption of the functioning of a community or a society causing widespread human, material, economic and/or environmental losses.

The last domain covers the added influence of human activity on the water cycle. Generally, the water uses refer to use of water by agriculture, industry, energy production and households, including in—stream uses such as fishing, recreation, transportation and waste disposal. All of those uses are directly linked to specific activities and processes that are potential targets for deployment of ICT solutions. In order to stick to the reality of the water management operated by entities in charge of water services, the traditional classification can be reviewed. The main water uses appear then as agriculture, aquaculture, industry, recreation, transport/navigation, and urban.

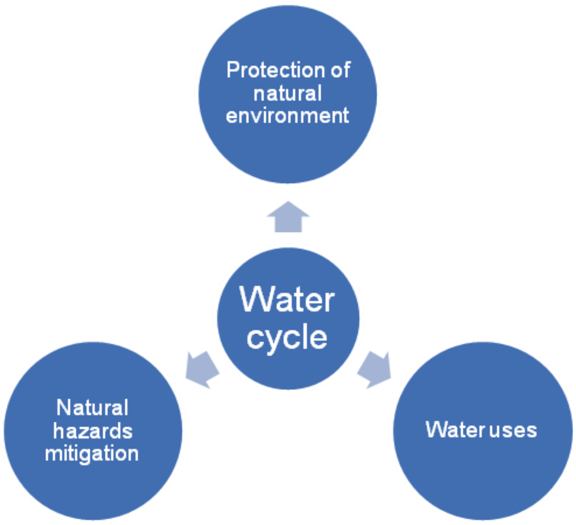

Figure 1 Domains of water cycle

2.3 Description of Domains in Water Cycle

Natural environment: Encompasses all living and non-living things, including natural forces occurring naturally on Earth or some region thereof, providing conditions for development and growth as well as of danger and damage. It is an environment including the interaction of all living species. Referring specifically to water environment, there are different biotopes than can be distinguished in continental waters (rivers, lakes, reservoirs …), coastal and maritime environments.

Natural Hazards: Unexpected or uncontrollable natural event of unusual intensity that will have a negative effect on the environment or people by threatening their lives or activities. Atmospheric hazards are weather-related events, whereas geologic hazards happen on or within the Earth's surface. However, it is important to underline that atmospheric hazards can trigger geologic hazards, and geologic hazards can trigger atmospheric hazards. In the water domain, natural hazards are related to floods, droughts, tsunamis, limnic eruptions[2], and seiche[3].

Water Uses: Are composed of the water cycle with the added influence of human activity. Dams, reservoirs, canals, aqueducts, intakes in rivers, and groundwater wells all reveal that humans have a major impact on the water cycle. According to the defined water domains, the water uses represent the largest field where ICT solutions can be developed and implemented. Overall, the Water uses considered in this framework are:

- Agriculture: Irrigation water use is water artificially applied to farm, orchard, pasture, and horticultural crops, as well as water used to irrigate pastures, for frost and freeze protection, chemical application, crop cooling, harvesting, and for the leaching of salts from the crop root zone. In fact, irrigation is the largest category of water use worldwide.
- Aquaculture: also known as aquafarming, is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants. Aquaculture involves cultivating freshwater and saltwater populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish. This implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators and so forth. It also implies individual or corporate ownership of the stock being cultivated. Similar to agriculture, aquaculture can take place in the natural environment or in a manmade environment. This activity uses part of the water bodies in order to develop activities. Aquaculture can be more environmentally damaging than exploiting wild fisheries on a local area basis but has considerably less impact on the global environment on a per kg of production basis.
- Industry: This water use is a valuable resource for such purposes as processing, cleaning, transportation, dilution, and cooling in manufacturing facilities. Major

[2] A limnic eruption, also referred to as a lake overturn, is a rare type of natural disaster in which dissolved carbon dioxide (CO2) suddenly erupts from deep lake waters, forming a gas cloud that can suffocate wildlife, livestock and humans.

[3] A seiche is a standing wave in an enclosed or partially enclosed body of water.

water-using industries include steel, chemical, paper, and petroleum refining. Industries often reuse the same water repeatedly for more than one purpose.

- Recreation: It often involves some degree of exercise as well as visiting areas that contain bodies of water such as parks, wildlife refuges, wilderness areas, public fishing areas, and water parks. Some of the activities that imply the uses of water for this purpose are fishing, boating, sailing, canoeing, rafting, and swimming, as well as many other recreational activities that depend on water. Recreational usage is usually non-consumptive; however, recreational irrigations such as gardening or irrigation of golf courses belong to this category of water use.
- Energy: Derived from the force or energy of moving water, which may be harnessed for useful purposes, such as Energy production. There are several forms of waterpower currently in use or development. Some are purely mechanical but many primarily generate electricity. Broad categories include conventional hydroelectric (hydroelectric dams), run-of-the-river hydroelectricity, pumped-storage hydro- electricity and tidal power. Cooling of thermo-electric plants is another essential use of water in the field of energy.
- Transport/navigation: It refers to the transport of goods or people using water as a means of transportation (on rivers as well as canals). This water use refers only to commercial transport, since recreational transports such as sailing is considered above in Recreation water use.
- Urban: Urban water use is generally determined by population, its geographic location, and the percentage of water used in a community by residences, government, and commercial enterprises. It also includes water that cannot be accounted for because of distribution system losses, fire protection, or unauthorized uses. For the past two decades, urban per capita water use has levelled off, or has been increasing. The implementation of local water conservation programs and current housing development trends, have actually lowered per capita water use. However, gross urban water demands continue to grow because of significant population increases and the establishment of urban centres. Even with the implementation of aggressive water conservation programs, urban water demand is expected to grow in conjunction with increases in population.

Using the concept of the five activities taking place in the various domains (Investigating/Surveying, Observing/Monitoring, Designing, Building & Decommission, Operating), business processes can be identified for the identified domains.

2.4 Urban Water Uses

The uses in urban environment, carried out by water utilities, can be defined with a limited number of business processes – 29 in total summarized in Table 1 Business processes for urban uses - which are covering drinking water, wastewater and storm water management. From this list of BPs, ICT solutions providing a real benefit can be identified. This diagnostic has to be shared by professionals and operators in order to ensure a coherent deployment.

Business Processes		Business Processes	
1 -	Asset management	16 -	Water primary network management & water balance
2 -	Crisis management	17 -	Water secondary network management
3 -	Field intervention management	18 -	Leak detection
4 -	Field works	19 -	Meter reading (AMR & MMR)
5 -	Use of GIS	20 -	AMR & MMR management
6 -	Maintenance of GIS	21 -	Public service contract management
7 -	Management of plant maintenance	22 -	Waste water network management (WWNM)
8 -	Electro mechanical maintenance	23 -	Storm water network management (SWNM)
9 -	Laboratory activity and quality control	24 -	Waste water treatment plant (WWTP) management
10 -	Automation & sensors	25 -	Sewer inspection and sewer cleaning
11 -	Real time network management	26 -	Billing
12 -	Planning and design of new assets & plants	27 -	Customer care & communication
13 -	Water resources management	28 -	Innovation & pilots
14 -	Environment management	29 -	Supports
15 -	Drinking water treatment plant (DWTP) management		

Table 1 Business processes for urban uses

Upon closer analysis, these 29 BPs are merged by homogeneous categories in terms of ICT, with the same (or similar) data, functionalities and potential gaps. The merged BPs and their respective needs and functions are listed in Table 2 Business processes categories for urban uses and Table 3 Data, functionalities of business processes categories for urban uses.

Business processes category	Remarks
1 - Management of Plants	This BP includes Drinking Water Treatment Plant Management and Waste Water Treatment Plant Management. It concerns not only plants but also (pumping) stations, including as well automation, in the sense of a "customer" of the needed automation.
2 - Management of Networks	This BP is the merger of Drinking Water Network Management, Waste Water Network Management, Storm Water Network Management and Real Time Networks Management (RTNM)
3 - Asset Management	In this BP, besides the study of ICT related to a general vision of Asset Management
4 - Work Management	This BP describes 2 levels of decision/actions: the management of jobs and interventions (field & plants) and the field and plant work in general. It also includes the inspection and cleaning of sewers (which, at this level of analysis, are not so different from the other field interventions)
5 - Geographic Information (GI)	This merged BP includes the maintenance and use of geographic information. It could be said that GI is not a BP per se, but it is included as such due to the major importance of Geographic Information. *(Note: the following discussion refer to the "legacy role" of GIS)*
6 - Measurements	It includes Automation & Sensors (including measurement systems), AMI “Smart Metering” and Laboratory activity & Quality Control.
7 - Customers	It includes Billing, Customer care and communication (including manual meter reading). In this BP, focus will be on: Manual metering; Billing; Customer care
8 - Public Service Contract Management	-
9 - Transverse BPs	This includes Crisis management, General reporting and communication.

Table 2 Business processes categories for urban uses

Business processes category	Data Required / Processed	Purpose / Function
Management of Plants	• Measurements(both real-time and offline) of DW and WW quality & quantity, status and consumption of electromechanical equipment and on-line sensors, laboratory results, description of plants • Assets description (including attributes and detailed drawings/charts (e.g. electrical cabinets), technical handbooks • Geographic information of the plants. • Rules of Operation, Daily Organization of work and Administration data	• To provide permanent access and visualization for processing data of DW and WW • PLC programming • To report on technical performance and administrative • Daily work organization and supporting activities

Business processes category	**Data Required / Processed**	**Purpose / Function**
Management of Network	• Measurements (both real-time and offline) of DW and WW quality & quantity, status and consumption of electromechanical equipment, laboratory results • Description of networks like assets description, condition of assets, geographic information of technological areas, Standards for geographic objects • Rules of Operation, Daily Organization of work and Administration data	• To provide access, visualization and control for processing data (quantity and quality) in real time (water balance capacity production - AMR/AMM System) • For modeling hydraulic, quality and CSO scenarios. • Reporting, daily work organization and supporting activities
Asset Management	• Asset description which includes Asset Register / GIS, Condition of assets, Standards for assets description, Vulnerability/exposition to external risk and Design hypothesis data & decision done. • Events and measurements • Interventions & Work (done, planned, on-going) • Customers, contracts, finance aspects • Laws and regulations	• To provide assessment of assets' condition, performance and risk • To define capital investments strategies, maintenance policy and purchase policy • To provide feedback on asset management medium term efficiency and follow-up application of strategies and policies
Work Management	• Requirements and rules for choosing, prioritizing and launching the jobs and interventions • Resources information (availability and location) • Status of jobs & interventions • Reports Technical info (Plant management / Network management), including actual current status of manual valves (or sluices)	• To transform the triggers into "job requests", including link with customer care. • To launch and monitor the jobs / projects, including management of the "unexpected" • To monitor the unitary actions / interventions: including assignment (i.e. matching of interventions and "relevant" resources, meaning by "relevant" all competent, available and adequately located resources) • To provide reports at 3 levels, job manager / team manager - foreman / operator
Geographic Information	• Geographic context: base maps, cadaster maps, aerial or satellite photos, etc.; administrative boundaries, shared address system with aliases. • Description of the assets: above- and underground - with attributes (including condition and current status) use of topologic functions of the GIS for the description of networks AND plants geo-indexation of multimedia info. • Geo-anchorages of alphanumeric info: i.e. alphanumerical "objects" such as customer complaints, work orders, anomalies, projects, etc.	• To provide integration of "geographic" data in all BPs' functions; • To provide integration of IGR "Implicit Geographic Relationship" in all BPs' functions • To provide cartographic HMI • To provide integration in all devices & web services

Business processes category	Data Required / Processed	Purpose / Function
Measurements	• Asset condition data • Equipment description • Administration and external data	• To provide data for acquisition, validation, storage, aggregation and assimilation • To generate and provide for visualization, automated reports, and decision support /early warning (open loop), process control (closed loop), and efficient communication between the "field equipment" and the central IS
Customer	• Customer related data like customer details, technical information, communication records, and financial status and records	• To provide billing support, including flexible tariff handling • To provide bidirectional real time access to customer data
Public Service Contract	• All data used across the organization, i.e. performance indicators (environmental, financial service)	• Collecting, collating data in a common standard format - to be collated from a variety of IS (incl. emails & digitized analogue sources) & carrying out complex contract data modeling; • Provision & visualization of the data & model outputs to both – service provider & regulator; • Comprehensive auditing facilities & tracing capture; • Contract maintenance & change control, charges and cost monitoring; ordering, payment & budget procedures, resource management and planning, management reporting, asset management; • Automated, integrated case management & escalation; • Reporting & data exporting; • KPI real time system.
Transverse BPs	• In the regards of all ICT needs for the rest of BPs, it was concluded that the specific needs in this BPs are rather low, as the depend on the data collected and managed by all the other BPs.	

Table 3 Data, functionalities of business processes categories for urban uses

2.5 Smart City

One of the primary goals of building a Smart City is to improve the quality of life with technology to improve the efficiency of services and meet residents' needs. A Smart City should have the ability to integrate multiple technological solutions, in a secure manner, for the management of the city's assets[4]. In addition,

[4]http://www.academia.edu/21181336/Smart_City_Roadmap

Smart Water Grid is one of solution for the city systems (water) that manage the water resources of the city.

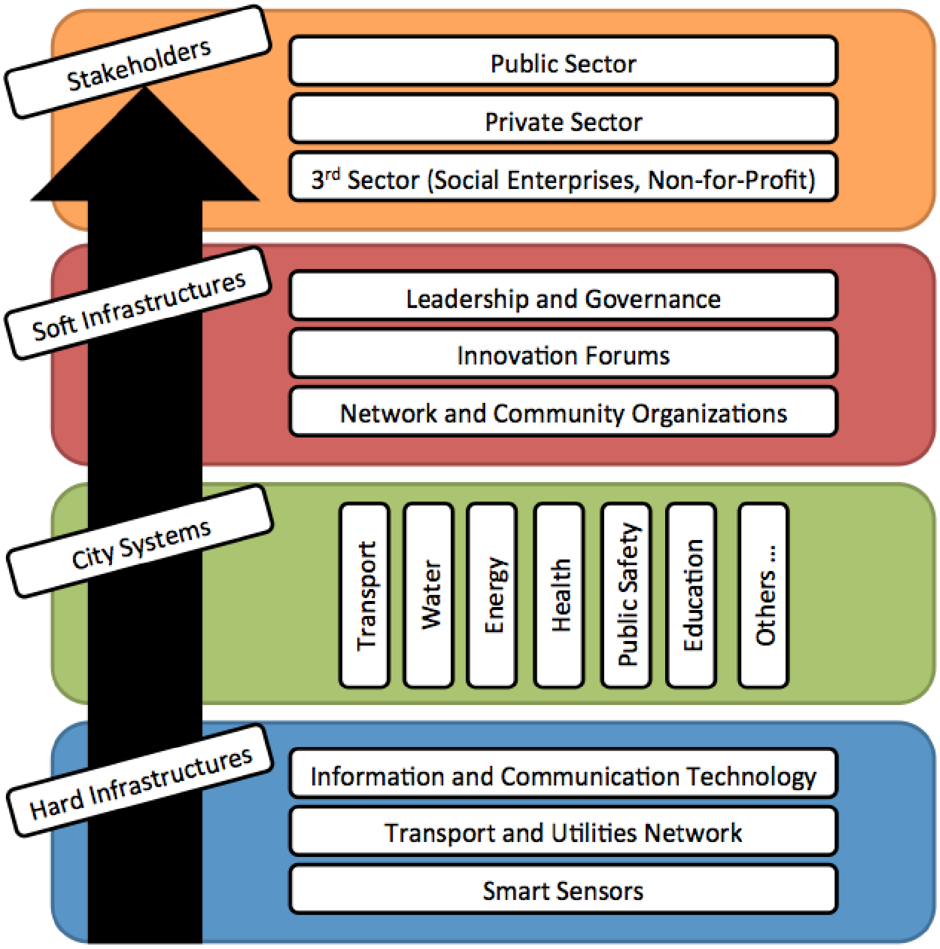

Figure 2 Structure of a typical Smart City

The technical challenges encountered will be the "interconnections" within and between the different layers shown in Figure 2 and Figure 3:

i. Hard Infrastructures and City Systems, where data and measurements from the smart sensors are efficiently transferred to the water information system

ii. Integration of Decision Support System with Real-Time Modelling and Monitoring System within the Water Management City System

iii. A overall system that integrates all the different city systems (including Smart Water Grid) together to facilitate the governance as well as provide visualizations for the current and forecast situations of the city.

In addition, social challenges will also need to be overcome for the successful implementation of "Smart Water" City. They are:

i. Policies to safeguard the security and integrity of the data

ii. Motivation and incentives for innovations and implementations in Smart Water technology from all sectors

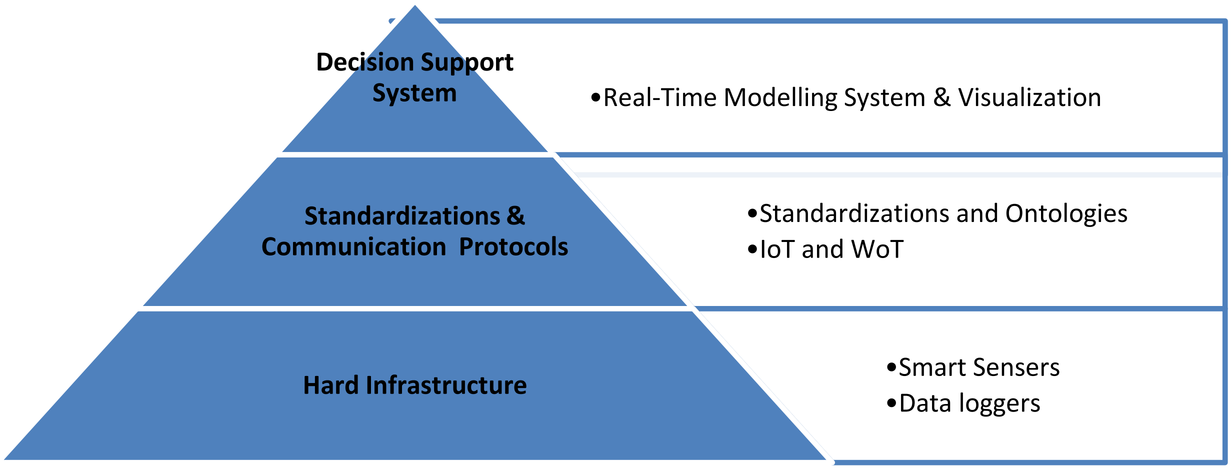

Figure 3 Diagram of Water System Architecture

3. Current Trends & Limitations

In the topical roadmaps of D2.1 (Semantic Interoperability and Ontologies)[5], D2.2 (Smart City Connection)[6], and D2.3 (Smart Water Grid)[7], the state of the art as well as the limitations and challenges are explored and analysed. A brief summary of the analysis conducted will be presented in this section, which will be used to align the overall roadmap objective.

3.1 Semantic Interoperability and Ontologies

i. Ontologies On Water Management

From all identified ontologies that are related in Water Management from the previous reports in the WIDEST, it has been found that these ontologies cover the following areas:

- Basin Management
- Customer Relationship
- Data Management and Smart City Services
- Management of the Water Cycle
- Sea Water
- Sustainable Development, Circular Economy, & Ecosystem Services,
- Wastewater and Stormwater Collection (including Flood Risk Management)
- Wastewater Treatment (Including Recovering of Resources)
- Water Quality
- Water Reuse and Recycling
- Water Scarcity and Droughts
- Water Supply and Distribution
- Water-Energy-Nexus

However, it should be noted that a number of the ontologies are not freely available, and even if they are, they are often used for specific purposes.

ii. Standards On Water Management

For the Hydrological information, there has exists many different standards and tools available for collecting, processing and managing them. They includes: Archydro, WaterML2.0, Australian Water Data Transfer Format, Water Quality Exchange (WQX), XHydro, KISTERS, EA Time Series Data Exchange Format (UK-EA-TS), The French National Service for Water Data and Common Repositories

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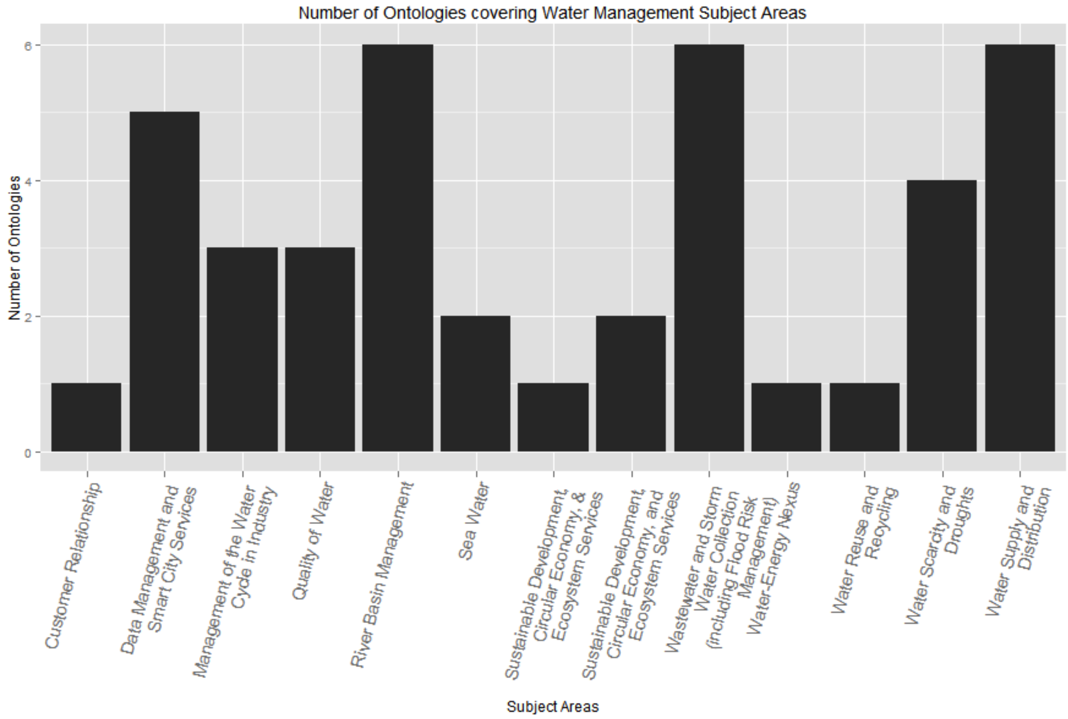
[5] http://www.widest.eu/images/downloads/roadmaps_downloads/widest_roadmaps/D2.1_-_Semantic_Interoperability_and_Ontologies_Topical_Roadmap_v2.3.pdf

[6] http://www.widest.eu/images/downloads/roadmaps_downloads/widest_roadmaps/D2.2_-_Smart_City_Connection_topical_roadmap.pdf

[7] http://www.widest.eu/images/downloads/roadmaps_downloads/widest_roadmaps/D2.3_-_Smart_Water_Grid_topical_roadmap.pdf

Management (SANDRE), The Open Modelling Interface (OpenMI), DelftFEWS, Climate Science Modelling Language (CSML), CUAHSI Hydrologic Information System.



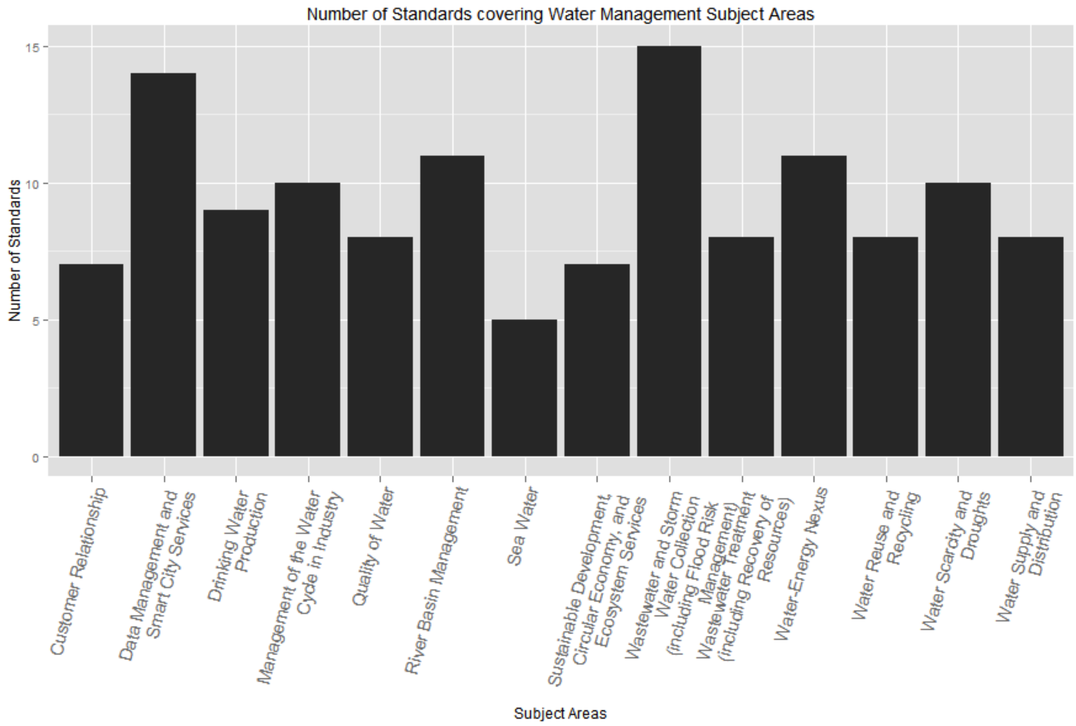


Figure 4 Statistics of ontologies (top) and standards (bottom) in Water Management

Water Management Topics and Technologies	Data and Service Sharing	Interoperability ofSpatial Data Sets and Services	Metadata	Network Services
Customer Relationship	10	3	6	10
Data Management and Smart City Services	16	9	14	16
Drinking Water Production	5	1	6	5
Management of the Water Cycle in Industry	14	6	13	14
Quality of Water	7	4	8	7
River Basin Management	18	13	20	18
Sea Water	12	7	11	12
Sustainable Development	9	9	14	9
Sustainable Development, Circular Economy and EcosystemServices	18	10	17	18
Wastewater Treatment (including Recovery of Resources)	11	4	11	11
Wastewater and Storm Water Collection (including Flood Risk Management)	7	2	6	7
Water Reuse and Recycling	16	6	15	16
Water Scarcity and Droughts	18	10	17	18
Water Supply and Distribution	17	7	13	17
Water-Energy Nexus	10	3	6	10

Table 4 Statistics of standards and ontologies in each technical aspect for Water Management

Using the framework directive INSPIRE for Geospatial[8] information, the different fields in water management can be defined into four aspects, Metadata, Network Services, Interoperability of Spatial Data Sets and Services and Data and Service Sharing.

Moreover, from Table 4, it is evident that there is a need a lack of standards and ontologies in the area of interoperability of data sets and services. This translates to more development required in the transfer of data between:

- Sensors to Data Information systems
- Modelling systems, Information systems and Visualization systems
- Smart Water system and other city Resource Management systems

However, there is a lack of standards and anthologies on water business processes, which play a big role in the water system in the smart city.

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[8]http://inspire.ec.europa.eu/index.cfm/pageid/48

3.1.1 Standards Applicable to the Identified Water Business Processes Categories

Table 5 below list the various identified standards that can be used to properly define the different water business processes such that it can improve the standards and semantics of the water business processes definitions.

	Management of Plants	Management of Networks	Asset Management	Work Management	Geographic Information (GI)	Measurements	Customers	Public Service Contract Management	Transverse BPs
Basin Management	✓	✓	✓		✓	✓			✓
Customer Relationship					✓		✓		✓
Data Management and Smart City Services					✓	✓		✓	✓
Management of the Water Cycle	✓	✓			✓	✓			
Sea Water	✓	✓			✓	✓			
Sustainable Development, Circular Economy, & Ecosystem Services,			✓		✓			✓	✓
Wastewater and Stormwater Collection (including Flood Risk Management)	✓	✓			✓				
Wastewater Treatment (Including Recovering of Resources)	✓	✓			✓				
Water Quality				✓	✓	✓			
Water Reuse and Recycling	✓	✓			✓				
Water Scarcity and Droughts	✓	✓			✓	✓			
Water Supply and Distribution	✓	✓	✓		✓				
Water-Energy-Nexus	✓	✓	✓	✓	✓			✓	✓

Table 5 Standards applicable to the water business processes

3.2 Smart City Connections

The purpose of developing Smart Cities is to improve the social, economic and environmental aspects of the cities by:

- Increasing the quality of life of the city inhabitants,
- Enhancing the efficiency and competitiveness of the economy,
- Reaching sustainability of the cities through efficient resource management.

In the perspective of water management, the "smart connections" that will be required for the Smart Cities to function efficiently will be defined for this report in three scales: Micro-scale, Meso-scale, and Marco-scale.

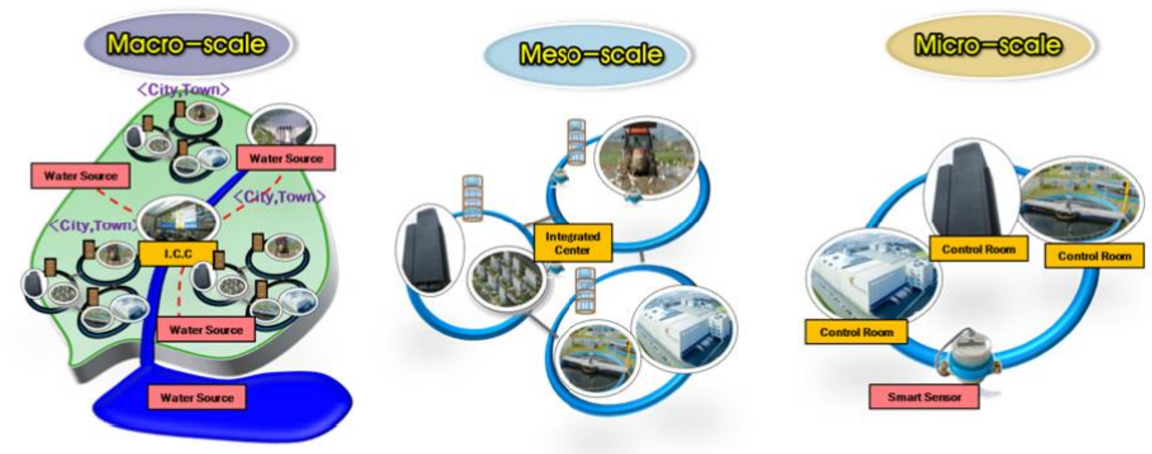

Figure 5 Figure of Micro-scale, Meso-scale and Marco-scale in Water Management[9]

In Micro-scale, the "connections" refers to the machine-to-machine connections. These include connections between smart sensors to the control room, which collects and records the measured data.

In the Meso-scale, the "connections" will be between the different control rooms for each water management fields like water supply management, wastewater management, runoff management, etc. All these control-rooms will be integrated into an overall control centre that will provide real-time analysis, forecasts and visualization of the water situation in the city. This essentially is the essence of the Smart Water Grid.

In addition, the connections between the integrated water control centre (Smart Water Grid) and the city's other resource integrated control centres like energy management, transport management, waste management, etc., are also considered within the meso-scale.

[9] http://www.swg.re.kr

In the Marco-scale, the "connections" concerned are the ones between the different cities' integrated control centres. The reason why these connections should be of concerned is because the watershed catchment area often spans over several cities, and thus requires inter-cities water management. In addition, in the event of water shortage or abundance, the connections will also facilitate the management of water between a water-shortage city and a water-abundance city.

3.2.1 Smart Meters

Smart meters are now implemented to provide real-time measurements for the water utility companies. The smart meters provide the water utility companies to detect leakage, track water consumption as well as provide data for predictive analytics to regulate supply and set up alarm notifications for any anomalies. This enables the water utilities to reduce their operation costs as well as their carbon footprint.

However, this brings about the management issue for the huge volume of data collected by the smart meters. Issues like the transmission and storing of data, analysis of data as well as the security of the data are major concerns for the water utility companies, the governmental bodies and the customers.

It is worthwhile to note that in the Smart Grid Task Force[10] assigned by the European Union, report analyses are conducted on the implementation of Smart Meters on electricity and gas, but not on water. The EU aims to replace at least 80% of the electric meters with smart meters by the year 2020, wherever it is cost-effective. In a 2014 commission report on smart metering deployment, a potential investment of €45 billion will be used to installed 200 million smart meters and 45 million smart meters in the EU for electricity and gas respectively by 2020.This will translate to about 72% of the European consumers having access to smart meter for electricity and 40% of the European consumers having access to smart meter for gas. In addition, it is reported that the estimated cost of installing a smart meter in the EU is on average €200 and €250.

In Europe alone, smart water metering is expected to generate a cumulative investment of $7.8 billion. Should the investment environment improve, bolstered in part by strong government support, this market should grow further to $13.4 billion over the same period.[11]

[10]https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters

[11]http://www.waterworld.com/articles/wwi/print/volume-26/issue-5/regulars/creative-finance/smart-water-metering-networks-an-intelligent-investment.html

3.2.1 Big Data and Data Analytics

As more smart meters are being employed in the water system, the amount of data available for collection has increased exponentially. In addition, add this to the data collected from other domains like energy, economy, meteorology, etc., this 'Big Data' easily become a "headache" to manage efficiently.

According to Gartner[12], other organizations and industry authorities, the characteristics of 'Big Data' comprises of the following:

i. Volume: There is neither data sampling nor analysis. Data are merely tracked and recorded.
ii. Velocity: The data is often available in real-time.
iii. Variety: The data comprises of information from metering data, text, images, audio, video and much more

Hence, by using Big Data analytical platforms to manage the huge volume of high velocity and variety of big data, one can obtain useful information from it. For example:

- Completing missing information through data fusion like using of videos and images in conjunction with water data for a more comprehensive vision
- Imputing the data to Machine Learning models for forecasting of the water network system status as well as validating the quality of the collected data itself

Some of the highly favoured advances that Water Management can benefit from Big Data are:

- Better real-time operations decision-support
- Better networks management (drinking water, storm water and sewer water)
- Leak detection of the networks
- Better understanding of consumer consumption behaviour
- Improved customer relationships and communications
- Water conservation and flood education of the public
- Flood mapping

[12] http://www.gartner.com/newsroom/id/1731916

3.2.2 Systems for Smart Water Management

i. Internet of Things

The Internet of Things (IoT) is a system of physical objects that can be discovered, monitored, controlled or interacted with by electronic devices, which communicate over various networking interfaces, and eventually can be connected to the wider Internet.[13]

Cyber Physical Systems (CPSs) are systems that link the physical world (e.g., through sensors or actuators) with the virtual world of information processing. They are composed from diverse constituent parts that collaborate to create some global behaviour. These constituents will include software systems, communications technology, and sensors/actuators that interact with the real world, often including embedded technologies.[14]

It should be noted that the focus of IoT is often more on sensing and connectivity, whereas CPS places more emphasis on reliability, security, and system control.

One of the main challenges for the deployment of IoT networks is the connectivity among its components. Depending on the situation of the deployment site, suitable solution has to be determined.

In topical roadmap for Smart City Connections (D2.2)[15], a summary of standard protocols for smart meters' connectivity for smart meter was carried out and presented in Table 6.

Domains	Remarks
IEEE 802.15.4	• A radio technology standard for low-power and low-data rate applications with a radio coverage of only a few meters. The standard has been developed within the IEEE 802.15 Personal Area Network (PAN) Working Group. Because of its designated nature as low power and low complexity, an increasing number of IoT devices have been built as IEEE 802.15.4-compliant devices. • Many well-known standardization organizations are also active in developing low-power protocol stacks based on IEEE 802.15.4, such as WirelessHART[16] and ZigBee[17].

[13]http://webofthings.org/2016/01/23/wot-vs-iot-12/

[14]http://www.cpse-labs.eu/cps.php

[15]http://www.widest.eu/images/downloads/roadmaps_downloads/widest_roadmaps/D2.2_-_Smart_City_Connection_topical_roadmap.pdf

[16]http://en.hartcomm.org/main_article/wirelesshart.html

[17] http://www.zigbee.org/what-is-zigbee

Domains	Remarks
IPv6	• Established by IPv6 over Low-Power WPAN (6LowPAN) Working Group • IPv6 has been selected as the only choice to enable wireless communication. Its key features, such as universality, extensibility, and stability, have attracted a lot of attention and may become the de facto solution for future Internet technology. • IPv6 over Low-Power WPAN (6LowPAN) Working Group was established to work on protocol optimization of IPv6 over networks using IEEE 802.15.4.
RPL (Routing Protocol for LLN)	• RPL is a distance-vector routing protocol, in which nodes construct a destination-oriented acyclic graph (DODAG) by exchanging distance vectors and root with a controller. • This routing protocol RPL supports three kinds of traffic flow: point-to-point (between devices inside the LLN), point-to-multipoint (from a central control point to a subset of devices inside the LLN), and multipoint-to-point (from devices inside the LLN toward a central control point).
Constrained Application Protocol (CoAP)	• It is a specialized web transfer protocol for resource-constrained nodes and networks. • It realizes a subset of HTTP functions and is optimized for constrained environments and offers features such as built-in resource discovery, multicast support, and asynchronous message exchange.

Table 6 List of standard protocols for smart meters' connectivity

These standards help to facilitate communications between IoT elements. Moreover, with the introduction of cheap Open Hardware platforms such as RaspberryPi or Arduino, architectures can be easily implemented by using tiny, cheap and highly customizable pieces of hardware. This enables the users to construct a final prototype without having to spend a lot of time and money. The openness also helped in the development of operating systems that already incorporate standard protocols, this is the case of Contiki[18], TinyOS[19], FreeRTOS[20], Riot[21], and OpenWSN[22].

At the other end of the IoT communication are the servers, which collect and analyse the data for the user. These 'end points' are commonly referred as “IoT platforms”. The common services and functionalities of these IoT platforms are:

[18] http://www.contiki-os.org

[19] http://tinyos.stanford.edu/tinyos-wiki/index.php/TinyOS_Documentation_Wiki

[20] http://www.freertos.org

[21] https://www.riot-os.org

[22] https://openwsn.atlassian.net/wiki/pages/viewpage.action?pageId=688187

- **Connectivity & normalization:** harmonizes the inherent dispersion of protocols and data formats of the connected devices and services.
- **Device management:** ensures the connected “things” are working properly, seamlessly running patches and updates for software and applications running on the device or edge gateways. Database: offers a scalable storage solution.
- **Processing & action management**: allows defining rule-based event-action-triggers. Analytics: Integrates some sort of analytic tools to extract information from the collected data.
- **Visualization**: includes data visualization tools.

Some of the well-known IoT platforms includes Kaa[23], Temboo[24] and Fiware[25].

ii. Systems of Systems (SoS)

Samad & Parisini[26] defined SoS is constructed by multiple systems, which have:

- Operational independence of components where the component systems fulfil valid purposes in their own right and continue to operate to fulfil those purposes if disassembled from the overall system;
- Managerial independence of components where the component systems are managed (at least in part) for their own purposes rather than the purposes of the whole.

3.3 Real Time Modeling and Decision Support System

The aim of the DSS is to develop an integrated, risk-based decision support system to evaluate intervention strategies and provide decision makers with the required information to operate a sustainable water system. New methodologies were developed and tested supporting near real-time decision making for operators of Water Distribution Systems (WDS) dealing with a variety of failures (including pipe bursts, pump failures, etc.). These methods require considerable information inflow, hence the Decision Support System (DSS) was developed to analyse, process and present data efficiently, allowing the operator to reach timely, informed decisions. The DSS was based on a risk approach (in terms of both failures and interventions) to assist the operator in evaluating the likelihood of occurrence and impact of undesired events and in prioritizing necessary actions for mitigating the impact of the event. The primary source of

[23] http://www.kaaproject.org/smart-energy

[24] https://temboo.com/iot-applications

[25] https://www.fiware.org/2016/03/08/iot-fiware-along-the-revolution-of-smart-digital-services

[26] http://ieeecss.org/sites/ieeecss.org/files/documents/IoCT-Part3-04SystemsOfSystems.pdf

information for the DSS was near real-time logger data reporting pressures and flows at selected points throughout the system.

One example is the NEPTUNE Project[27].

NEPTUNE was a collaborative project involving two leading UK Water Service Providers (WSPs) (Yorkshire Water Services and United Utilities), a major provider of automation technologies (ABB) and seven UK universities (Universities of Cambridge, De Montfort, Exeter, Lancaster, Leicester, Sheffield and Imperial College).

The aim of NEPTUNE was to advance knowledge and understanding about water supply systems in order to develop novel, robust, practical techniques and tools to optimize, via dynamic control or otherwise, efficiency and customer service. Project NEPTUNE addressed research in three main areas; these were:

- data and knowledge management
- pressure management (including energy management)
- associated complex decision support systems on which to base interventions.

An on-line methodology for automated detection of leaks and bursts in water distribution systems is developed at the University of Exeter. The methodology makes use of several Artificial Intelligence techniques:

- Wavelets for de-noising of the recorded pressure and/or flow signals.
- Artificial Neural Networks for the short-term forecasting of future pressure and/or flow signal values.
- Statistical Process Control analysis for the analysis of discrepancies between the predicted (i.e., expected) and the actually observed signal values.
- Bayesian Network based inference system for classification of discrepancies and rising of alarms.

3.4 Smart Water Grid

A Smart Water Grid (SWG) is a two-way real time network with sensors and devices that continuously and remotely monitor the water distribution system (Martyusheva, 2008). It is proposed that the SWG should integrate these five prime research areas (Mutchek et al., 2014):

1. Platform configuration in both water and ICT networks
2. Guarantee water resources including both natural and manufactured water
3. Intelligent control of water flow using bi-directional communication in water infrastructure
4. Better management scheme dealing with risk-minimization for assets in the water infrastructure
5. Energy efficiency in operating and maintaining water infrastructure

[27] http://emps.exeter.ac.uk/engineering/research/cws/research/distribution/neptune

In order to facilitate the two-way flow of information and water, smart devices like smart meters, smart valves, smart pumps, and flood sensors are installed in the network system. Table 7 shows the list of technologies and devices that are implemented in the smart water grid.

Domains	Remarks
Sensing Devices	• Their purpose is to collect and transmit data about the water system on a real-time basis. • They are capable of collecting all kinds of information like: o Water flow and pressure (water meters) o Water quality (contaminant sensors and biosensors) • Another notable is the flood sensor where it can detect strains on water infrastructures[28], thus providing support to early warning systems and real-time emergency management.
Automated Meter Reading (AMR)[29]	• This technology allows readings from sensors to be automatically read, transmitted and recorded by having a device pinging on the meters. • ARM systems can be walk-by, drive-by[30] or fixed network. • It should be noted that the communication is only one-way, from the meter to the pinging device. • AMR systems are useful if the main objective is to read the meters quickly and accurately.
Automated Meter Infrastructure (AMI)[29]	• AMI can be considered Smart Water Grid in the "purest" form • This technology is a step-up from the AMR, where it allows two-way communication over a fixed network between the utility system and the metering endpoints. • Meter readings, are recorded and sent to a meter data management system (MDMS), from which they may be accessed by the utility's customer information system (CIS) and other systems, • If the utility desires, the information can be made available to customers through a web portal, or mobile apps.

[28]http://www.urbanflood.eu/Pages/default.aspx

[29]http://www.waterworld.com/articles/print/volume-27/issue-8/editorial-features/special-section-advanced-metering-infrastructure/advanced-metering-infrastructure-drivers-and-benefits-in-the-water-industry.html

[30]http://arad.co.il/solution/walk-by-drive-by/

Domains	Remarks
Smart Pumps and Valves	• Smart pumps and valves work in the same way as in regular pumps and valves, except that they are connected to a central system where they can be remotely controlled. • The smart pumps can also be equipped to detect clogs in the systems and responds according by breaking up clogs and/or reversing the flow. This is especially useful for wastewater and raw water conveyance • They can also be used to control leakage in the event of leak detection, or control and restrict water flow in certain conditions like sewer overflows to prevent environmental contamination. • They can also be used to control the amount and behaviour of water consumption like irrigation.

Data Transmission and Power	• The data collected from the sensors has to be either stored on data loggers or transmitted to a MDMS.
	• For this transmission, there are two alternatives: wired communication or wireless communication.
	  ○ Wired communication provides most of the benefits of a reliable, secure and robust data transmission; however, it is sometimes impossible to have such infrastructure due to physical or economical restrictions.
	  ○ Wireless transmission provides a fast and cheap alternative (depending on the technology used).
	• One issue for these devices is the source of power. In situations where direct connection to the power grid is not feasible, like in the water pipe distribution system, other alternative of power source has to be considered, like solar panels, water turbines or long-life batteries.

Table 7 Technologies and devices implemented in Smart Water Grids

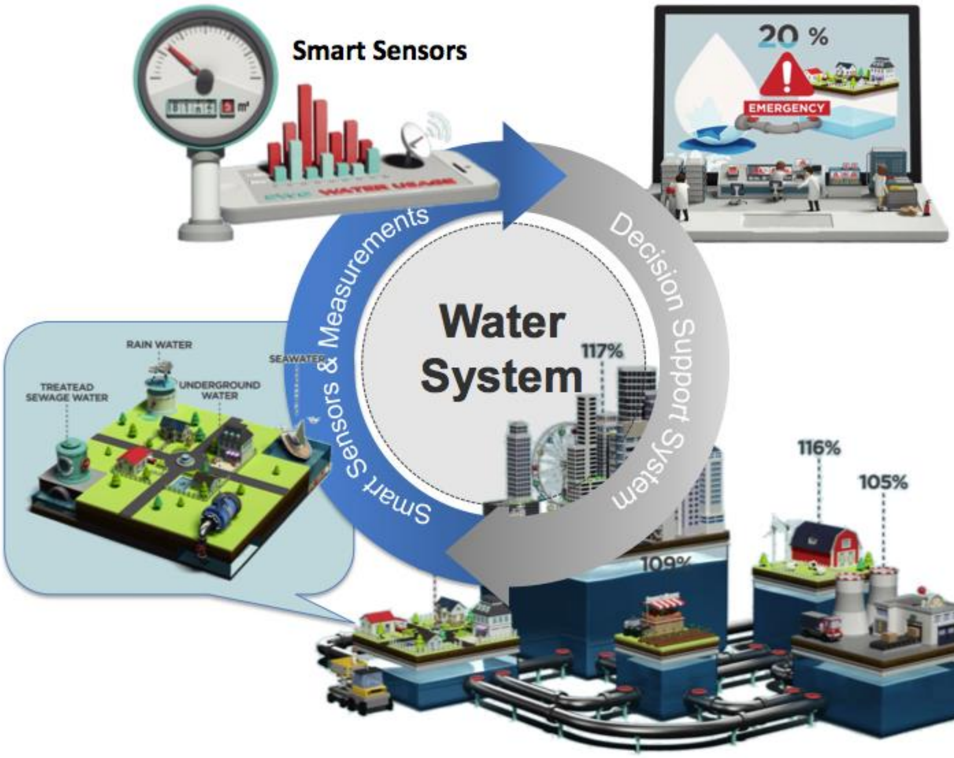

Figure 6 Diagram of Smart Water System Workflow[31]

Figure 6 shows the workflow of a Smart Water System. It consists of the hard Infrastructure that contain the smart sensing devices and their respective pipes, pumps and valves; which are in turn transmitting the recorded data to a Water Information System where the collected data are analysed and input into hydrological and hydraulic models for forecast. The forecasts are used to help the stakeholders and decision makers manage the water resources in the city through visualization of the model forecasts results. It also serves as calibration and validation input for the forecast models against the measured data from the smart sensing devices.

[31]Images taken from https://vimeo.com/125423323 (SWG Research Group)

4. Challenges

From the previous deliverables, these major issues have been identified:

i. Open Data & Big Data Management
ii. Standardization & Communication Protocols
iii. Water Management Information System
iv. Real Time Modelling & Decision Support System
v. Asset and Work Management
vi. Management of Geographical Information
vii. Smart Sensors Technology

4.1 Open Data and Big Data Management

There are three main issues concerning Open Data and Big Data management:

1. Real-Time Data Integration
   - Real-time monitoring provides the users up-to-date information for fast decisions, thus reducing losses. This is especially in the case of work maintenance where utilities are able to dispatch maintenance crew to the exact location of the incident (be it leakage in pipe or pump failures) in minimal time.

2. Availability of Data
   - Open data, especially open government data, is a great resource that is largely untapped. Many individuals and organisations collect a broad range of different types of data in order to perform their tasks. Government is particularly significant in this respect, both because of the quantity and centrality of the data it collects, but also because most of that government data is public data by law, and therefore could be made open and made available for others to use[32].
   - According to study by EU[33] Commission, if the Public Sector Information (PSI) policies were open, with easy access for free or marginal cost of distribution, there could have been a savings of up to EUR 40 billion through the direct PSI use and re-use activities.
   - For the period 2016-2020, the direct market size for Open Data is estimated at EUR 325 billion for Europe[34].

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[32]http://opendatahandbook.org/guide/en/why-open-data

[33]https://ec.europa.eu/digital-single-market/news/review-recent-studies-psi-reuse-and-related-market-developments

[34]https://www.capgemini.com/news/new-european-data-portal-is-a-key-step-in-seizing-multi-billion-euro-potential-of-open-data

- A report from the World Bank (2014) provides some examples of such savings:
  - In the United Kingdom[35], the estimated the direct economic benefits of public sector information at around £1.8bn a year, with an overall impact including direct and indirect benefits (such as time saved by access to real-time travel data) of around £6.8bn.
  - In Spain (World Bank, 2014), a study found that revenue of 330-550 million Euros generated annually can be directly attributed to Open Data reuse.
- In Europe, Open Data[36] initiatives are starting to make an impact in respect to both public sector information, and scientific data, while the Research Data Alliance[37] has been established to accelerate and facilitate research data sharing and exchange at the global level. In addition, open access to different data sources can help to take decisions at a higher level and foster the decision taking.
- However, there is still much room for improvement. Study[38] shows that the EU28+ have completed just 44% of the journey towards achieving full Open Data Maturity and there are large discrepancies across countries.

3. Security and Anonymity of Data
   - The security and safety issues are important for intelligent sensors as they are elements of wireless sensor networks that communicate directly or indirectly with other. There are already layers of security in WS (HTTPS, SSL, WS-Security to mention a few), but it has to be assured that these security tools arrive to the consumer, as security faults can be a major drawback in the adoption of interoperable open technologies.
   - There should also be reliable standards and procedures in place to safeguard the anonymity of the data. Research has shown that sensitive user behaviour can be inferred even from seemingly harmless sensors (e.g., accelerometers, gyroscopes, or magnetometers). Thus, it is of great importance that robust anonymity assurances are necessary when data is being shared.

4.2 Standardization & Communication Protocols

There is a need for Standard Ontologies (or at least standard Templates and dictionaries of data) for the main domains of data:

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[35]https://www.gov.uk/government/publications/shakespeare-review-of-public-sector-information

[36]https://ec.europa.eu/digital-single-market/node/70

[37] http://rd-alliance.org/about.html

[38]https://www.europeandataportal.eu/en/content/open-data-maturity-europe

- Measures such as Open Data, Semantic Sensor Networks (an ontology for sensors as is available on the W3C Website.
    - http://www.w3.org/2005/Incubator/ssn/wiki/images/2/2e/SemanticSensorNetworkOntology.pdf), *Water equivalent to the Common Information Model (for Electricity).*
- Interventions & Works, Standard job plans,
- Asset description (which will be further discussed in detail in section 4.6)
- Events, with a need to normalize how events are logged (coming from multiple sources)
- Customers, and triggers who will generate service requests (and default detection, which are usually called "complaints)

This will improve on the situation of data redundancy as well as conflicting data due to different data formats, not-up-to date data across all the board and such.

There is also a need to categorize these ontologies as well as for the data into:

- "survival kit"(minimal)
- "nice to have" (basic)
- “luxury" (optimal)

There’s also a need for cost based determination of what the pivotal/essential data is, and what is the minimal amount of data that is needed, say, to describe a water network, which impacts the GIS.

This brings about the notion of "Cost of ignorance". Every data has a cost, so the key notion for each data type is the cost of ignorance (how much it hurts the utility company NOT to have this data?) and cost of possession (seen as cost of acquisition plus cost of maintenance).

For many data, cost of ignorance is an order of magnitude lower than cost of possession (for example: highly detailed plant description), but there are counter examples (sense of closing of a manual valve).

In fact, for the data to be classified as "needed", it should be based on three criteria:

1. Data must be useful and used
    - Data is not useful just because it exists, is available or is easy to obtain. Its usage must be explicitly documented before being selected as a useful input to asset management.
2. Data must be maintained
    - Each piece of data must be associated to a formalized procedure for its collection and its update. This covers its observation on the field or in reports, its recording as well as its verification and its validation. It is also very important to find the best source for each data.
3. The reliability level of the data must be known
    - The quality of the various data will be variable in the same company. Thus, it is necessary to quantify the reliability of each piece of data. This proves again the absolute necessity

of a strong consistent approach of metadata, as an essential part of the ontologies to be defined.

Data Management has been improved using many technologies that are now generally available. In Information Management, structural approaches are used to provide flexibility and help manage complexity. The focus is now on Knowledge Management where Information can be managed to represent insights, experiences, and results. This issue is a key element for the water domain where the ontologies and the standards are missing in many aspects of the BPs.

4.3 Water Management Information System

There are many models of the utilities business are available on the market, with most of them coming from software vendors, whose objective is selling their software package solutions and not on creating or ensuring interoperability of the system with others.

Therefore, there is a need for an overall consistent approach made of an integrated model of the water business processes where the ideal Information System (IS) is based on Business Process (BP) model.

This consistent IS can be reach by a real integration and by gateways or interfaces. Targeting an IS, helps to establish a single definition and way of managing each data item. In other words, this consistent IS, together with standardised ontologies, is the key to real interoperability. The processes of generating or capturing data need to be managed and monitored and reference data and how they are shared within the information system has to be defined. However, above all, the target system should be fully aligned with the water business processes.

The approach has been already promoted for example within the Smart Water Management Initiative taken by K-water (Choi et al. 2016).

4.4 Real-Time Modeling and Decision Support System (DSS)

There is a need for systems taking into account all the real-time measurements from AMI and AMR sensors. The first domains of application could be in the quality management in drinking water networks, and in the generalised real-time monitoring of water level in sewers (Gourbesville, 2016a).

For Decision Support Systems (DSS), there is a need to take into the account of detection of unexpected alarms. Another need of the same sort is about tools of "Event detection" in the analysis of "Big Data", e.g. analysis of a series of several years of environmental data captured at a 3-minutes time step (Gourbesville, 2016b).

By definition, Decision Support Systems (DSS) are a specific class of computerized information system that supports business and organizational decision-making activities. In cities, the DSSs are supposed to streamline and integrate rules, procedures and decisions needed for solving complex problems: when relationships between required sets of data are unclear, the data comes in multiple formats and/or pertinent problem-solving methods required to be applied are not straightforward (Stair et al, 2010). The growing complexity of urban environments requests to develop a holistic approach that integrates the dynamic of the various functions and services under various situations like flooding or lack of drinking water.

In the water sector, the services provided to the inhabitants have been gradually integrated in various platforms that provide a real time overview of the various business processes. Major water utilities like Suez and Veolia have already produced specific services that are integrated in hypervision platforms promoted by IT providers such as IBM, CISCO, Schneider Electric, etc. In most of the cases, the real-time data on water consumption, potential leakages and quality monitoring are available for the technicians and the decision makers. Several experiments have been conducted successfully in Europe, Asia and USA. One of the most impressive achievements takes place in Malta with the full coverage of the country with an Automated Meters Reader (AMR) solution promoted by Suez and IBM (Sempere-Payá et al., 2013)

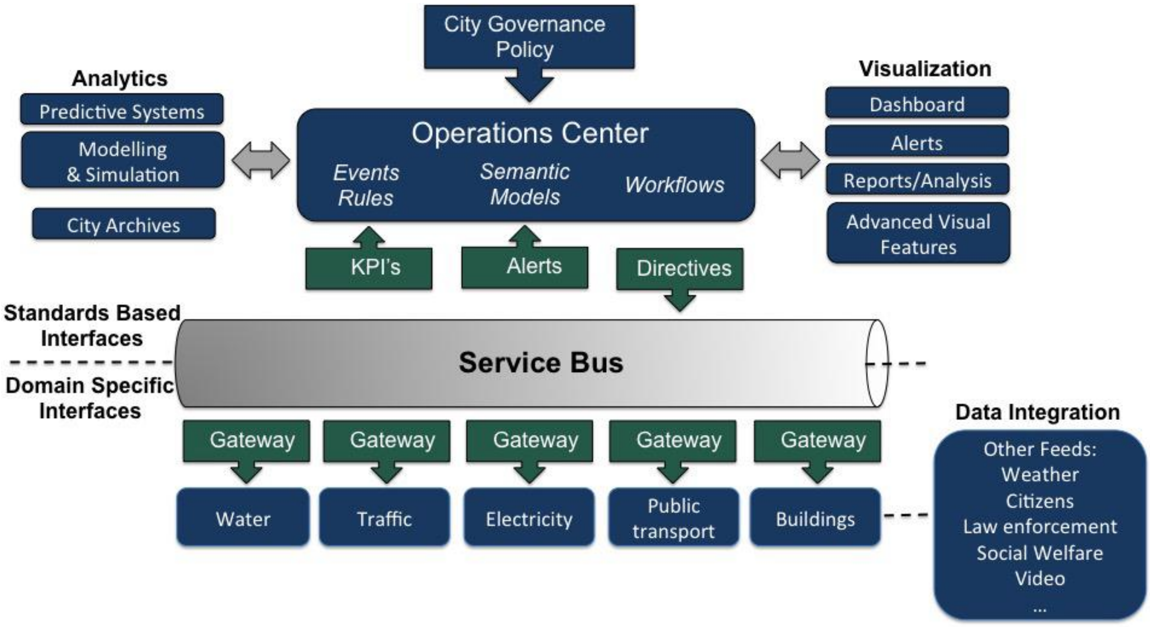

Figure 7 Concept of hypervision platform dedicated to urban monitoring and management (from IBM)

The current demands are in favour of a platform elaborated over a service bus dedicated to collect and integrate field data that are related to various processes including the water services and the natural hazards. Data are formalizes through various tools such as Key Performance Indicators (KPIs), predefined alerts and directives. A synthetic dashboard allows visualizing the current situation. In addition, in order to provide a real support to the decision process, several tools dedicated to the data analysis and to the simulation are interfaced with the core part of the platform. The models used in this analytics domain start with basic statistical tools and go to complex determinist models such as those commonly used in hydroinformatics. This architecture concept for the urban information system is today commonly shared and appears as a consensus solution (Gourbesville, 2011). However, several serious technical challenges are still there and will request efforts for a real integration and functional interoperability. If the concept is now shared, the maturity has to be gained in particular with the definition of the requested standards for managing the workflows among the various applications.

4.5 Asset Management

There are two limitations in the current commercial tools of A/M. Firstly, most of the commercial tools do not really comply with the analysis of the BPs of Asset Management. Typically, the essential distinction between "condition" and "performance" is never totally understood by the software providers. In the same domain, the separation between the major concepts of an "Asset Descriptor"; i.e.; the difference between "Where" (topofunctional description) and "What" (physical objects) is barely outlined with the notions of "location" and "component". The indispensable multigraph relationships are completely missing in the software packages of the market

The other limitation of the commercial products comes from the "silo-effect". They are built as self-sufficient tools, quite isolated from the rest of the Information System of the utility, and even if so-called "gateways" or "interfaces" with other applications are available, they are often not efficient, making it not so "interoperability"-friendly.

4.6 Work Management

Two limitations are identified. The first being that the commercial products do not comply with the essential specifications of the BP. Secondly, it is difficult to integrate the software package in a consistent information system, which can be also called "lack of interoperability".

In addition, there is also a need for some technological evolutions for:

- Augmented reality / 3D like / remote maintenance / Immersive environment;
- Buried asset electronic identification and tagging devices (including wireless communication through road materials.)
- "Wearable computers" for field workers, giving access in real time to all data bases of the company with interfaces consistent with field conditions

4.7 Management of Geographic Information: Towards Geographic Intelligence

Geographic Information should include the development of standard tools for enabling the transformation of the applicative architecture of the world of network management from its current "GIS centric" (or, more precisely, "GIS enabled") structure, to a "spatially enabled" architecture.

This means that the new role of geographic information (and not "GIS" strictly speaking) should has the following goals:

- Irrigate / sprinkle the IS (and/or the BPs) with "grains" of geography (data as well as services).
- Provide a direct access to location data.
- Propose context-adapted user interfaces, including cartographic GUI when it is useful - and only when it is useful regardless of any constraint due to the logic of a GIS tool.

In addition, there is a need for the co-existing of two different sets of tools:

- Classic GIS tools, which still have a place but with a slightly different role:
  - for the maintenance of the GI (typically digitization),
  - for mass or specialized GI processing (e.g. data transfers, conversions, etc.)Web services
- A more "agile" applicative engine, based on a set of web services, composed of:
  - a dedicated server (such as e.g. Geoserver) for geo-spatial services, compliant with the standards "Web Mapping Services" (WMS), "Web Feature Services" (WFS), or emerging standards like WPS.
  - an infrastructure of web services, for example provided by the ESB (Enterprise Service Bus) of the water entity, for business web services that are not directly linked to WMS/WFS standards, or for combined services (mashups).

These services share the same layer of enterprise data, of which the major components are the repositories of the data describing the networks and the other technical assets (i.e. the ontologies described several times, in this deliverable).

This new flexible architecture for GI could bring a great number of direct advantages, which all contribute to a much better interoperability:

- Service Oriented Architecture, which complies with the principles of architecture of modern IS, and enables an easy integration of GI, without any tragic transformation of the existing tools / data.
- Strict compliance with IT standards in order to allow easy connection and integration of all technologies: GPS, tablet, virtual reality devices, other business applications, Office tools, relational DBs etc.
- Integration of multiple GI sources at the level of the server:
  - directly compatible with relational DBs such as Postgres/Postgis or Oracle Spatial,
  - and also any other data sources (if standard formats of the market), for cooperative uses with stakeholders / partners / customers / local governments.
- Integration, at the level of the client applications, of "general public" data sources as Google Maps or Bing maps, or institutional data sources as the French IGN, BRGM or SANDRE, in the framework of the INSPIRE directive.

It must be noted that the OGC (Open Geospatial Consortium http://www.opengeospatial.org) - which works on all geospatial / geographic issues - has already developed several interesting concepts that could be the basis of the design of WatBIS (Water Business Information System)

4.8 Smart Sensors Technology

WssTP (www.wsstp.eu) has a Task Force on Sensors and Monitoring has produced quite an exhaustive report called "Sensors and Monitoring - State-of-the-art and research needs[39]. It has suggested that there is a need for a new generation of real-time sensors optimized for operation that is self-sufficient in terms of energy and telecommunication (autonomous, self-calibration, adequate level of accuracy and precision, low power, small) in accordance with the needs of the specific applications.

One of main challenges encountered by the utilities and the governments is the decision to implement smart sensors and what type of technology between AMR and AMI for their water systems. The factors for causing this dilemma are presented in the table below:

Factors	AMR VS AMI
Cost of Implementation	• AMI systems tend to cost 10% to 20% more than AMR systems since the former require a fixed network of data collectors, more complex software and backhaul communications.[40] Although in recent years, the price difference between the two technologies has decreased significantly, it is still wide enough for utilities to consider AMR instead of AMI.
Payback Period	• The time for cost of recovery is long term. Thus, some utilities see benefits of smart technology as optional, rather than critical.[41]
Size of Infrastructure	• Small to medium size utilities will be more favourable to consider AMI due to lower cost needed for equipment purchases and installation for fewer connections. (Between10,000 and 30,000 connections)[43]

[39]http://www.ondeosystems.com/wp-content/uploads/2013/06/SM-Report-VI1.pdf

[40]http://www.owasa.org/Data/Sites/1/media/customerService/ami-study-combined-documents.pdf

[41]http://bv.com/Home/news/solutions/water/smart-water-technology-benefits-challenges-and-three-action-steps-for-utilities

Factors	AMR VS AMI
Additional software development	• For AMR, there is little to no additional software development required (for example the billing system). • For the AMI, in order to have the full benefits of producing useful information, systems like the meter interface unit, the AMI system server (or "head-end"), the meter data management system and the billing system have to work together harmoniously. This requires significant software development for the integration of the AMI systems with other systems.
Real-time Status of the System	• AMI system will be able to provide real-time information, unlike AMR system. It enables the utility access to real-time pricing, automated billing, remote control of water connections and proactive response to leakages.

Table 8 Factors utilities consider for implementation of Smart Technology

5. Case Studies

This section will present successful case studies from Malta, Singapore and South Korea, all of which has implemented smart water technology in their cities. A brief introduction on the solutions implemented will be presented, together with the benefits and lessons learnt.

5.1 Malta

In 2010, the Automated Meter Management Project (AMM) was launched in Malta.[42] The AMM system being deployed by the Water Services Corporation today is of the fixed-network type. It makes use of the always-on wireless broadband GPRS network to connect every consumer meter to a centralised water management system. A Meter Interface Unit (MIU) is installed on each meter through a pulser unit, which transmits to a receiver gateway, which communicates to the central system through the GPRS network. The meter reading ends up at the central system where the data is stored, analysed and used for bills and water management tools. The schematic diagram below shows the basic architecture of an AMM system.

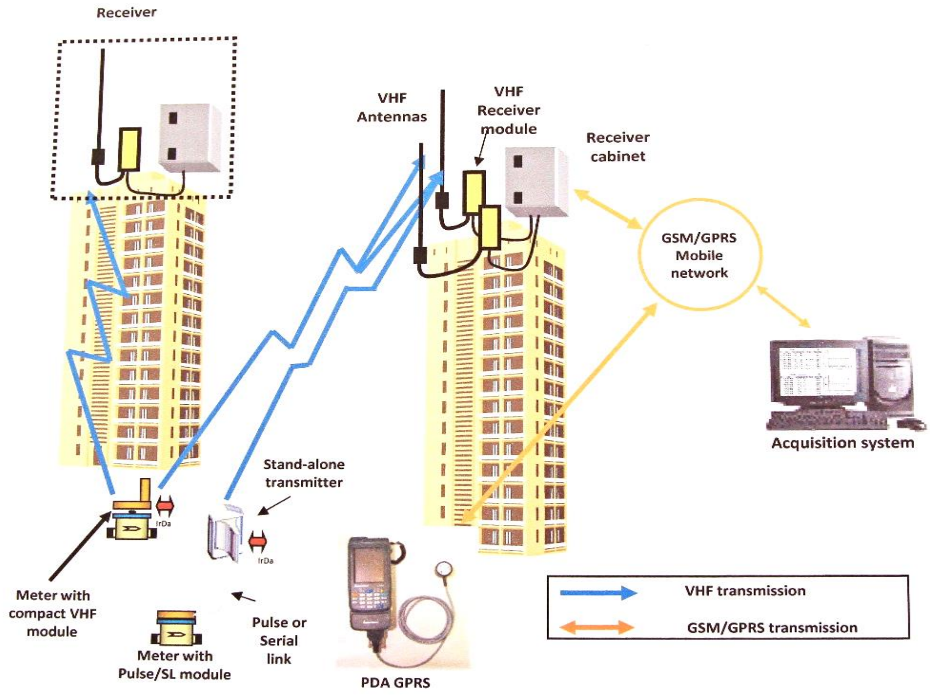

Figure 8 Schematic diagram below shows the basic architecture of an AMM system[43]

[42]http://www.wsc.com.mt/portals/0/Annual%20Report%202010/annual_report_2010_-_Water_Operations_2.pdf

[43]http://www.siww.com.sg/sites/default/files/Session%203-1%20-%20Mr%20Luke%20Pace.pdf

Using a solution from “SUEZ Smart Solutions”, the Automated Meter Management in Malta uses a fixed network a fixed network consisting of 2-layer technology (RF transmitters, receivers). It uses 169 MHz VHF, an EU authorized channel for remote reading. It has long-range transmission capabilities (no need for repeaters), 15-year battery life with the MIUs having cross-meter compatibility. Up until end of June 2016, over 86% (229k modules out of a total of 267k customers) have been installed.

The main objectives for WSC to implement the AMM are:

- Improve Billing
- Cash Flow + reduction/elimination estimated bills
- To access meter data remotely & continuously
- Customer oriented – a communication platform
- Permits Total Water Balancing

The strategy being employed to drive smart metering in our water network includes:

- Better inter-department coordination to ensure all (old) meter replacements result in smart metering installation,
- Geocoding of all important features of the water network,
- Development of reports and software to analyse data being provided from smart meters,
- Correct monitoring and maintenance of entire AMM solution.

Through precise and real-time measurement of water consumption, customers are billed more accurately thus eliminating estimated meter reading, improving revenue collection and avoiding unpleasant surprises for customers. In addition abnormal usage, tampering of the water system and leakages are easier to be identified, enabling the utilities reduce the loss incurred on non-revenue water.

5.1.1 IUBS Programme

To ensure that Malta is able to deliver affordable secure energy and water while protecting the environment, the water utility (Water Service Corporation) and energy utility (Enemalta Corporation) partnered with IBM to implement the IBUS programme which is a Smart Grid project which integrates AMM, ERP and CRM together.

The lessons learnt from the programme are:

- AMM solutions are not always plug and play. There is a need to have strong relationships with vendors to allow solutions to be customized to meet needs.
- The Return of Investment (ROI) is inversely related to the duration of implementation. Thus, the less time it takes to get the solution to be deployed, the sooner the utilities can start reaping the benefits.
- Customer buy-in is required for faster installation. Tailored communication campaign are carried out to smoothen the implementation of the AMM system and maximize the hit rate.

- To ensure the success operation of the Smart Grid, system knowledge is required in order to understand the process and the factors that need to be managed in order to yield positive results. In addition, MDM and monitoring system are required to intelligent reports for operational and strategic agendas of the utilities.
- It has been reported that with the implementation of the AMM, there has been a net annual gain of €0.42M shown in Figure 9.

Annual expenditure before Project	Annual expenditure after Project	Tangible benefits provided by Project	Net annual gains after Project	Intangible benefits
€0.6M	€1.73M	€1.55M	€0.6M - €M1.73 + €1.55M = **€0.42M**	Customer Related benefits

Before		After	
Meter readers	€0.6M pa	Field Maintenance	€200k pa
		Licenses	€80k pa
		Upgrades	€50k pa
		Depreciation	€1.4M pa
	€0.6M pa		**€1.73M pa**

Figure 9 Operating and profits for the AMN project[44]

5.2 Singapore

In Singapore, the Public Utilities Board (2016) supplies 430 millions of gallons per day (MGD) of water to customers. The Water Supply Network (WSN) Department has in recent years embarked on a Smart Water Grid journey to ensure good water is supplied to its customers 24 h a day, 7 days a week. Singapore current technology, Smart technologies experimentation and its technology roadmap are listed in Table 9.

[44]http://www.siww.com.sg/sites/default/files/Session%203-1%20-%20Mr%20Luke%20Pace.pdf

Domains	Remarks
Leak management and Network Operation Enhancement	• Existing Methodologies / Technologies: ○ Field crew to survey water mains for leaks. ○ Pipeline Failure Analysis Model using Bayesian statistics to identify pipes in the network where failures are most likely to occur • Smart Technologies Experimentation: ○ High rate pressure sensors(developed by PUB and Vinsenti[45]) that comprises 300 multi-parameter probes to detect both leaks and water quality issues in real-time ○ Plans to expand the sensor coverage in the network to 90 % by 2018 with 400 additional multi-parameter sensors.
Water Quality Monitoring	• Existing Methodologies / Technologies: ○ Depends on customers to act as sensors for water quality issues like discoloured water. • Smart Technologies Experimentation: ○ Collaborated with Sandia National Laboratories[46] to develop CANARY (EPA 2010[47]), a water quality event detection tool, in the distribution network. ○ WSN aims to own a real-time water quality model by 2030.
Automated Meter Reading	• Existing Methodologies / Technologies: ○ Mechanical water meters for billing customers, where the low frequency of manual meter readings does not offer sufficient granularity for understanding customer water consumption patterns. • Smart Technologies Experimentation: ○ Tested various fixed network AMR technologies: ▪ Short range systems with endpoints operating in unlicensed free Radio Frequency (RF) bands (UHF) and their data concentrators using cellular 2G/3G networks. ▪ Systems with endpoints directly using 2G/3Gnetworks.

Table 9 Singapore's current technology, Smart technologies experimentation and its technology roadmap

[45] http://www.visenti.com

[46] www.sandia.gov

[47] https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=221394

5.2.1 WaterWiSe Platform[48]

WaterWiSe is a platform for real-time monitoring of water distribution systems that can be used by utilities to improve system management and operation by providing integrated measurement and analytics.[49] It can operate as a self-contained system with its own analysis and management interfaces, or can be integrated into a water utility's existing infrastructure and geographical information platforms. The core WaterWiSe platform has two key components:

i. the Integrated Data and Electronic Alerts System (IDEAS),
ii. the Decision Support Tools Module (DSTM).

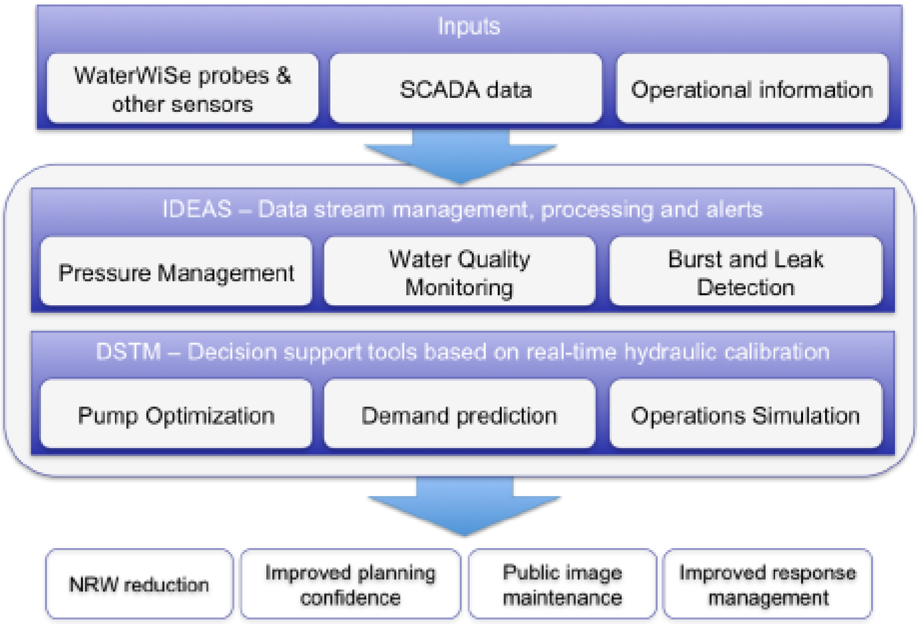

Figure 10 Overview of the WaterWiSe platform's functionality

Figure 10 shows the WaterWiSe platform comprising IDEAS and DSTM in context. Inputs to the platform are shown (both data and information), as well as a selection of beneficial outputs seen by the utility. The IDEAS and DSTM boxes both show a selection of applications that are enabled by each component. These components, discussed in more detail below, provide key services to help both water supply network planning and operations teams in the office and in the field.

Some of the benefits from the implementation of WaterWiSe include:

[48]https://dspace.mit.edu/handle/1721.1/92733

[49] http://dspace.mit.edu/bitstream/handle/1721.1/92733/Allen%20et%20al%20-%20SIWW%202012.pdf?sequence=1

- Pressure anomaly detection and localization of pipe bursts through pressure transients, and numerous pressure abnormalities relating to both planned and unplanned system operations
- Post-event analysis to trace back the sequence of events before a confirmed leak or burst event to understand which operations may have contributed to the leak
- Real-time visualization on demand and consumption, as well as determination of optimal sensor placement using the real-time hydraulic network model in the platform.

5.3 South Korea

K-water (Choi et al., 2016) proposed the SWMI (Smart Water Management Initiative) as an innovative water management technology to supplement traditional water management technologies. SWMI is a smart water management technology that combines the accumulated advanced ICT of Korea with K-water's experienced water management know-how.

For the implementation of SWMI, a three-step strategy was proposed:

i. K-Tech Tree, which involves the development of necessary technologies for SWMI implementation based on the current state of technologies.
ii. STEP-ISP, which includes the standardization of developed and will be developed technologies depending on the technology types.
iii. Standardized frame for applying technologies developed by K-Tech Tree and STEP-ISP.

The expected outcomes from the SWMI includes:

- More accurate weather forecasting by collecting and analysing information in real-time not only from rain gauges installed on the ground but also from precipitation data and satellites.
- Optimized flood and drought control through information sharing among different water management facilities and systemized operations
- Provides an optimal utilization system by combining all available water resource including underground water, seawater and rainwater not dependent on the supply capacity of water sources. This enables water supply on demand and water reuse, thus eliminating the need to construct additional large-scale infrastructures such as dams.
- Real-time analysis of information collected from smart devices provides improved response time to any incident, subsequently reducing the risk of accidents and waste of manpower and time.
- Help in the decision process to improve the water management level through the proposal of correct and accurate directions for investment and business.

5.4 Summary of the case studies

The case studies further validate the identified needs and expected changes required for the Water Industry to move towards Smart Cities and Smart Water Grids, where the Water Information System should be able to:

- Cope with Big Data with the implementation of smart sensors and AMI
- Have consistency/uniqueness of description in SCADA/EAM/GIS and better integration of these three tool categories to ensure interoperability
- Efficiently manage, analyse, and produce geospatial data and to perform highly developed analysis and visual production of geospatial data. (Geographical Intelligence)

6. Recommendations

This section will discuss recommendations that will help to overcome the limitations and challenges faced by the utilities and the government. They will be classify into the following three categories:

1. Adoption of Smart Water Technology
2. Implementation of Smart Water Technology
3. Operation and Maintenance of Smart Water Technology

6.1 Adoption of Smart Water Technology

In order to engage the interest of utilities, governments and the public in Smart Water Technology, multiple strategies comprising of technical solutions, policy-making and awareness campaign and education are required.

The first action is to ensure the specifications for interoperability and data sharing across services (water, energy, etc.) and their infrastructures. This can be achieve through the development of semantics tools to properly contextualize the business processes in the water domain (Water Uses and Services, Environmental Management and Natural Hazards Management) by using and adapting of existing ontologies (mainly sensors and real-time measures) and creating of new water-specific ontologies for those that are not available. To support the development of semantics tools, it is important to provide an open repository where all the ontologies are made available (free if possible).

The second action is to promote cross-domains data sharing (Water-Energy Nexus) by developing and providing Open Data interfaces and establishing Open Data policies.

The third action is to get the support for pilot projects on Smart Water technology. The outcomes of these pilot projects will contribute to the establishment of guidelines and best practices for future SWG implementation.

- For the governing bodies, besides offering the financial support, there should also be legislative support to ensure the security of the data collection, transmission and storing across all domains.
- For the utilities, proposed pilot projects should be self-financing within 3-5 years. The pilot projects should start with a small-scale implementation (SSI) carried out within the 1 year of the project. This will enable the utilities to make use of the results of the SSI to learn, optimize and re-engineering the processes in the project for the later phases. In addition, it will serves as a validation checkpoint that will reduce the risks, uncertainties and implementation time of the project.
- For the public, awareness campaigns should be carried out by the government and utilities to ensure customer buy-in. Such campaign can include seminars and conferences, printed media

and videos. This will smoothen the implementation of the AMM during the pilot project, thus optimizing the implementation time of the project.

6.2 Implementation of Smart Water Technology

For the implementation of Smart Water technology to be a success, there should be development of systems standards for cities and communities to ensure the interoperability solutions. Both the "inter" systems (like MDM, DSS) within the water system and the water system itself should not only be able to operate individually within its own set of operation protocols and standards, but also interact with other systems. In the case of the water system, there should be interoperability among the other Smart City systems. Recommendation includes:

- Develop Open Data initiative by making Open Data should be made easily accessible and free (if possible) to the researchers, as it will enhance and accelerate the development on the interoperability solutions
- Definition of the Water Information System for all common business processes models of all the domains (Water Uses and Services, Environmental Management and Natural Hazards Management) of the water industry, at least at a macro level.

6.3 Operation, Maintenance and Optimizing of Smart Water Technology

The challenge of smooth operation, maintenance and optimizing of the SWG can be overcome by developing performance benchmarking on an EU level. This can be built on work by IWA Water Utility Efficiency Assessment Matrix and Effective Utility Management Collaborating Organizations and extend the benchmarking to consider the processes involved in the smart water grid. The following actions are recommended:

- Identifying key performance metrics and indicators for SWG
- Develop a benchmarking framework and assessment methodology
- Develop a supporting benchmarking tool
- Test and validate the framework across the utilities in EU
- Making the tool available to the water utilities and sector

Follow-up actions upon the development of the benchmarking framework and tool are:

- Providing for cross-utility comparisons of utility targets and performance
- Developing a process for future updates to the tool and self-assessment process

6.4 Checklist Tool for Smart Meter Implementation

Based on the market research by Frost & Sullivan[50], a checklist tool is developed by Widest to provide the water utilities and the government an overview on how committed they are to implement the smart water technology in their existing system.

The questions of the checklist is as follows:

Q1. How important is the mass uptake of the smart water technology and validated (proven) benefits?

- Not at all
- Slightly
- Moderately
- Very
- Extremely

Q2. How important is the affordable cost of implementing the smart water technology?

- Not at all
- Slightly
- Moderately
- Very
- Extremely

Q3. How important is the reduction of fragmentation in Data Management Market?

- Not at all
- Slightly
- Moderately
- Very
- Extremely

Q4. How important is the performance optimization (like leak detection, consumption behavior) of your water system?

- Not at all
- Slightly
- Moderately
- Very
- Extremely

Q5. How important is the public's acceptance of the smart water technology?

- Not at all
- Slightly
- Moderately
- Very
- Extremely

Q6. How important is the presence of government support for smart meter technology? (in terms of regulation and legislative)

- Not at all
- Slightly
- Moderately
- Very
- Extremely

The scoring system of the checklist is as follow:

	Not at all	Slightly	Moderately	Very	Extremely
Qn 1	5	4	3	2	1
Qn 2	5	4	3	2	1
Qn 3	1	2	3	4	5
Qn 4	1	2	3	4	5
Qn 5	1	2	3	4	5
Qn 6	1	2	3	4	5

[50] https://www.engerati.com/sites/default/files/Day3-0900-Fredrick%20Royan.pdf

The score analysis is as follows:

Score	Commitment Level	Remarks
6-12	Minimal	• You are not actively exploring Smart technology due to the high cost of implementation • Financial support from the government or municipality can be a means of funding part of the implementation plan. • In addition, a small-scale implementation project can be carried instead of the full-scale.
13-20	Average	• You are exploring Smart technology with the objective to optimize your water system • However, you are concerns about the high cost and the fragmentation of the data management market. • AMR would be an ideal starting point for the upgrading of your water system as it has proven actual real benefits and improved efficiency to the water system operations. • AMI, the more expensive alternative, would be suitable if your water system endpoints are small to medium sized. (10,000 to 30,000 endpoints). However, attention should be given to the interoperability of the implemented systems to ensure that it will be able to be easily upgraded in the future.
21-30	Highly	• You are actively exploring Smart technology with the objective to optimize your water system • Since cost is not a critical concern, AMI solution would be the technology for your water system. • However, attention should be given to the interoperability of the implemented systems to ensure that it will be able to be easily upgraded in the future.

In addition, this checklist tool can also be used for identifying the mindset of the utilities and governments on the implementation of smart water technology.

7. Action Plan

No.	Activity	Challenges Addresses	Short Term (1-2years)	Medium Term (3-5years)	Long Term (>5 years)
1	Development of semantics tools to properly contextualize the business processes in the water domain	To ensure the specifications for interoperability and data sharing across services (water, energy, etc.) and their infrastructures.	x		
2	Development of cross-domains data sharing (Water-Energy Nexus)	To develop and provide Open Data interfaces and establishing Open Data policies so as to facilitate the data flow between different system domain	x	x	x
3	Development and support for pilot projects	To establish best practices and guidelines on SWM implementation so as to promote adoption of SWM To raise awareness in SWM among the stakeholders (utilities, governing bodies and end-users)		x	x
4	Development of performance benchmarking	To identify key performance metrics and indicators for SWG in order to develop benchmarking framework and assessment methodology Provide benchmarking tool available to the water sector		x	x
5	Development of systems standards for cities and communities	To identify and develop interface standards essential for the integration of systems	x	x	
6	Development of Open Data initiative for free flow and easy access of data	To promote and accelerate the development on standards and ontologies on data To facilitate the integration of different systems	x	x	
7	Provide review analysis and guidelines for the ICT solutions and systems in SWG	To promote the established standards and best practices obtained from the pilot projects and their relevant experiences and research on operating and maintenance.			x

8. Conclusion

This report is the Overall Roadmap to analyze key issues across three topical roadmaps in WP2 ("Semantic Interoperability and Ontologies", "Smart City Connection" and "Smart Water Grids"), assimilate information across these topics, advice about effective implementation of the holistic approach and provide specific analyses and recommendations for policy makers and other readers.

To identify the challenges in the adoption and implementation of the Smart Technologies, a review analysis has been conducted through current literature and informal meetings with involved stakeholders. The results are presented in Section 32 where the interest falls mainly in the field of semantic interoperability and ontologies for Smart Water Management and the technologies implemented in Smart Water Grid (Smart Meters, Big Data and Data Analytics and Water Management System).

In Section 4, the challenges are identified based on the trends and limitations in section 2. They includes Open Data and Big Data Management, Standardization & Communication Protocols, Real-time Modeling and Decision Support System, Asset and Work Management, Management of Geographic Information and Smart Sensors technology.

In Section 5, case studies of smart water technology implementation are presented. They include the Automated Meter Management Project (AMM) and the IBUS Programme in Malta, AMR implementation and real-time monitoring system (WaterWiSE Platform) in Singapore and the Smart Water Management Initiative (SWMI) in South Korea.

The rest of the report is devoted to the recommendations and identification of actions to be taken in the future. The recommendations are discussed in three categories, namely the adoption, implementation, and operating and maintenance of Smart Water Technology. A checklist tool for Smart Water Implementation is also developed to give the utilities a view on how committed they are to the implementation of Smart Water technology. Lastly, a 5-year action plan based on the recommendations for the stakeholders concludes the report.

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