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Report on International Asset Management Practices

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TABLE OF CONTENT

1	INTRODUCTION.....	4
1.1	What is Asset Management?	4
1.2	Objective of Asset Management	4
1.3	How Does Asset Management Work?	5
1.4	Benefits of Asset Management.....	6
1.5	Need for Asset Management in Public Utilities.....	6
2	APPROACHES TO ASSET MANAGEMENT	8
2.1	PAS 55	8
2.2	AWARE-P Approach	9
2.3	The Common Framework for Capital Maintenance Planning in UK Water Utilities.....	11
3	ASSET MANAGEMENT PRACTICES.....	13
3.1	Asset Management Policy/Strategy/Objectives/Plans.....	13
3.1.1	Case Study: Water Utilities in UK.....	14
3.1.2	Case study: Water Utility in Portugal.....	17
3.2	Asset Management Human Resources.....	18
3.2.1	Case study: Yorkshire Water Services Ltd (UK).....	19
3.3	Asset Inventory Management	20
3.3.1	Case study: Scottish Water	20
3.3.2	Case study: Yorkshire Water Services Ltd (UK).....	22
3.4	Maintenance and Capital Investment Prioritization Activities.....	23
3.4.1	Asset performance.....	24
3.4.2	Risk assessment	25
3.4.3	Cost assessment.....	26
3.4.4	Case study: Water Utility in Portugal.....	26
3.4.5	Case study: Scottish Water	29
3.5	ASSET MANAGEMENT INFORMATION TECHNOLOGY	31
3.5.1	Introduction to information management	31
3.5.2	IT Solutions for Asset Management.....	32
3.5.3	Case Studies	40
4	LITERATURE	49

1 INTRODUCTION

1.1 WHAT IS ASSET MANAGEMENT?

Asset management is an integrated approach to monitoring, operating, maintaining, upgrading, and disposing of assets cost-effectively, while maintaining a desired level of service. It may apply to both physical assets, such as buildings and equipment, and non-physical assets, such as intellectual property. Asset management applies to industries as diverse as transportation, electric power, manufacturing, public service companies and many others.

This document deals specifically with management of physical assets in public utility companies, referred to as *infrastructure asset management*.

Asset management implies a set of practices intended for decision-makers and operators to improve decision-making process thus improving the overall business performance.

The core of asset management includes processes or activities addressing a proactive management of infrastructure assets, as follows:

- Maintaining a systematic record of individual assets (an inventory) with regard to acquisition costs, original and remaining useful life, physical condition, and cost history for repair and maintenance;
- Having a defined programme for sustaining the aggregate body of assets through planned maintenance, repair, and/or replacement;
- Implementing and managing information systems in support of these elements.

These processes are interrelated and in some cases interdependent. The Figure 1 illustrates and input/output model of an asset management system showing a general relationships among all the elements.

1.2 OBJECTIVE OF ASSET MANAGEMENT

The primarily objective of asset management is to assist organizations in meeting a required level of service in the most cost-effective way through the creation, acquisition, operation, maintenance, rehabilitation, and disposal of assets to provide for present and future customers, thus ensuring a long-term sustainability of any organization or company, including public utilities.

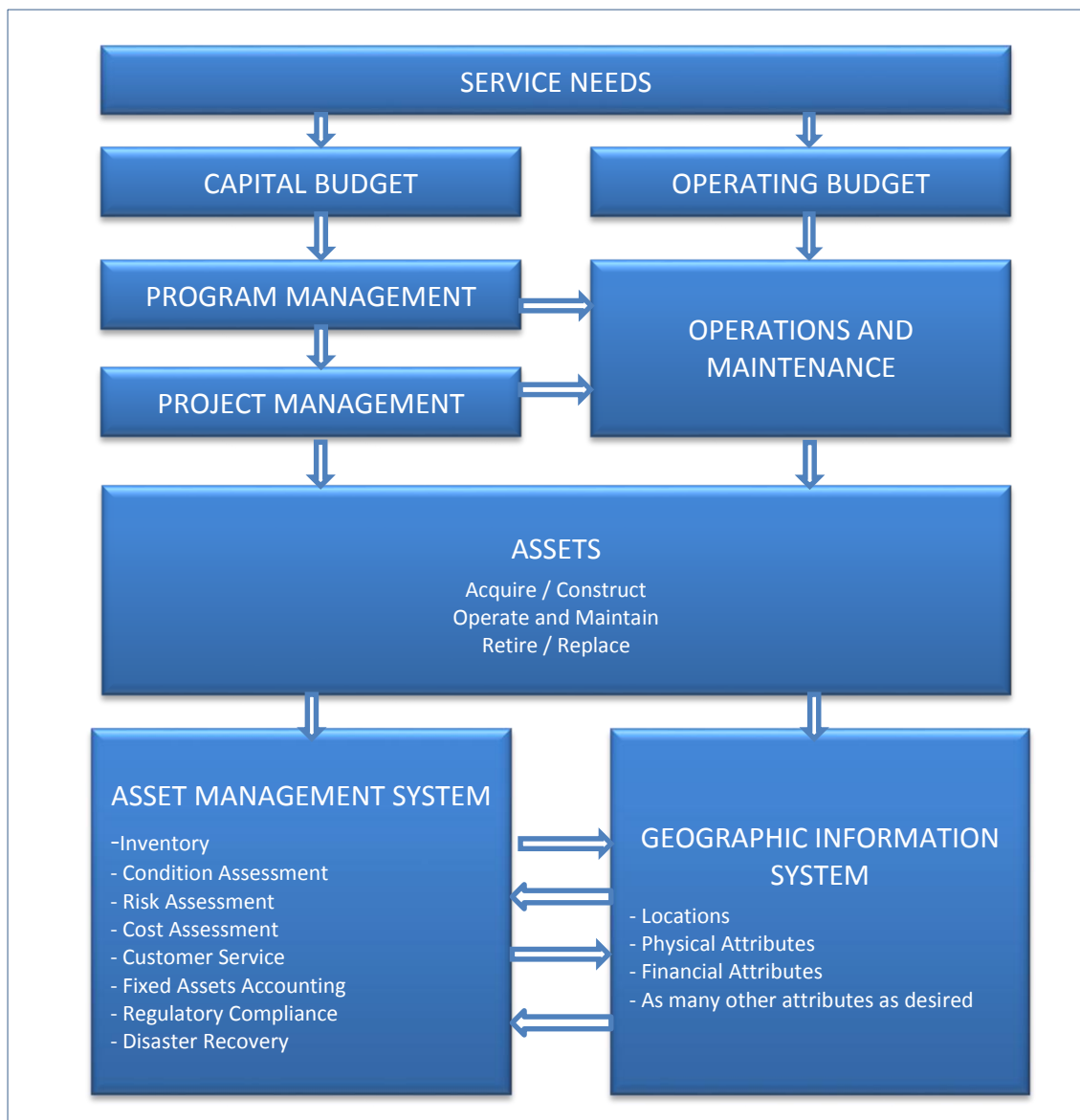


Figure 1: Asset Management Model¹

1.3 HOW DOES ASSET MANAGEMENT WORK?

The basic premise of infrastructure asset management is to intervene at strategic points in an asset's normal life cycle to extend the expected service life, and thereby maintain its performance. Normally, an asset tends to run at a fairly level condition state for a majority of its life. After a number of years, this relatively stable period is followed by degradation of asset's condition at an increasing rate as asset's components wear out. This causes degradation of asset's performance and increases the operating costs significantly. To avoid this from happening, a long-life-cycle asset requires multiple intervention points including a combination of repair, preventive and/or predictive maintenance activities, and even overall

¹ Cagle, Ron F., Infrastructure Asset Management: An Emerging Direction, AACE International Transactions, 2003

rehabilitation. This means to spend money to improve physical condition and improve performance with the objective of extending service life. The longer service life can be extended before the asset has to be completely replaced, the more economical is the overall performance. Costs decrease with planned maintenance rather than unplanned maintenance. Yet, excessive planned maintenance increases costs. Thus, a balance between the two must be recognized.

An asset or system of assets having a very long life cycle may require a combination of repair and maintenance activities followed by an overall rehabilitation. This cycle could occur multiple times over the course of asset service life before complete replacement is necessary. Each condition improvement raises the asset to a higher level on its condition curve. Each rehabilitation resets the condition curve, although perhaps not to as high level as the original new asset or a complete replacement. By employing strategically timed investment, the net effect of these activities is to keep elevating the condition curve, thereby extending the overall asset life cycle.

The strategic points for intervention in the asset condition are before degradation has reached a point that it is more economical to replace than to rehabilitate. Identifying these strategic points requires experience and professional judgment. Equally important is the availability of reliable data on asset condition, historical costs of repair and maintenance, and estimated costs of rehabilitation.

1.4 BENEFITS OF ASSET MANAGEMENT

There are many positive benefits of asset management. Organizations/companies that fully embrace asset management principals may achieve many or all of these benefits. However, companies may receive some of these benefits just by starting asset management. The benefits of asset management include, but are not limited to, the following:

- Improved knowledge of own system of assets;
- Integration of data (asset system, O&M, commercial, etc.);
- Better internal coordination within the company;
- Better focus on priorities;
- Better understanding of risks/consequences of alternative investment decisions;
- Established sound tool for decision making support and planning for future actions;
- Capital improvement projects that meet the true needs of the system;
- Improved effectiveness / efficiency (in meeting the target level of service).

1.5 NEED FOR ASSET MANAGEMENT IN PUBLIC UTILITIES

Public utility should care about managing its assets in a cost effective manner for several reasons: 1) these types of assets represent a major public or private investment; 2) well - run infrastructure is important in economic development; 3) proper operation and maintenance of a utility is essential for public health and safety; 4) utility assets provide an essential customer service; and 5) asset management promotes efficiency and innovation in the operation of the system.

The most important trigger for public utilities to implement asset management practices is concern about aging physical assets for which they are responsible. There is a significant need to replace and/or to upgrade these aging assets, as they are frequently failing to deliver a required level of service. Normally utilities don't have enough financial resources to rehabilitate or replace all deteriorated assets at once, and therefore, are in need of a strategic and integrated approach which provides answers on how to prioritize among investments/interventions and make better decisions.

Other reasons are to increase system reliability and understanding risks and consequences of asset failures. As most of the asset maintenance occurs unplanned as a response to system failure, making the system unreliable, utilities need to reduce these unexpected interruptions in service delivery. Furthermore, consequences of asset(s) failure may be broader than interruptions in service delivery, including environmental, economic and health consequences.

A specific situation in public utilities is that they lack basic data on characteristics and location of assets, as these are often known by the aging/retiring workforce, and it is necessary to transfer their knowledge into asset records/inventory.

Also, public utilities seek to reduce large costs of system failure. Planned maintenance and timely upgrade of the system allows them to focus on those interventions/investments that provide improved service at reasonable costs.

All of these crucial issues for public utility operations are dealt with throughout various components of Asset Management Practices.

2 APPROACHES TO ASSET MANAGEMENT

Among numerous literatures available on asset management, one can find some different approaches to this issue. Three most profound ones are presented below.

2.1 PAS 55

The leading document in setting the standards in Asset Management is PAS 55 which was published in 2008 by the Institute of Asset Management in UK. This document, soon after it was published, became one the most referenced one in addressing the issue of asset management.

PAS 55 comprises:

- Definition of terms in asset management.
- Requirements specification for good practice.
- Guidance for the implementation of such good practice.

PAS 55 provides objectivity across 28 aspects of good asset management, from lifecycle strategy to everyday maintenance (cost/risk/performance).

The PAS 55 was a basis for development of a standard ISO 55000 which was published in January 2014.

The PAS 55 is focussed primarily on physical assets, but takes into account other assets as well, as they all affect the optimal management of physical assets. Other considered assets are: human assets, information assets, intangible assets and financial assets. Knowledge and competence of human resources have a fundamental influence on the performance of physical assets. Financial assets are required for infrastructure investments, operation, maintenance and materials. Information assets providing good quality data and information are essential to develop, optimize and implement asset management plans. Intangible assets, such as organization's reputation and image, can have a significant impact on infrastructure investment, operating strategies and associated costs.

According to PAS, all aspects of asset management are integrated in the overall, so called, asset management system. Elements of asset management system, according to PAS 55, are presented in Figure 2.

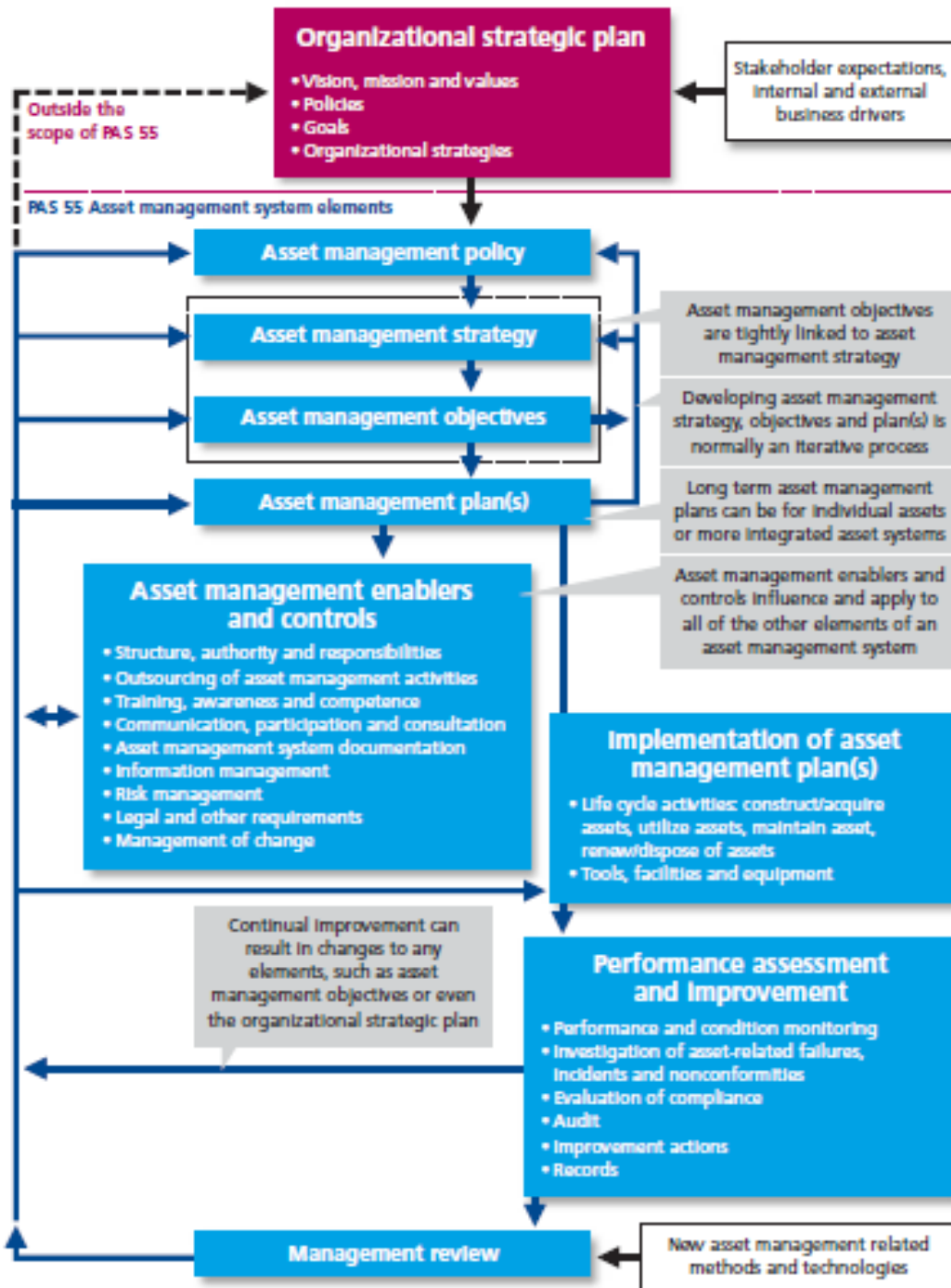


Figure 2: Elements of asset management system²

2.2 AWARE-P APPROACH

Aware-P is a project developed by cross-disciplinary core team from LNEC (Portugal), IST (Portugal), Addition (Portugal), Sintef (Norway) and Ydreams (Portugal), with support from the Portuguese water services regulator ERSAR. AWARE-P is considered to be the innovative

² The Institute of Asset Management, PAS 55-2:2008

methodology for planning infrastructure asset management as it is supported with technical manuals, plan templates, case studies, publications and open-source software tools.

The Aware-P project was funded from multiple sources of financing: Financial Mechanism of the European Economic Area, ERSAR - Water and Waste Services Regulator (Portugal), and project's end-user partners: AdP Serviços S.A, AGS S.A., SMAS Oeiras & Amadora and Veolia Águas de Mafra.

The objective of the project was to develop and implement procedures for infrastructure management (IAM) in water utilities. It built on previous experience and feedback of earlier R&D projects (CARE-W - Computer Aided Rehabilitation of Water Networks, and CARE-S - Computer Aided Rehabilitation of Sewer Networks). Together with successive projects, it aimed at providing water utilities with concrete know-how and tools for sustainable planning in IAM.

Main outputs of the project were inter alia:

- Open-source software for planning and decision support;
- Best practice IAM manuals;
- Pilot studies;
- Training courses;
- Technical and scientific papers and reports.

The project was succeeded by rollout & capacitation project in Portugal based on AWARE-P methodology, software and training materials (own IAM systems developed for sample 30 utilities), as well as R&D project in Portugal and pilot projects in Spain (EU-funded TRUST project) and the USA.

Spin-off projects focused on knowledge and tools transfer to targeted water utilities aimed to foster their capabilities for efficient decision-making. The reach was dozens of utilities ranging in size (population served from 3000 to 300000), scope (water, wastewater, stormwater), institutional framework (municipal, inter-municipal, concession) and IT readiness and maturity.

The benefits to utilities were usage of advantages of AWARE-P methodology and software to raise level of local expertise in structured and technically sound approach to system rehabilitation planning supported by software, so that their tactical and strategic IAM plans could be developed. Expectation was that the impacts of a more sustainable IAM approach could have meaningful impact nation-wide.

The benefits were mutual, as the projects' took advantage of its multi-stakeholder nature to receive feedback to their approach and tools by stress testing them in intensive, realistic professional environments. That resulted in contribution to a range of open-source software tools and capabilities.

AWARE-P methodology is an innovative infrastructure asset management planning methodology intended specifically for implementation in water utilities. The methods and tools developed under the AWARE-P project are based around an approach which implies three planning decisional levels: a strategic level, driven by corporate and long-term views and aimed at establishing and communicating strategic priorities to staff and citizens; a tactical level, where the intermediate managers in charge of the infrastructures need to

select what the best medium-term intervention solutions are; and an operational level, where the short-term actions are planned and implemented.

This approach implies that planning future interventions includes assessment and comparison of intervention alternatives from the performance, cost and risk perspectives over the analysis horizon. The required knowledge competence for making such decisions is threefold: business management, engineering and information. The figure below symbolises the described approach.

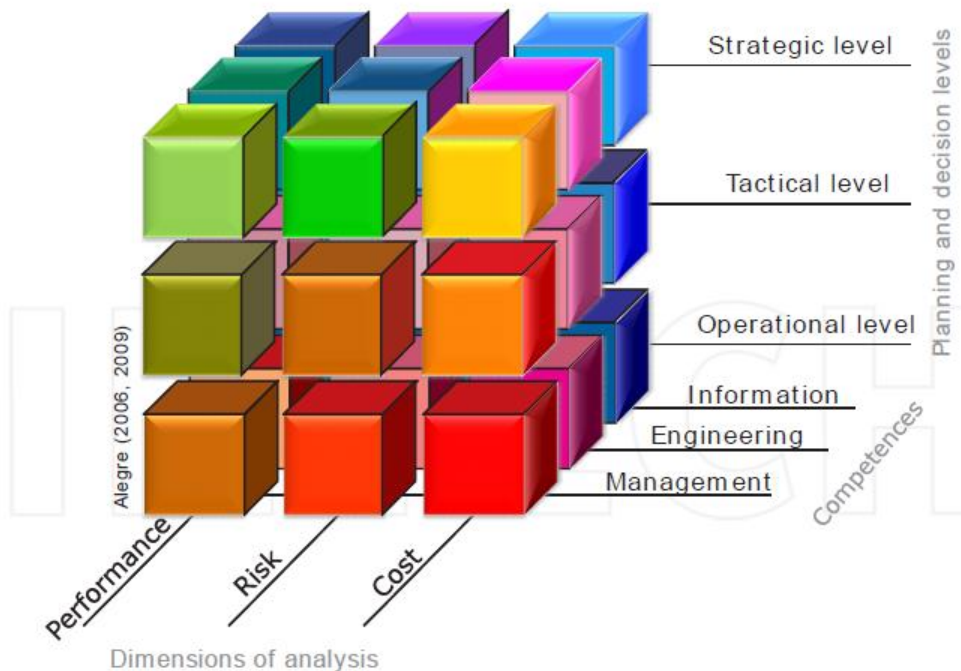


Figure 3: General IAM approach by AWARE-P³

Each level of management and planning comprises the following stages: (i) definition of objectives and targets; (ii) diagnosis; (iii) plan production, including the identification, comparison and selection of alternative solutions; (iv) plan implementation; and (v) monitoring and review.

2.3 THE COMMON FRAMEWORK FOR CAPITAL MAINTENANCE PLANNING IN UK WATER UTILITIES

UK Water Industry Research Ltd (UKWIR) has developed a framework for capital maintenance planning for UK water utilities. This framework is based on the analysis of risk of asset failure and encompasses an economic approach which allows the trade-off between capital and operational cost options to be considered.

The following key concepts for the basis of the framework:

- Service is assessed using serviceability indicators (equals to performance assessment in AWARE-P approach);

³ Helena Alegre and Sérgio T. Coelho, Infrastructure Asset Management of Urban Water Systems, 2013

- Capital maintenance should be justified on the basis of current and forecast probability and consequence of asset failure with or without investment (equals to risk assessment in AWARE-P approach);
- For every capital maintenance option, least-cost approach to Opex versus Capex should be demonstrated, and proactive versus reactive maintenance (equals to cost assessment in AWARE-P approach).

The Common Approach consists of three stages:

- Historical analysis, which identifies historical levels of maintenance expenditure and serviceability indicator trends;
- Forward-looking analysis, which identifies future maintenance expenditure to meet regulatory objectives;
- Conclusions, which compares and explains results of historical and forward-looking analysis; makes the case for the required level of future maintenance.

3 ASSET MANAGEMENT PRACTICES

3.1 ASSET MANAGEMENT POLICY/STRATEGY/OBJECTIVES/PLANS

The starting point for any organisation seeking to develop and implement an asset management system and become an Asset Management practitioner, is to review and compare the organisation's current management of its assets against the available good management practices, guidelines and standards, and determine the extent to which these requirements are currently met, what are the gaps and what improvements can be made. Based on the findings and conclusions, an organization will make future policies, strategies and plans for improving the current practices by setting the vision, goal, objectives and respective activities related to asset management.

The *Asset Management Policy* should provide a high level statement of the organization's principles, approach and expectations relating to asset management.

The *Asset Management Strategy* should set out how the *Asset Management Policy* will be achieved throughout the business activities, including the methods of activities' prioritization, optimization, sustainability and risk management, as well as a whole-life costing approach. The premise of strategic planning is the definition of desired level of service that has to be provided to the customers. All other objectives serve the purpose of achieving that defined level of service. The Strategy should include reference to performance and condition requirements for assets in providing the desired level of service. When establishing its *Asset Management Strategy*, the organization should consider the following:

- stakeholder requirements that influence the management of the assets (including legal, regulatory requirements);
- desired level of service including the forecast demand for the service;
- the physical condition of the assets, age profile;
- asset deterioration curve, and failure trends and effects;
- historical asset-related information such as reliability, maintenance records, operational performance and condition data;
- criteria for investments/interventions and for comparing alternatives;
- contingency planning, i.e. considering the effects of unexpected events and possible responses.

The asset management strategy should clearly define objectives that organization will strive to achieve in a given timeframe, usually 3-5 years. The objectives should be specific, measurable, achievable, realistic, and time based, to the extent possible.

Based on the asset management strategy and objectives, an *Asset Management Plan* should be developed. The plan should include documentation of:

- a) the specific actions required to optimize costs, risks and performance of the assets;
- b) the designated responsibilities and authorities for the implementation of such actions and for the achievement of asset management objectives;
- c) the financial resources and timeframe by which these actions are to be achieved.

3.1.1 Case Study: Water Utilities in UK

Water Utilities in UK develop long-term Strategic Direction Statements normally for the period of 25 years. This document consists of four parts:

1. The challenges that Water Utilities face in the next 25 years concerning provision of service;
2. The overview of customers' needs;
3. Answers of the Utility to customers' needs;
4. Priorities and strategy going forward.

Within the fourth part of the Strategic Statement, the Utilities define priority areas for improvement and within each priority area are described commitments of the Utility to achieve improvements.

The Strategic Statement sets out Utility's vision for how they will meet customers' expectations for the next 25 years, but it is only the start the journey. Utilities review and update this plan every five years within their Business Plans.

The Business Plan is developed for the period of five years which is fully aligned with the Utility's Strategy. The constituent part of the Business Plan is Asset Management Plan.

The Asset Management Plan is developed using a forward-looking risk-based approach that is entirely compliant with the principles of the Common Framework for Capital Maintenance Planning to derive their future investment requirements.

3.1.1.1 Strategic Direction Statement: Southern Water Services Ltd. (UK)

Southern Water Services is the private utility company responsible for the public wastewater collection and treatment. The company supplies drinking water to roughly one million households.

The latest long-term strategy of Southern Water Service for water and wastewater services sets the direction of their business for the period 2015 to 2040. The approach to developing the long-term strategy has been all about taking customers' priorities on board. Three years prior to development of a Strategy, the Utility has started the process of interviews to thousands of their customers – from homeowners and businesses, to other interested parties, such as local councils and environmental groups – all with the aim to really understand their priorities.

The priority areas and commitments of the Utility to improve these areas are identified and presented in table below.

	Priority area	Utility's commitments
1	A constant supply of high quality drinking water	Reliable water supply
		Acceptable water pressure
		Drinking water quality
		Water hardness
2	Removing wastewater effectively	Reliable wastewater service
		Minimise flooding
		Limit unpleasant smells
3	Looking after the environment	Rivers free from pollution
		Clean coastline

	Priority area	Utility's commitments
		Minimise carbon emissions
		Environmental sustainability
4	Responsive customer service	Quick and effective responses
		Address customers' individual needs
		Reflect local issues
5	Better information and advice	Information on ways to save water
		Advice on blocked drains
		A clear, easy-to-understand bill
		Info about where customers' money goes
6	Affordable bills	More efficient services
		Ways to save water/money
		Helping vulnerable customers
Green – Maintain current service; Orange – Improvement required; Red – Significant improvement required		

Table 1: Strategic priority areas and commitments of Southern Water Service

The identified Utility's commitments are further analysed and divided in 10-years activities and 25 years activities.

3.1.1.2 AM Policy: Southern Water Services Ltd. (UK)

Southern Water Services, within their five-year Business Plan/Asset Management Plan, state their asset management policy briefly describing how they intend to deliver it. Statement of their most recent policy (2015-2020) is provided below:

“We will:

Provide responsive customer service, a constant supply of high quality drinking water, better information and advice, effective wastewater removal and look after the environment while ensuring affordable bills for current and future generations

Meet, or exceed the performance levels promised to our customers

Deliver our statutory and regulatory obligations to the timescales agreed with our regulators

Accommodate regional growth and additional demand without detriment to our performance.

To deliver these outcomes we will:

Continue to engage with our customers to understand the outcomes they value and their views on how these can best be met to ensure our plans continually reflect their priorities

Ensure our plans reflect the needs of stakeholders and statutory requirements, while providing the best value for customers and the environment now and in the future

Educate and inform customers how their behaviour influences our performance and our services

Work in partnership with a range of stakeholders, agencies and in our communities, across the whole water cycle

Take a holistic approach to decision-making that understands future needs and optimises total whole-life cost to manage risk and performance in an integrated way

Understand and balance risks between the performance of our assets and the needs of our customers and stakeholders

Use high quality information to make risk-based decisions to deliver the required performance

Use robust, integrated planning and project management systems to analyse and report information on customer service, environmental and asset performance, cost and project management

Use best-in-class processes, tools and capability in planning, integrated risk management, design and engineering, project delivery, programme management and operation of our assets and networks

Drive efficiency, improve performance and reduce total cost through innovation, risk management, partnership working and effective contract management

Employ great people, with the right capability, training and experience to develop and implement our strategies and plans, embedding a customer-centred culture

Assign clear roles and responsibilities to all those involved in looking after our assets to meet the needs of customers and the environment through our asset lifecycle process.

3.1.1.3 AM Plan: Southern Water Services Ltd. (UK)

Structure of the Southern Water Service 5-year Asset Management Plan is as follows:

1. Service Summary: Planning Objectives Direction and Delivery – Water Service;
 - a. Stakeholder Engagement,
 - b. Leadership, Policy and Strategy,
 - c. Reporting,
 - d. Company Process for Asset Maintenance,
 - e. Corporate Management of Risk,
2. Overall Approach to Capital Maintenance Planning – Water Service
 - a. Management,
 - b. Processes,
 - c. IT Systems,
 - d. Data Quality and History,
3. Business Case by Asset Group – Water Service
 - a. Water Infrastructure – Water Mains
 - b. Water Infrastructure – Communication Pipes
 - c. Water Infrastructure – Leakage
 - d. Water Non-Infrastructure – Water Supply Works
 - e. Water Non-Infrastructure – Water Booster Stations
 - f. Water Non-Infrastructure – Service Reservoirs
 - g. Water Non-Infrastructure – Impounding Reservoirs and Aqueducts
 - h. Water Non-Infrastructure – Revenue Meter Replacement
4. Further Commentary – Water Service
5. Business Case by Asset Group – Sewerage Service
 - a. Sewerage Infrastructure
 - b. Sewerage Non-Infrastructure – Wastewater treatment works
 - c. Sewerage Non-Infrastructure – Wastewater Pumping Stations
 - d. Sewerage Non-Infrastructure – Sludge Treatment Centres

6. Further Commentary – Sewerage Service
7. Management and General
 - a. IT Overview
 - b. Business Systems
 - c. Departmental Requirements
 - d. Industry Comparison
 - e. Specific Scheme Business Cases (to improve efficiency and cut costs).

The most extensive and most detailed analysis is structured in Chapters 3 and 5, where business cases for each asset group are underpinned by complex engineering and financial assessments, which are compliant with the principles of the Common Framework for Capital Maintenance Planning in Water Utilities in UK.

3.1.2 Case study: Water Utility in Portugal

The Portuguese water utilities are applying the unique infrastructure asset management approach developed by AWARE-P project in developing asset management strategy.

Example of the development of an asset management strategy in a mid-sized Portuguese water utility, serving fewer than 100,000 people, is presented here.

The first stage in strategic planning, as it is set by AWARE-P methodology, is the definition of clear objectives, performance criteria, metrics to assess them, and finally, targets for every metric. In this case, objectives, criteria and metric that were selected, are presented in table below.

Objectives and criteria	Metrics
1. Adequacy of the service provided	
1.1 Service accessibility	Economical accessibility of the service (WS, WW)
1.2. Quality of service provided to users	Service interruptions (WS) Quality of supplied water (WS) Reply to written suggestions and complaints (WS, WW) Flooding occurrences (WW)
2. Sustainability of the service provision	
2.1. Economic sustainability	Cost coverage ratio (WS, WW) Non-revenue water (WS)
2.2. Infrastructural sustainability	Adequacy of treatment capacity (WS) Mains rehabilitation (WS) Mains failures (WS) Sewerage rehabilitation (WW) Sewer collapses (WW)
2.3. Physical productivity of human resources	Adequacy of human resources (WS, WW)
3. Environmental sustainability	
3.1. Efficiency of use of environmental resources (water, energy)	Energy efficiency of pumping installations (WS, WW) Real water losses per service connection (WS)
3.2. Efficiency in pollution prevention	Adequate collected wastewater disposal (WW) Emergency overflow discharges control (WW)

Table 2: Objectives, criteria and metrics for strategic planning in Portuguese water utility

The second stage of the planning process is diagnosis, consisting of an analysis of external context (global and stakeholder-specific) and of the internal context (both organizational and infrastructure), anchored in the objectives and targets established. SWOT (strengths-weaknesses-opportunities-threats) was used to express the results of this stage.

Strengths	Weaknesses
<ul style="list-style-type: none"> - Good information systems on the water supply infrastructures - Sufficient information to assess the water supply systems condition and performance - Strong competence of human resources - Relation between information systems and work orders 	<ul style="list-style-type: none"> - Insufficient information systems on wastewater infrastructures - Financial restrictions - Inadequate tariffs - Poor structural infrastructure condition - Poor functional infrastructure performance - Insufficient historical records - Inadequate quality of data
Opportunities	Threats
<ul style="list-style-type: none"> - Equipment and technologies available to support IAM - Portuguese regulation by ERSAR * - Portuguese legislation related with IAM - Incentives for sustainable use of energy 	<ul style="list-style-type: none"> - Portuguese legislation and regulation by ERSAR* (increase in costs) - Political uncertainties - Economic crisis and financial restrictions - Demographic development uncertainties - Illegal cross connections in wastewater systems
* ERSAR: the water and waste services regulator in Portugal	

Table 3: SWOT analysis in Portuguese water utility

The third stage of the planning process is the formulation, comparison and selection of strategies that lead to meeting the targets, given the diagnosis. For drinking water, the key selected strategies were *Control water losses* and *Promote proactive rehabilitation practices*, whereas for wastewater the strategies established were *Reduce untreated wastewater discharges* and *Reduce cross connections and infiltration/inflow in wastewater systems*. The common strategies of both types of services were *Improve infrastructure information systems* and *Increase system reliability*.

The elaboration of these results is expressed in a document, the strategic plan, a document that is synthetic, clear, and effectively disseminated to all relevant internal and external stakeholders.

3.2 ASSET MANAGEMENT HUMAN RESOURCES

The successful implementation of asset management requires the commitment of top management.

Top management is normally best placed to ensure that the asset management, policy and strategy are consistent with the organizational strategic plan and to identify where poor asset performance might jeopardize the achievement of the organizational strategic plan.

Top management should ensure that adequate resources are available for establishing and maintaining the asset management system, including equipment, human resources, expertise and training.

Top management should assign clear responsibilities to its staff for the management of assets. Top management should ensure that those who are given responsibilities are competent, have adequate skills and training to perform their duties and deliver the required outcomes, in line with the asset management policy, strategy and objectives.

Asset management responsibilities should be documented in a form appropriate to the organization. This can take one or more of the following forms: working procedures and task descriptions; job descriptions; training packages.

Top management should ensure the viability of the asset management strategy, objectives, targets and plans. Organizational structure, working procedures, and the importance of meeting asset management requirements should be clearly communicated to all relevant employees.

3.2.1 Case study: Yorkshire Water Services Ltd (UK)

Yorkshire Water is a water supply and treatment utility company. It serves 1.9 million households and 130,000 business customers.

Yorkshire Water has a written documentation related to roles, responsibilities and procedures associated with the Asset Management Planning and Investment process and is located and maintained on a central database, where it can be viewed by all.

Role descriptions and job interviews are competency based to ensure the person appointed has the capabilities to match the role requirements. Employees are subject to quarterly reviews which provide regular evaluation of performance against progression plans, role statements and agreed personal priorities, identifying skill gaps and providing opportunity to identify further training requirements through personal development plans. These are all aimed at ensuring that people are equipped to carry out their function and have access to the learning and development they need. Yorkshire Water runs a variety of 'in house' training courses. Records of attendance on these courses are other external training courses are held by managers and individuals.

Alongside process and systems improvements, the technical competence of asset managers within YW is being raised. To date more than 50 modules have been delivered with approx 600 colleagues in attendance from both YW and Partner organisations. Particular emphasis is being given to raising competency in risk management. The Company has made an industry first in partnering with the University of Edinburgh to undertake an accredited risk training programme that is tailored to their needs and requirements. Opening the risk management practices up to all rather than keeping it confined to a small specialist group embeds a risk management culture into Yorkshire Water. Over 180 colleagues and partners have taken part in the risk training programme. In addition, over 100 colleagues and partners have also taken part in training on the asset management planning and investment cycle training.

Staff training records and competency profiles ensure the Company has an understanding of its management capability. Where gaps are identified appropriate recruitment or

development programmes are put in place. Managers assign priorities and objectives to staff based on business plan targets.

3.3 ASSET INVENTORY MANAGEMENT

One key element in developing an asset management plan is developing and inventory of infrastructure and plan assets. This requires a number of decisions to be made in terms of organizing asset hierarchies by factors such as location or system; tagging the assets themselves; developing asset nomenclature that is consistent across utility departments, and defining attributes for different types of assets that should be recorded. These activities have a significant impact on the usefulness of the asset inventory.

Asset inventory should contain information on:

- Age, condition, location;
- Size and capacity;
- Manufacturer and construction materials;
- Installation data and expected service life;
- Maintenance and performance history;
- Criticality, derived from the utility's risk management framework.

3.3.1 Case study: Scottish Water

Scottish Water is among the five largest water utilities in the UK, providing regulated water and wastewater services to five million customers in 2.4 million homes and 124,000 businesses. A major focus of Scottish Water's strategy is investment in its infrastructure, maintaining and upgrading its physical assets to assist in the provision of clean drinking water and the efficient removal and treatment of wastewater.

Largely significant section of the asset management in Scottish Water is their asset inventory compiled for both non-infrastructure (above ground) and infrastructure (below ground) assets. All the information on inventory is kept in the Geographic Information System (GIS). The asset inventory is structured like a tree to allow assets to be associated with their locations, zones and regions, as well as with other assets on the same site. The inventory holds information regarding the physical attributes of the assets and equipment as well as latest information from surveys regarding condition and performance. The capacity of almost every function (e.g. water treatment works, sewage pumping station) is recorded but the capacity of each unit within a works has not yet been captured universally (e.g. kW rating of every pump, capacity of every tank).

How was all this data and information gathered?

Data contained in the GIS-based asset inventory were previously transferred from the three former Scottish water authorities that were in charge of water supply and wastewater services in Scotland prior to the foundation of Scottish Water. Since there were some missing records, Scottish Water carried extensive asset survey in order to fill these gaps on their assets. In general, asset inventory holds condition and performance information about all potable water mains (including trunk mains) and sewer gravity pipes and rising mains.

In 2007, another asset survey was carried out with an objective to collect information about each site, including photos, videos and sketches. These data facilitate more efficient asset management regarding capacity, configuration and condition of assets. The surveys have provided or confirmed condition and performance grades on all the units that could be assessed readily during the site visits. The following operational functions have been surveyed:

- Ground water source,
- Raw water pumping,
- Secondary disinfection,
- Sewage pumping station,
- Sludge treatment centre,
- Sewage treatment works,
- Treated water pumping,
- Treated water storage, and
- Water treatment works.

They have gathered information about each unit at each works, including:

- Unit type or description;
- Number of each Unit;
- Unit Tag Number(s);
- Operational status;
- Year of construction or installation;
- Year of decommissioning (if appropriate);
- Date of last major refurbishment and extent of refurbishment;
- Condition and Performance grade (Buildings and Civil);
- Condition and Performance grade (Electrical & Mechanical);
- Reason for condition grades;
- Reason for performance grades;
- Confidence grades – (e.g. whether information was directly surveyed (A1) or advised by a knowledgeable local operator (C2));
- Operational observations; and
- Health and safety observations.

In order to support the visual inspection of assets, video recording and photographs of the following were gathered:

- Location;
- Panoramic views of the complete location;
- A photograph or video sequence depicting each process stage;
- Photographs that support the description of specific defects or grade assessments;
- Photographs highlighting Health & Safety concerns.

As of 2010, the Scottish Water inventory holds over 80% of the condition and performance grades for building and civil engineering structures, and over 75% of the condition and performance grades for electrical and mechanical units.

3.3.2 Case study: Yorkshire Water Services Ltd (UK)

The asset records processes and procedures of Yorkshire Water have been assessed and certified as meeting the requirements of ISO 9001:2000.

The asset records of Yorkshire Water are stored on seven integrated computer applications. These contain information on the number of units of all water and wastewater assets, their value, condition, and assessment of changes in condition over time. Asset records database is interlinked with the systems such as: Operational Process Records, Investment Planning Records, Financial Records, and HR records. These systems also provide data to asset record. When an operation or maintenance activity occurs, the information about it is transferred to the Asset Record changing the asset's value and condition.

A dedicated Asset Records team monitor the records supply chain to ensure the appropriate records are received and recorded in the appropriate application.

The asset records systems are available on the PC network and staff have access to the systems. Training programmes ensure that staff achieve a minimum level of competency.

Yorkshire Water undertakes periodic review of asset stock and its condition every 5 years and summarized its finding into a comprehensive document. Their general approach to the review of asset condition is the following:

- Experts from the relevant operational areas have undertaken site surveys;
- A fixed questionnaire has been used on all asset groups;
- To achieve consistency all assets within each asset type have been surveyed by one team;
- Where assets could not be accessed directly experts from the relevant fields using the best available knowledge have undertaken desktop surveys;
- Unless otherwise stated the condition grade assessments have been undertaken at individual sub-assembly level.

Table below presents methods of survey for specific groups of water supply assets.

Asset Group	Site Surveys	Desktop Surveys	Statistical method	Other
Water Treatment Works	100%	-	-	-
Service Reservoirs and Water Towers	50%	50%	-	-
Pumping Stations	100%	-	-	-
Dams and Impounding Reservoirs	-	100%	-	-
Raw Water Aqueducts and Catchwaters	100%	-	-	-
Mains	-	-	-	100% "Cohort" methodology
Communication pipes	-	100%	-	-
Revenue Meters	-	100%	-	-
Operational Buildings for above asset groups	-	100%	-	-

Table 4: Methods of survey for assessment of assets' condition in Yorkshire Water

For operational above ground assets, condition grades have been based on the criteria presented in table below.

Condition	Visual	Remaining Life Expectancy	Increased Opex
Good	As new	As new	None
Fair	Superficial wear	Long	Minor
Adequate	Significant wear and tear	Medium	Acceptable for age
Poor	Work required	Short	Becoming unacceptable
Awful	Worn out	None	Unacceptable

Table 5: Criteria for water supply assets' condition grades in Yorkshire Water

For Communication Pipes the criteria for condition grading was somewhat different and adjusted to the specifics of the assets, as presented in table below.

No	Condition	Description
1	Good	Smooth bored mains and communication pipes not subject to corrosion or with sound factory lining, no level of service problems.
2	Fair	As 1, but with loose deposits that are noticeable under abnormal flow conditions, slight tuberculation which may give a rough surface, but does not substantially reduce the cross-sectional area of the pipe. May require routine flushing or air scouring.
3	Adequate	Some problems with loose deposits or deterioration of linings leading to occasional complaints. Risk of quality failure, pipes with tuberculation causing 20% blockage by encrustation.
4	Poor	Frequent problems causing complaints, water quality known to have failed on more than one occasion under normal operating condition during previous twelve months. Pipes with tuberculation causing 20-40% blockage by encrustation.
5	Awful	Pipes suffering severe problems of infestations and loose deposits. Water quality cannot be ensured. Pipes with tuberculation causing 60-80% blockage by encrustation.

Table 6: Criteria for communication pipes' condition grades in Yorkshire Water

3.4 MAINTENANCE AND CAPITAL INVESTMENT PRIORITIZATION ACTIVITIES

Good asset management practice requires organizations to maintain and improve the processes that manage all phases of life of asset systems. Individual assets owned by organization have a "life-cycle" which includes asset creation, operation and maintenance, renewal, and eventually decommissioning and disposal.

When planning a new asset or deciding among alternatives for maintenance intervention, it is important to consider the costs and benefits throughout its whole useful/remaining life. Main parameters that need to be analysed before deciding on asset intervention are: (i) asset's performance to provide a desired level of service, (ii) risk of asset failure and related consequences, and (iii) costs of intervention. This analysis should be performed within a specified (usually longer) time horizon, taking into account the objectives and targets of the organization defined in relevant strategies and plans. The objective of this life-cycle approach in decision-making is to ensure that the service provided meets the targets over

time, keeping the risk in acceptable levels and minimizing the overall costs from a long run viewpoint.

Assessing performance, risk and cost is therefore a key to effective infrastructure asset management. These three criteria are basis for prioritization and ranking of interventions on assets.

3.4.1 Asset performance

Normally, assets need to be in a good or fair condition in order to perform as required and be able to meet the desired level of service. The organisation needs to have reliable and updated information on assets' condition and performance in order to plan asset interventions and associated costs.

The organization needs to establish, implement and maintain processes and procedures to monitor and measure the performance and condition of assets, providing for the consideration of:

- reactive monitoring for any asset-related deterioration, failures or incidents;
- proactive monitoring to seek assurance that the assets are operating as intended. This shall include monitoring to ascertain that the asset management policy, strategy and objectives are met, the asset management plan is implemented, and that the processes, procedures or other arrangements to control asset life cycle activities are effective;
- both qualitative and quantitative performance measures, appropriate to the needs of the organization.

Reactive monitoring comprises structured responses to an indication of a deficiency or failure of the assets or asset systems. This indication could be the failure of an asset, or assets failing to perform as expected. The organization should have procedures for handling and investigation of failures, incidents and nonconformities associated with assets.

All information and the results of investigations should be recorded.

Proactive monitoring comprises timely routine and periodic checks, to determine the level of conformance of asset's performance in provision of required level of service and organization's objectives in general.

Performance measures should provide data on compliance or non-compliance with the performance requirements of asset management plan. They provide warning signs of potential problems, either before they occur or before they become significant.

The principal categories of performance measures include:

- *Performance indicators*, which are quantitative efficiency or effectiveness measures of the asset. A performance indicator consists of a value expressed in specific units. Performance indicators are typically expressed as ratios between variables; these may be commensurate (e.g. %) or non-commensurate (e.g. \$/m³). The information provided by a performance indicator is the result of a comparison (to a target value, previous values of the same indicator, or values of the same indicator from other asset).
- *Performance indices*, which contain a judgment in itself, e.g. 0 – no function; 1 – minimum acceptable; 2 – good; 3 – excellent.

- *Performance levels*, which are performance measures of a qualitative nature, expressed in discrete categories (e.g. excellent, good, fair, poor), adopted when the use of quantitative measures is not appropriate.

3.4.2 Risk assessment

Every asset failure or a possibility of failure is a result of asset's (poor) condition and every asset failure brings minor or major consequences to the provision of the required level of service.

The organization seeking to implement asset management practices needs to establish, implement and maintain processes and procedures for the ongoing identification and assessment of asset-related risks, and the identification and implementation of necessary control measures throughout the life cycles of the assets. Risk management is an important foundation for proactive asset management. Its overall purpose is to understand the cause, probability and consequence of adverse events occurring, to optimally manage such risks to an acceptable level.

Risk assessment process consists of the following steps:

- Prepare a list of assets and gather information about them;
- Identify types of risks: create a table of potential event and their causes;
- Identify risk controls, if any;
- Determine the level of risk (also referred to as criticality of assets): estimate the probability and consequences for each potential event.
- Determine the tolerability of the risks: decide whether planned or existing controls are sufficient to keep the risks under control.

The data available to assist in determination of probability of failure is: asset age, condition assessment, failure history, historical knowledge, experiences with that type of asset in general, and knowledge regarding how that type of asset is likely to fail. An asset may be highly likely to fail if it is old, has a long history of failure, has a known failure record in other locations, and has a poor condition rating. The rating of probability of failure can be a simple rating on a scale from 1 to 5 or may be more sophisticated. The ability to produce a more sophisticated failure rating is dependent on the amount and quality of data available.

Failures can result in a range of potential consequences not only to the organization itself, but the consequences can also include socio-economic disruptions and environmental impacts. It is important to consider all of the possible costs of failure. The costs include: cost of repair, social cost associated with the loss of the asset, repair/replacement costs related to collateral damage caused by the failure, legal costs related to additional damage caused by the failure, environmental costs created by the failure, and any other associated costs or asset losses.

Classes of probability and consequences may be defined from the range of 1 to 5: 1 – insignificant; 2 – low; 3 – moderate; 4 – high; 5 – severe.

A risk matrix should have at least three risk levels (low, medium and high risks) that are to be associated with the acceptance levels of risk: Low or acceptable risk (green); Medium or tolerable risk (yellow); and High or unacceptable risk (red).

		Consequence				
		1	2	3	4	5
Probability	5					
	4					
	3					
	2					
	1					

Figure 4: Risk matrix⁴

If assessment proves that a high level risk cannot be controlled, it means that the risk is intolerable. In this case, a cost-estimate is the next step in asset life-cycle activities which will finally add up to prioritising possible interventions.

3.4.3 Cost assessment

When analysing options for interventions, cost are another fundamental parameter. All relevant costs and revenues items that take place during the analysis horizon and which differ from the status quo, should be accounted for, for any of the intervention alternatives considered.

In general and simplified terms, the main cost items include:

- Investment costs, expressed as a given amount at a given point in time, and with a given depreciation period.
- Operational costs, normally organized in three classes: (i) Cost of goods sold; (ii) Supplies & external services; (iii) personnel; operational costs are expressed as annual values, over the analysis period.
- Revenues, either through lump sums occurring at specific points in time (e.g. public subsidies), or distributed over the analysis period (e.g. revenues from tariffs). Revenues are also expressed by their annual value over the analysis period.

All costs and revenues are expressed as a Net Present Value in order to compare among different intervention alternatives.

3.4.4 Case study: Water Utility in Portugal

Prioritization of investments on assets using the abovementioned approach is applied in Portuguese water utilities. The aim is to define the intervention alternatives which are to be implemented in the medium term.

The key stages of the prioritization process are determining objectives, metrics and targets, which should be aligned with the same on strategic level. Metrics address all three dimensions of performance, risk and cost. The diagnosis is carried out based on the metrics selected, for the present situation and for the planning horizon. Due to the system behaviour of the water infrastructures, a progressive system-based screening progress is adopted, aimed at identifying the most problematic areas. In general, the water systems under analysis are divided into sub-systems, and the metrics assessed for each of them. For

⁴ Helena Alegre and Sérgio T. Coelho, Infrastructure Asset Management of Urban Water Systems, 2013

each subsystem, the intervention alternatives are compared, and that alternative which best balanced the set of metrics for the chosen objectives, over the long-term, is selected. The best intervention alternatives, compatible with the financial resources that can be mobilized and with the planning horizon, are included in the plan.

An example of tactical planning for a single utility's strategic objectives will be further explained, which is to *Improve the efficiency of use of environmental resources* (water and energy). The diagnosis was that utility's networks displayed undesirable failure rates (pipe breaks) and the energy bill for pumping was higher than would appear reasonable; the network had high water losses and localized pressure problems during peak consumption hours. The problem was approached by providing answers to three questions developed by AWARE-P project, which can be applied for every diagnosed problem.

These questions are:

- How do we act?
- How do we prove that our decisions are effectively addressing the strategic objective?
- How do we quantify the impact of our decisions and of subsequent actions?

To answer the first question the following activities were carried out:

- 1) gathering an updated and reliable inventory of the existing assets and compiling as many reliable records as possible of their condition and failure history;
- 2) identification of the locations where there are pressure problems,
- 3) investigate pump efficiency and energy consumption;
- 4) assess the relative importance of each asset;
- 5) prioritize interventions within the budget constraints.

However, in order to answer the other two questions, a detailed analysis needs to be carried out. The problematic system is divided into sub-systems (DMAs – district metering areas). To achieve the strategic objective and criteria, the utility has selected performance, risk and cost metrics, for which certain targets needed to be met:

- Inv: investment cost, measured through the net present value at year 0 of the investments made during the 5-year plan.
- IVI: infrastructure value index - the ratio between the current value and the replacement value of the infrastructure; it should ideally be close to 0.5.
- Pmin: minimum pressure under normal operation index, measuring compliance with the minimum pressure requirements at the demand locations.
- Pmin*: minimum pressure under contingency conditions index, measuring compliance with the minimum pressure requirements at the demand locations when the normal supply source point to this DMA fails and an alternative entry point is activated.
- AC: percentage of total pipe length in asbestos cement; although this metric may seem unconventional as a performance indicator, it was selected as a proxy for system resilience, reliability and ease of maintenance (or the lack thereof), given the poor track record of the aging asbestos cement pipes in this utility.
- RL: real losses per connection.

- UnmetQ: risk of service interruption. This reduced service metric is given by the expected value of unmet demand over 1-year period. The risk of service interruption associated to a specific pipe depends on the likelihood of its failure and on its consequence on the actual service. This risk is calculated for each pipe as a combination of failure probability and component importance.

Metrics were further divided into 3 ranges (good, fair and poor) according to the quantifiable thresholds set by the utility, based on the experience of their key staff.

	Good (green)	Fair (yellow)	Poor (red)
Inv (cost units)	0 - 350	350 - 450	450 - ∞
IVI (-)	[0.45 - 0.55]	[0.30-0.45]; [0.55-0.70]	[0 - 0.30]; [0.70 - 1]
Pmin (-)	3,2	2,1	1,0
Pmin* (-)	3,2	2,1	1,0
AC (%)	0 - 9	9 - 15	15 - 100
RL (l / connection / day)	0 - 100	100 - 150	150 - ∞
UnmetQ (m3/year)	0 - 20	20 - 30	30 - 100

Table 7: Performance criteria and metrics for the case study in Portuguese water utility

Usually for every sub-system (DMA) a few alternatives for intervention are defined which are then being analysed in detail.

For problematic area which is the subject of this specific case study, three alternative solutions were taken into consideration:

1. Alternative A0 (status quo, or base case): corresponds to keeping the existing network as it is, and retaining the current reactive capital maintenance policy (which in the present case was based on repairs after break only).
2. Alternative A1 (like-for-like replacement): an IAM project consisting of a prioritized list of pipes to be replaced by the same-diameter HDPE pipes. The prioritized list was developed using advanced software, following a like-for-like replacement strategy.
3. Alternative A2 (system-driven solution): an IAM project based on an ideal redesign for the network, as if it were built from scratch for the present-day context. This ideal redesign, heavily backed by network modelling, driven by performance and risk assessments, is viewed by the utility as a future target reference, to be gradually reached by incrementally changing individual pipes as they are replaced, and by making some key layout modifications. It addresses the same pipes targeted in A1, but replaces them with new pipes of optimal diameter (often smaller, as the original network has overcapacity in places).

The assessment of the three alternatives was carried out for the 5-year planning horizon and for a 20-year analysis horizon. Each alternative was quantified using the selected assessment metrics and the obtained results were compared. The results have shown that alternative A2 displays the best allround long-term balance of performance, risk and cost, as expressed by metrics that reflect the tactical objectives, in full alignment with the utility's strategic objectives.

The adoption of a structured IAM approach in the utility illustrated by this example provided answers to all the questions initially formulated:

- Using a coherent and aligned system of objectives, criteria and metrics enables the IAM manager to show that the decisions are effectively addressing the strategic objectives, and to quantify their impact.
- The hydraulic problems were duly taken into account by splitting the whole system into subsystems and analysing in more detail, including in hydraulic terms, the most problematic ones.
- The selection of sizes and materials for the new pipes was driven by the ability of the existing network in meeting current and future needs and in minimizing energy consumption.

3.4.5 Case study: Scottish Water

Similar approach, as the previous one, is applied in Scottish Water. Scottish Water performs regular monitoring of assets' performance trends which shows where they can safely extend replacement cycles (and where they must not) and helps them to control capital maintenance costs and maintain service standards.

The Capital Maintenance Plan is a dynamic output of the process which defines these replacement cycles within a broader business management framework. The business cases for each service area are robustly challenged. Senior Management decides on the balance of investment across all service areas supported by the Scottish Water Investment Support System (SWISS), a tool for investment optimisation based primarily on risks to service. All competing needs for investment are entered into the SWISS system. This scores the risk of a service failing by combining how likely this is with the consequence that this would have to the customer. The SWISS process combines individual competing needs into coherent sub-programmes of projects which can then be balanced to provide the optimal results in terms of costs and performance.

When prioritizing interventions concerning asset maintenance and rehabilitation, they divide the system into distribution zones and perform the analysis for each identified zone, referred to as *DOMS investigations* (Distribution Operation and Maintenance Strategy). These investigations are divided into three levels:

1. *Level 1: Prioritization of the needs* based on a review of corporate data on condition and performance of assets. This is used to rank all zones across Scotland and this ranking is updated every two years.
2. *Level 2a: Desktop investigation* on performance history trends and elaboration of a preliminary intervention programme.
3. *Level 2b: Site-based investigation* to confirm the need for an intervention and an assessment of the likely intervention. *Cost-benefit analysis* is also part of this phase comprising the assessment of all costs of interventions, including capital expenditure (capex) and operating expenditure (opex).
4. *Level 3: Post-renovation assessment* which is conducted periodically to monitor the success of any intervention.

Team of planners in Scottish Water are using DOMS screening investigations (Level 1) area by area across the whole country to examine all aspects of network and other assets' performance relating to serviceability. This phase is used to identify areas of the network

that are performing poorly, areas incurring high levels of reactive maintenance and areas containing critical assets, and affecting the customer and the environment. PSP⁵ programme visually displays water network assets and associated performance information such as bursts, customer contacts, leakage levels and water quality data. The objective of the Level 1 investigation is to provide a prioritised list to be taken forward for site by site (Level 2) investigations.

The list of sites identified by the screening is then subject to detailed scoping by experienced engineers (Level 2 investigation). This generally involves a site inspection together with a collation of the performance, cost and other data associated with the site (Level 2a). This is drawn together in a site scoping report which serves two purposes. Firstly, it provides a clear basis for assessing priorities based on the service risk and cost of refurbishment. Secondly, the report provides the key information required to initiate feasibility and detailed design work for the assets that pass the priority test. However, for some locations, field work such as pipe testing may be required to confirm the problem, or hydraulic modelling may be necessary to assess broader system impacts. In such instances this requires a more detailed (Level 2b) study. The Level 2 assessments identify clear business cases for investment or operational interventions.

Once completed, the post-renovation assessments (Level 3) will be reviewed periodically to monitor the success of our overall processes.

⁵ Perform Spatial Plus - an Integrated Network Management water distribution analysis tool

3.5 ASSET MANAGEMENT INFORMATION TECHNOLOGY

3.5.1 Introduction to information management

Research found that collecting and managing data are key challenges for implementing asset management. Regardless of its size, each water utility executes comparable operational and business roles and accordingly utilises similar information systems. In smaller water utilities those systems may even be based on paper records and spreadsheets, while larger water utilities usually have in place automated computer-supported information systems.

Significant advances have been made during the last decade in developing municipal and water utilities infrastructure asset management systems. These solutions are generally used to store and manage asset data, and to support operational and strategic decision making processes.

In general, the role of an asset management system can be identified as *“an integrator, a system that can interact with and interpret the output coming from many dissimilar systems.”*

Many software/assisted technologies and approaches have emerged to support the asset management of water and sewage/storm water systems. In most generic terms, these functionalities can be summarized as follows:

- Facilitating technical and functional means for data gathering and storing to data repositories, such as relational database management systems (RDBMS);
- Extending the usability of data repositories with software add-ons for data management, analysis and reporting aligned with the purpose of an organization, to establish fully functional information systems;
- Providing means for data sharing, such as interfaces for external systems and export functionalities;
- Integrating systems to attempt to produce corporate information system that operates as a single entity; targeting data visibility across an organization and its relevant roles and processes; and
- Designing customized technical functionalities within generic systems to fully account for and support core business roles relevant to asset management: life-cycle, performance measurement, operational maintenance, risk management, strategic planning, budgeting, etc.

It is important to emphasize that apart from being able to give this holistic view of the assets concerned, an asset management information system also needs to be integrated with other business information systems, reducing the amount of manual transfer of data between systems and maximising the effectiveness of both the business process itself and the existing underlying IT investment.

3.5.2 IT Solutions for Asset Management

Conventional water utility asset management system comprises two principal components: relational database with asset data, and software tools for analysis and decision support. Inputs and outputs to the system are standardized, such as manual data entry forms or pre-defined reports with processed data from the system (automatically generated or on-demand).

More recent versions include interaction and representation of some aspects of data by interfacing with other systems. Most prominent example is visualization of assets spatial component in Geographic Information Systems (GIS), but other functionalities include: asset performance analysis and water system modelling, asset life-cycle cost management, planning investments and their impacts, maintenance management, customer support, etc.

In terms of their coverage of asset management scope, software can be categorized as general purpose and asset-specific software. The first category executes more generic functionalities so they must be adapted and customized for the purpose. Asset-specific software have more concrete purpose, which is accomplished through implemented built-in facilities in support of more narrow scope of water utility assets (certain types of assets).

General-purpose software mainly manages asset information related to their core properties and attributes, financial aspects, work management and scheduling, as well as budget and procurement management. However, their value is increased if they can interface to other systems that complement its functionalities (e.g. ERP, GIS, or CAD) and comprise corporate information system with added-value compared to a set of distinct systems. From technical aspect, they provide their functionalities by relying on underlying Relational Database Management Systems (RDBMS).

Asset-specific software have emerged during the last decade and manage sub-sets of water assets, which they are specifically designed to support. Their purposes vary and some examples include management of water distribution systems and sewage/stormwater systems. As general purpose systems, they also normally use RDBMS for information storage and may include GIS capabilities or support using external fully-fledged GIS systems. Their data management functionality is often supplemented by support for asset performance, condition surveillance and benchmarking. As significant examples, Engineered Management Systems (EMS) and remote monitoring systems are further elaborated in the remainder of this document.

3.5.2.1 General-purpose software solutions for asset management

A variety of general-purpose information systems are used by water utilities. For asset management purposes, the most important of these systems are financial and enterprise data management systems, GIS, computerized maintenance management systems and customer and billing information system.

Therefore, the most commonly used information systems that comprise core of support to asset-related operational activities and business processes in water utilities are:

1. **Enterprise Resource Planning System (ERP)** – Information systems for maintaining and analysis of General Accounting Ledger, tracking accounts payable/receivable, budgeting and fixed assets depreciation. They usually include: modules for end-to-end spare parts supplies and expendables inventory (from their procurement to

installation or consumption); human resources management; payroll; work-time tracking and similar.

2. **Customer Information System (CIS)** – Systems for gathering, management and analysis of services rendered to consumers and relevant consumption or provision of services (e.g. quantities of water consumption). They typically facilitate customer invoicing and help track billing. In ideal environments they are supported by meter reading systems of varying degree of automation.
3. **Computerized Maintenance Management System (CMMS)** – Systems designed to handle planning, logging and monitoring of preventive and corrective maintenance of water system assets. They undertake collection, monitoring and analysis of information related to assets condition and performance levels.
4. **Geospatial Information System (GIS)** – Information systems for visual presentation and analysis of water systems on georeferenced maps. GIS usually back water system modelling processes and maintenance of water assets. Another significance is their potential in decision-making and assisting in communicating data with spatial component.

These systems support most of key required functionalities necessary for asset management role in water utilities.

Each of them have a role and significance and fundamentally contribute to in asset management in two aspects: firstly, by gathering and storing data to empower a better understanding of the state of affairs to further foster governance and informed managerial decision making; and secondly, to enable improved efficiency of business processes, to make them more agile and affordable, yielding better outcome for customers.

A key concept for majority of identified core information systems is that each of them generates specific sets of data that benefit numerous business processes and roles within the companies exploiting them. However, the true benefits and fully potential is reached when they are used in synergy, as a single entity in which data flows predictably, in a clearly defined manner, through the integrated system of interdependent entities.

Nevertheless, it is unfortunately common that each system have their own databases, segregating the global parameters and properties of assets for specific purposes of the designed systems. That produces obstacles for company as a whole and interferes with processes of inevitable transparency and accessibility of relevant data on the corporate level for the purposes of management and exchange of information. Therefore, significant efforts need to be undertaken in integrating the relevant information systems for their prolific exploitation.

The remainder of this section reviews the "core" general-purpose information systems used in most of water utility companies, as well as shed light of their importance and role in operational and business functions within the water supply industry.

3.5.2.1.1 Enterprise resource planning systems (ERPS)

Enterprise resource planning systems are being used in water utilities for decades aiming to encompass essential business functions in a single software product. Initially, they were primarily intended for companies that needed to execute integrated supply chain processes, providing services, goods manufacturing or maintenance-related business roles, but were

later extended with more functionalities, such as: finance, financial operations, human resources management and other modules.

At present, ERP systems in water utilities are usually put in operation to manage several business functions:

- Finance and Accounting (e.g.: General Ledger accounting, Accounts Payable/Receivable, Financial Planning, Reporting and Analysis, Fixed Asset Accounting, Investments, Human Resources Management, Payroll, etc.);
- Supply Chain (Procurement, Inventory Management); and
- Key Performance Indicator Measures & Reporting.

ERP systems employ significant functional integration between the listed business functions, for instance, between inventory tracking, procurement and monitoring of suppliers. It is possible for system users to leverage that functional integration of an ERP system to execute their business processes easier, more efficiently and in a much more consistent manner. Apart from that, inherent integrability of an ERP system is less costly solution, as it requires no additional cost for integration of individual software products.

In practice, an alternative to ERP systems is the approach known as “Best of Breed”. Instead of a unique, single-vendor ERP solution, it implies procuring only a part of vendor’s ERP system and only modules that best support its business processes. Missing modules and functionalities are supplemented with software from different vendors (i.e. software modules from a different vendor). Often, separate software products are implemented for finance and human resources management roles, while the asset management functionality is bundled with software for Computerized Maintenance Management System. These three separate systems are being integrated through further process and additional custom software components. The benefit of this approach is that the resulting integrated system may better suit the specific needs of water utilities.

Our experience has shown that implementation of ERP necessitates changes in existing business processes of water utilities to avoid the common pitfalls causing implementation failures. That primarily relates to a good understanding of their business strategy and distinctiveness of the water supply business model before the ERP implementation has commenced.

Accordingly, non-integrated solutions have somewhat accomplished short-time needs, but have also presented a significant challenge in attempts to ensure consistent reporting mechanism and so called “single version of truth” (abbreviated as SVOT, a concept in IT business management promoting an ideal of a single database or synchronized database replicas across an organization). Integrated products accomplished significantly quicker and easier reporting procedures, as well as consistent and standardized access to relevant information.

Preference to using integrated ERP product is with large water utilities, which have sufficient resources and adequate expertise for successful implementation. However, many water utilities still prefer a combination and selection of “Best of Breed” applications as opposed to ERP from a single vendor, despite the fact that they require integration before they may operate as a cohesive, uniform information system.

However, it is important to note that an ERP system mainly provides only a financial view of water utility’s assets.

3.5.2.1.2 Customer Information System (CIS)

The Customer Information System (CIS) with billing support functionality is one of the essential information systems in water utilities. It incorporates many customer and service related aspects of business ranging from managing customer accounts, invoicing, collecting customers' requests and service orders, as well as their processing.

In practice, apart from its basic purpose of customer billing and invoicing, many well-designed CISs provide further benefits to water utilities:

- Unique, comprehensive view of customers. Customer information are particularly significant for water utilities as they facilitate effective collection/revenue management practices;
- Support launching customer portals to enable more simple and transparent access of customers to information of their interest: overviewing consumption, viewing and printing invoices and billing history, modifying their account information, report problems and submit service requests, etc.; and
- Collection and logging the consumption with different degrees of automation. Possible implementations vary accordingly:
 - o Digital meter reading (e.g. with hand-held devices in the field), with the benefit of reading meters with no requirement of access to interior of customer premises. That somewhat reduces the amount of field work and the number of appointments, but it also reduces the possibility of a human errors (e.g. while reading and logging analogue gauges).
 - o AMR, which is a fully automated, centralized meter reading (e.g. via a radio link), which can immediately be used as basis for invoicing. It significantly reduces operational costs of manual labour (manual meter reading fieldwork), but also supports more agile consumption data gathering for more efficient billing and inflow of payments, as well as better support to planning and decision making.

However, it is important to mention that both system types require significant investments, both in terms of infrastructure and equipment being put to use, as well as increased and more complex technical expertise needed for operation, support and maintenance of such systems.

A large number of implemented Customer Information Systems is currently in use, and their basic characteristic is that they are increasingly web-based. An efficient CIS imposes integration with other information systems, so it is common that it has more interfaces and integration points compared to other information systems.

3.5.2.1.3 Computerized Maintenance Management Systems

A Computerized Maintenance Management System (CMMS) is an application to track assets and maintenance history and costs.

Its basic characteristics are that it:

- Provides gathering and processing of asset data, related maintenance costs in support asset management decision making, supporting the overall asset management programme;

- Handles information related to priorities, physical condition, depreciation costs and maintenance of physical assets;
- Facilitates generating and tracking of work orders and allocation of resources;
- Centralizes processes of preventive maintenance and its scheduling;
- Supports integration with GIS systems to account for spatial information of assets and relevant geospatial analysis; and
- Enables integration with mobile devices, which makes possible access to information from the field.

CMMSs are often deployed as part of larger enterprise solutions. Regardless of the mode of their implementation, most of CMMSs comprises several major modules covering functionalities such as: Asset register, Work and Maintenance management, Purchasing and Materials Expenditure and Invoice Matching. Furthermore, it is also well supported by functionalities that support mobile access for maintenance workforce operations in the field, to efficiently and instantly track work orders and their life-cycle.

In addition to that, there are strong ties between the functions of CMMS and various other systems, including:

- Geographic Information System (GIS) – mapping and geospatial analysis of distributed water system assets, many of which are managed in a CMMS;
- ERP – management of the “supply chain”, in which the ERP (financial) system may be the system of record for inventory and purchasing of maintenance spare parts and supplies; and
- Customer Information System (CIS) or more specifically Customer Relationship Management System (CRM) – management of customer inquiries, complaints and service orders, typically coordinated with maintenance teams and the CMMS work order system for certain types of maintenance activities.

A CMMS supports some of key processes within water utilities, providing key benefits to the asset management role of a utility:

- Assisting in accounting for **total cost of ownership of assets** spanning entire life cycle through maintenance records. They support accounting for quantitative segment of supply chain management (work orders, labour, outsourced services, material, spare parts, etc.) and its optimization for improved resilience through supplementary processes within utility; and
- **Budgeting** and planning of expenditure. That is particularly useful in preventive maintenance, but also in corrective maintenance budgeting, since historical records provide input for a risk assessment process, which in turn supports budgeting and resource allocation.

Many of CMMS applications are web-based, whereas the earlier technologies were based on client-server architectures. Early CMMSs required customization to work with GIS, but modern iterations have built-in integration as a norm.

3.5.2.1.4 Geospatial Information Systems (GIS)

Geospatial Information Systems, as systems for management of spatial data and associated attributes is increasingly important application in water companies. The reason for this is the fact that most of water assets are geographically distributed and that the information

about the assets are often stored in diverse forms and separate data repositories and that a need exists to integrate them.

Assigning a spatial component to data, as the principal objective of GIS in water utilities from the asset management standpoint, enables data analysis and making informed operational and strategic decisions.

Moreover, as GIS can assign spatial component to any data, most of its use-value applies to asset georeferencing, assigning asset properties, interdependence in the water supply and sewage network, but also assisting in problem locating and logging of work and maintenance of assets. That benefits far beyond the instinctive perception of GIS as a tool to display the maps, since it considerably simplifies corrective maintenance and directly supports decision-making, implementing investment strategy and preventive maintenance.

Nevertheless, the mapping features and outputs are also of paramount importance for field workers during the interventions and maintenance. Adequate mapping information noticeably reduces time to location and diagnostics during the repairs (as much as a quarter of work order time is quoted as benefit). In that regard, GIS naturally interfaces well with a CMMS, expanding its functionalities by georeferencing the asset data.

In addition to the benefits above, properly implemented GIS in a water company plays an important role in the analysis of parameters of water and sewage networks, as well as the evaluation and planning of improvements of performance and service levels.

Integration of GIS with other information systems in water utilities can be realized in several modes, which principally relate to that in which system the asset information will be kept. One approach is to implement GIS and CMMS as unified information system, whereas there may be some sort of integration with the other information systems. The alternative approach is to procure and implement GIS, CMMS, ERP and other information system as independent components that may have partly or fully defined interfaces to each other. The disadvantage of the former is that the separate storage of individual views of an asset breaks the integration of the overall enterprise system, meaning that all components operate independently to some extent, making it difficult to ascertain a holistic view of assets.

3.5.2.2 Asset-specific software solutions for asset management

In practice, a range of asset-specific software exists for broader purpose of asset management, such as:

- Supervisory Control and Data Acquisition System (SCADA) – Systems aimed at automatization and remote surveillance and control of water system in real time;
- Capital Program Management Software (CPMS) – Systems intended for planning, monitoring and control of capital projects related to water supply and sewage/stormwater infrastructure;
- Laboratory Information Management System (LIMS) – Systems for logging, management and analysis of water quality samples from water supply network; and
- Engineered Management Systems (EMS) – Information systems for evaluation of asset conditions in terms of performance levels and tool for assessment of requirements for maintenance.

An example of the asset specific software solutions are Engineered Management Systems (EMS), which assist in evaluation of asset condition, estimate maintenance requirements through performance criteria, including consideration of maintenance operations prioritization.

These systems embraced a methodology for estimation and measurement of performance level of infrastructure assets, which assumes using infrastructure asset condition data to derive a Condition Index (CI) and classifying it within predefined rating criteria. Index therefore suggests asset components performance levels, which are in turn used as an input for investments in maintenance work.

Many water utilities dedicate resources to undertake development of their own, in-house software solutions, in majority by customization of some more general purpose tools. For such approach, widely-available commercial software is used to establish a platform that is further adapted for asset management purposes (notable examples being spreadsheets, CAD and GIS applications and relational databases - RDBMS). Over time, these systems have matured to cover several more asset-specific processes, e.g.: work management and maintenance, procurement, etc.

One more noteworthy example of asset-specific software is asset remote monitoring accomplished by a range of sensors, meter and Supervisory Control and Data Acquisition systems (SCADA). They are considered legacy IT systems, but play an important role in operational management (e.g. can raise alarms to staff in case of important events or problems so that corrective maintenance can be carried out).

Moreover, they also provide important feedback to performance measurement that can be further analysed. For example, information systems dealing with maintenance planning can assess that information, compare against expected levels and other similar assets to support decision-making in business roles dealing with investments and maintenance planning. Historical information also contributes in strengthening both technical and business processes within the organization by providing knowledge base and record of auditable information. Overall, such systems and their information can also contribute to improving capabilities for improved efficiency of water systems through system modelling process and assessing effectiveness of investment and maintenance policies.

Integration of remote monitoring systems to overall asset management processes and relevant other information systems therefore helps deepen the knowledge on assets performance, impacting organizations' ability to improve the return on assets.

The following matrix illustrates versatility of information systems and one view on benefits in different business processes within water utilities.

Core Information Systems	Functional Areas that Derive Benefits							
	Water System Operation	Customer Service	Asset Management	Water Quality Management	Financial Management	Supply Chain Management	Capital Project management	Human Resource Management
Financial ERP System	D	S	D	D	P	P	S	S
Customer Information and Billing System	S	P	S	D	P			
Computerized Maintenance Management System	S		P			P		
Geospatial Information System	P	P	P	P			S	
Industrial Control System/Process Control	P	S	D	S				
Capital Program Planning and Management System	D	D	P	S	P		P	D
Laboratory Information Management System	P	D	S	P				

Legend:

P	Primary beneficiary of the system
S	Secondary beneficiary of the system
D	Provides data for reporting and decisions

Table 8: Matrix of information systems and their benefits⁶

⁶ Source: EPA

3.5.3 Case Studies

Two case studies have been elaborated to illustrate the role of information technology in asset management and to account for different approaches in systems acquisition and implementation. Furthermore, the case studies also demonstrate the extent of an effort, to contribute to understanding of the specifics of information systems for water supply business and the current levels of maturity of available systems.

Scottish Water case describes undertaking of an in-house effort, while AWARE-P Project is more outwards-oriented. Unlike Scottish Water, AWARE-P used a large test sample of water utilities across the country to receive feedback for their methodology and software tools in the real environments and attempts to measure its impact on a national level, overall goal being the world-wide, universal relevance and applicability.

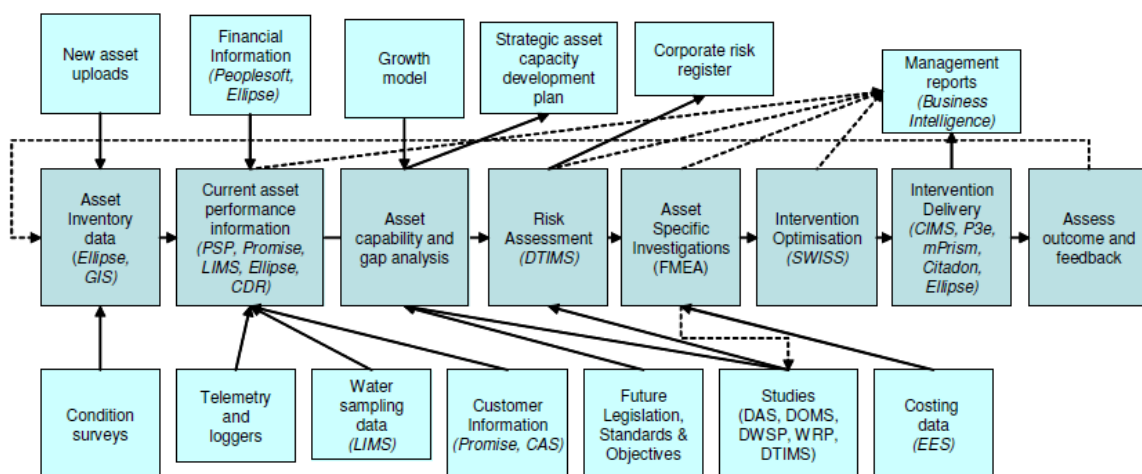
3.5.3.1 Case Study: Scottish Water

Scottish Water has developed several asset management plans for each of the asset categories to facilitate optimal operational and capital investments and aiming to improve and elevate their service levels and quality of their products.

Strategic decision of Scottish Water's management was to pursue investments that will optimize the utility's performance, expenses and investment risks. To make it feasible, it was necessary to understand all input parameters and their interactions, which in turn required solid information foundations being provided by the implemented information systems.

Information critical for operational and strategic decision-making as well as the asset management, was organized in several information systems. That approach required a high degree of integration of information systems to ensure data format adequate for corporate reporting with Business Intelligence.

The figure below gives an overview of information systems and tools for asset management in Scottish Water.



(Source: Scottish Water)

The core corporate systems for asset management in Scottish Water are:

- Ellipse (the Works and Asset Management System);
- GIS (Geographical Information System);
- CAS (Corporate Address Server);
- Promise (Customer Relationship Management);
- PeopleSoft (Financial information);
- CDR (Corporate Data Repository – including registers for interruptions to supply and pollution incidents);
- LIMS (Laboratory Information Management System); and
- CIMS (Capital Investment Management System)

Besides the core information systems, decision support systems are available for use, aiming to analyse information from core information systems to facilitate optimization of investments for maintenance or improvements to service levels:

- PSP (Perform Spatial Plus – the water distribution analysis tool);
- SWISS (Scottish Water Investment Support System);
- DTIMS (Deighton Total Infrastructure Management System); and
- EES (Engineering Estimating System).

Ellipse is the **Works and Asset Management System** (WAMS) and it is used to manage information about above ground assets, as well as managing all operational activities in Scottish Water of any asset type (above ground or underground). It is a fully integrated Enterprise Asset Management application that is used in Scottish Water for Asset Management, Customer Service, Customer Operations, Wholesale Billing, Stores and Scottish Water Solutions business teams.

The asset inventory, or Equipment Register, is one of the basic functions implemented in Ellipse and is the nucleus of that information system. This functionality implemented master listings of all assets necessary for storing information for individual assets and activities related to them, such as time and labour expenditure.

Assets are hierarchically structured and grouped (e.g. by Water Operational Area (WOA), Water Supply Zone (WSZ) and District Metered Area (DMA)), which makes feasible an “intelligent” grouping and association of related assets to enable work management and cost capture. This is also where the master asset coding is kept by means of a unique identifier that is common across all systems.

The asset inventory is a tree structure and it makes it possible to create associations of assets with locations, zones, regions and other assets on the same site, where term asset denotes a physical site, structure or an equipment item. To enable work cost capture on specific assets within a site, equipment is assigned to a series of higher-level assets. The inventory also stores physical attributes of assets and equipment and latest condition survey findings.

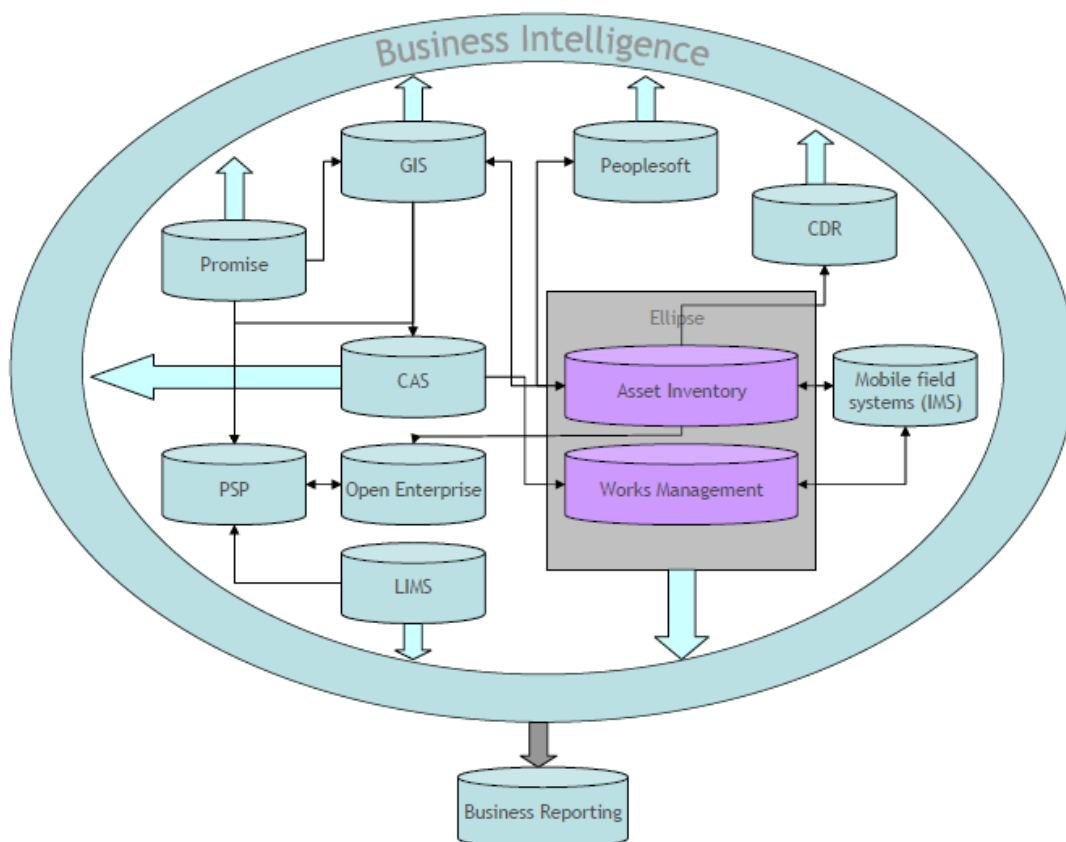
Apart from the asset register (asset inventory), Ellipse provides other important functionalities, such as:

- Works Manager – view of currently committed and future work, and also scheduling of work orders and planned maintenance tasks;
- Maintenance Schedule – remainder grouping facility with adequate level of work details (which equipment, frequency, staff, skills, etc.);
- Stores – field staff requisitions, usage and pricing; and

- Work Orders – task grouping into a single work order to enable tracking of all tasks associated with a single operational issue.

To ensure benefits of core information within Eclipse (asset inventory, work orders and the cost of labour and materials) to other systems, a systematic integration of Eclipse with other information systems have been carried out. The integration has been accomplished so that the core information are being maintained separately within each of the associated information systems, so that only a single system preserves master record of any inventory schedule. That key aspect of integration is contributing to data reduplication and supports users in maintaining their focus on improvement of quality and value of information, rather than on synchronization of the global system's components.

The following figure is a diagram of accomplished integration.



(Source: Scottish Water)

The **Geographical Information System (GIS)** in Scottish Water is being used to manage the register of underground assets. It is a software tool for geolocation and presentation of assets, but it can also encompass textual and numeric information related to assets, such as: material, size, depth, age and condition.

The relationship between water resource zones through to area served by water treatment works is established for water assets and then subdivided to sub areas supplied by treated water storage assets and then further to metered areas account for leakage management (hierarchy: Water Operational Area - Water Supply Zones - District Metered Areas).

Similarly, relations are established between wastewater assets within the same drainage areas and catchments.

These zones provide means to define interoperability and interdependence of assets in water and waste water networks, which is particularly significant for network management, financial reporting and incidents response, where GIS is heavily used.

Scottish Water has also defined procedures for continual update of GIS data to maintain the consistency between GIS database and water and wastewater rehabilitation plans (Q&SIII schemes). The established procedure undertakes sampling a number of schemes to compare scheme guidance notes that define their manifestation on GIS, against the actual situation after plans implementation. Identified discrepancies are mainly feedback to system operators for corrective actions, but also involve preventive component, since it also assesses the requirements for additional training to mitigate the same problems in the future. Furthermore, quality assurance warrants that operational status changes of all non-infrastructure assets must be marked in GIS, so that changes to connected infrastructure assets are adequately conducted.

GIS also allows displaying information with spatial reference from other information systems, e.g. including customer information from CRM system, permits spatial displaying of incoming support calls to call centre, since customers can be georeferenced.

GIS is connected to other information systems, such as: Promise (Customer Relationship Management (CRM) system), Ellipse, LIMS (Labware), Corporate Address Server (CAS) and to some Business Intelligence environments.

Promise is the Scottish Water customer relationship management (CRM) system. It comprises three main components:

- Oracle TeleService - automated contact centre work processes with a single view of customer history;
- Oracle Field Service – field agents work scheduling by contact centre agents; and
- Oracle Mobile Field Service – remote access for field personnel to access their work instructions with their schedules and report back on assignments status (using Promise laptops from the field).

Outputs from Promise system are important information for assessing operational and asset performance. In such a way, information regarding magnitude and location of contacts with customers are analysed for approximation of asset failures and pinpointing interesting locations for further research, operational or capital investments.

PeopleSoft is an Oracle Enterprise Financials System and is used by Scottish Water to manage and report on all financial information. As facility that manages financial aspects of assets it is naturally one of the important resources in asset management. It expectedly includes General Ledger, but also a Projects Ledger which provides sub-analysis below main ledger level, namely operating costs by project and work order which can also be related to lower-level assets, as well as capital project transactions by individual project. The described data assists in determining the total cost of ownership of assets (whole life costs) and also to assess the schedule of operational or capital investments.

Direct operating costs are structured within a department and product coding hierarchy which is based on a relationship to Ellipse function and stage details for operational assets.

Corporate Data Repository (CDR) is a set of simpler Oracle applications developed in-house, as part of a programme aiming to close gaps in other corporate information systems. CDR applications cover simpler functionalities and enable users to store and manage data within their local roles' scope, which is then made available to other systems and corporate reporting. CDR applications include: Interruptions to Supply, Low Pressure Register, Flooding Register, CSO Register, Environmental Pollution Incidents, Drinking Water Quality events notification and Licensed Provider notification.

Interruptions to Supply (ITS) is a corporate application (within the CDR) that stores data on planned and unplanned interruptions to supply. Interruptions can be sent to ITS by field workers from handheld devices, or alternatively, data can originate from Eclipse where scheduled interruptions are stored (e.g. planned downtime for maintenance).

If electronic data sending is not possible or feasible, there is a procedure to account for paper forms, which are then manually entered to the system (e.g. work conducted by external contractors). Local administration teams can monitor interruptions in their respective areas, but a warning is automatically raised when any incident reaches 100 of affected properties (to Regional Manager).

The system is useful for risk assessment modelling, as its historical data can help govern informed decisions related to future investments such as replacements or repairs of assets.

Low pressure register is a corporate application for management of low pressure complaints received from their customers. It aims to provide means to resolve low pressure issues by integration of relevant data to create one view of facts, enhancing the reporting and improving visibility and management of the complaints related to the issue.

Flooding register is a tactical resource for tracking sewer flooding incidents and mitigating measures, which also provides means for information change tracking to ensure audit trail. Since all Scottish Water's users have read-only access, it contributes to transparency, knowledge transfer and awareness of the flooding issues. Company considers Flooding Register a single source of information in support of planning of relevant operational and capital investments, since the investments are prioritised by their effects on the network, meaning that a proposed investment should effect in properties being removed from the register. That approach has been fruitful, as the number of registered locations at risk has been significantly reduced.

The Combined Sewer Outfall (CSO) register is a tactical application holding the intermittent discharge (ID) data. The CSO register is linked with Eclipse's asset inventory, which is then linked to GIS system. Eclipse provides general information (unique identifier, location, status of intermittent discharges), while CSO tool provides more detailed information (performance, size, discharge point, receiving water body, etc.). The information is being continually improved by Drainage Area Studies (DAS), Operations and strategic planner knowledge and investigative activities (which are recorded to unsatisfactory intermittent discharge (UID) capital programme and then to CSO register).

Laboratory Information Management System (LIMS) manage regulatory and operational analysis results, which are conducted in laboratories (e.g. drinking water quality at various points in the infrastructure). That provides information to track asset performance and deterioration trends, so that adequate operational and capital investments could be planned to meet standards. Operational analysis of wastewater is also carried out to

supplement the regulatory sampling and analysis information from SEPA (Scottish Environment Protection Agency).

Business Intelligence (BI)

The strategy of acquisition and adoption of multiple information systems dictated that Scottish Water put to operation efficient and effective system of information systems integration to facilitate a consistent and homogenous basis for corporate reporting. The company has selected Business Intelligence platform which collects data from multiple information systems and organizes it in a structure called data warehouse, so that adequate data analysis and corporate reporting can be conducted over aggregated information across the processes organization executes. In order to ensure consistency, universal keys for objects are being used across diverse systems on the level of corporation (e.g. equipment's inventory number).

Corporate Reporting

To accommodate reporting requirements and leverage information from existing systems, strategy was to build comprehensive system that ensures relevance by spanning across systems and freshness of data by minimizing offline reporting. To cope with large amounts of data from different systems and better make use of Business Intelligence, **Business Reporting Centre (BRC)** platform has been established as easily accessible central repository (a network share) of non-financial reports to provide "single version of truth" through read-only access to reports for corporate users. The reports comprise pre-defined data structures that are filled with information from other systems (template vs. data analogy). Most recent data from relevant information systems is read and aggregated at pre-defined time schedule so that the reports are refreshed with up-to-date information. To avoid unauthorized modifications after the reports publishing, a total of around 200 reports are published exclusively in read-only file format (Adobe's PDF).

Decision Support Systems (DSS)

Water Distribution Performance Analysis - Perform Spatial Plus (PSP) is Integrated Network Management water distribution analysis tool. It uses asset data from core corporate information systems (such as inventory number, type, location and classification of assets), as well as hydraulic information for losses detection in water supply networks and analysis of asset performance.

Combined with Strumap (spatial data engine), it integrates with GIS, Telemetry, Billing, Promise, Laboratory Information (LIMS) and Ellipse to accomplish an integrated visual overview of assets and associated performance information (bursts, leakage levels, water quality, customer contacts).

Primary PSP benefits are (quoted from *Scottish Water, Second Draft Business Plan, Appendix B: Strategic Framework for Asset Management*):

- *integration of asset and hydraulic data - service failures can be overlaid with current and historic hydraulic data (including leakage) and cost of delivery information;*
- *dynamic performance data analysis and validation – enables automated data imports from logger or telemetry interfaces; standardises and validates data format;*
- *leakage reporting - producing standard reports on levels of leakage;*
- *leakage modelling – enables production of reports on leakage profiles for individual areas, providing analysis and understanding of the cost of water;*

- *tracks, forecasts and allows setting of realistic targets for leakage that can be achieved through pressure management, leakage reduction, customer education, metering and grey water strategies; and*
- *Key Performance Indicators - collection and evaluation of information for specific KPIs and data for regulatory reporting.*

Aided by other systems (e.g. Low Pressure Register, Interruptions to Supply), it can help address problematic supply network areas.

The Capital Maintenance Plan is dynamic output of trends monitoring process for key performance indicators. Its primary purpose is to identify maintenance needs and optimize investment strategies. Monitoring itself is based around the analysis of data from core information systems through corporate Business Reporting Centre (BRC) and aided by Business Intelligence toolkit and other decision support systems.

The Capital Maintenance Plan covers competing capital investments requests including auxiliary services. The corporate senior management decides on investments aided by Scottish Water Investment Support System (SWISS), a tool for investment optimisation predominantly based on risks to the service.

All competing maintenance requests are entered to SWISS system. System can then calculate individual risks scoring, taking into account their likelihood and impacts on customers. The tool then combines individual competing needs to rational sub-programmes of projects so they can be balanced for optimal results in terms of costs and performance levels.

Quality of asset inventories

Scottish Water conducts continuous activities (within Information Improvement Programme) to improve quality of information in its information systems. Since data was inherited from three former water authorities, gaps were obvious and data needed to be systematically verified and updated, having in mind that some even trace back to paper records (maps being imported to GIS).

The non-infrastructure asset inventory (above ground assets) is continuously updated to show new assets and modifications to existing ones.

For infrastructure assets within GIS, activities conducted for the purpose were research of historical data (such as paper drawings and documentations) and their comparison with current GIS data, as well as field surveys at unit level. The surveys have resolved uncertainties regarding the condition, capacity and configuration of assets (using photos, videos, sketches, etc.), so that performance grading of assessed assets could be accomplished.

During the survey information was collected about each unit. The surveys did not capture information below unit level (e.g. individual pieces of equipment such as pump motors, valves or actuators).

The improvements resulted in improved quality of information and consequently confidence of data owners, which also contributed to dedication for persisting in continuous improvement activities.

3.5.3.2 Case Study: AWARE-P Project, Portugal

Methodology and analytic methods that were developed through the AWARE-P project were strongly supported by implementation of AWARE-P IAM software. The software itself is web-based collaboration platform with wide-ranging data structures and processes relevant to IAM decision-making: maps and GIS geodatabases, inventory records, work orders and maintenance, inspections/CCTV records, network models, KPIs, asset valuation records.

The software comprises a range of analytical software tools, which can be used individually for analysis and diagnostics, but it is also an integral framework for evaluation and comparison of planned alternatives and competing software solutions by means of matrices of performance, risks and expenses.

The software makes it possible to use coherent set of performance, risks and expenses estimates models, so they can be exploited for evaluation of user-defined alternatives of system modifications, planned solutions and competing projects for requested period of analysis. By using preferred planning goals and measurable criteria, system user can select a set of matrices within proposed portfolio and conduct evaluation of each planned alternative in chosen timeframe, which results in a concrete set of solutions represented by spatial matrix.

Software tools within AWARE-P software can be used stand-alone, such as: Analysis of Breakdown Rate, Risks of Service Interruptions, Water Quality Simulation, etc.

The software provides facilities for visualisation, diagnostics and evaluation of water supply wastewater or stormwater systems, which are being considered as networks or systems in their entirety, rather than as individual assets. Assessment models can utilize the simulation of system behaviour to the maximum extent possible by network simulators (such as Epanet, elaborated further in this document).

Analytical and visualization tools support more than pre-defined plans and existing projects so that users are equipped and encouraged to compare competing solutions and research alternatives. Standardized methods to facilitate choice and support decision-making are available for use both manually or with support of adequate tools. As such, platform also somewhat approximates system modelling software.

Software has to primary usage cases:

- Assortment of models and analysis tools for assessment of system, which can be used individually or in combination; and
- Facilitating IAM planning procedure that is oriented to definition of planning framework and metrics resulting from available tools.

PLAN is the tool for central planning framework, where the comparison of challenging solutions is conducted by means of performance, risk and cost metrics within interactive 2D/3D illustration of information.

Since plug-ins of AWARE-P have stand-alone capabilities for analysis they produce metrics that supports PLAN. Currently available plug-ins include (Infrastructure Asset Management of Urban Water, quote):

- *PI - Performance Indicators, quantitative assessment of the efficiency or effectiveness of a system through the calculation of performance indicators based on state-of-the-art, standardised PI libraries as well as user-developed or customised ones.*
- *PX – Performance Indices, technical performance metrics based on the values of certain features or state variables of water supply and waste/stormwater networks. The indices measure performance concepts related to level-of-service, network effectiveness and efficiency.*
- *FAIL – using models such as Poisson and LEYP, prediction of future pipe or sewer failures for a given network, e.g. in the context of estimating risk or cost metrics, based on an organized failure history in the form of work orders and pipe data.*
- *CIMP – calculates a component importance metric for each individual pipe in a network, based on the impact of its failure on nodal consumption. The measure is computed based on the network’s hydraulic model, using full simulation capabilities.*
- *UNMET – calculates a service interruption risk metric expressed as the expected volume of unmet demand in a system over one year, given the expected number of outages for each pipe, the average downtime per pipe outage, and the component importance of each pipe, expressed in terms of unmet demand.*
- *IVI - Infrastructure Value Index, representing the ageing degree of an infrastructure, calculated through the ratio between the current value and the replacement value of the infrastructure.*
- *EPANETJAVA – an efficient, Java-implemented Epanet simulation engine and natively integrated MSX library, for full-range hydraulic and water quality network simulation. It takes advantage of Baseform Core’s NETWORKS and its 2D / 3D network and results visualization.*

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