Water Policy 19 (2017) 128–146

Highlights of key international water infrastructure asset management initiatives, and trends, challenges and developments in Portugal

R. Amaral[a,*], H. Alegre[b] and J. S. Matos[a]

[a]*Civil Engineering Research and Innovation for Sustainability (CERIS), Instituto Superior Técnico, University of Lisbon (IST-UL), Av. Rovisco Pais, Lisbon, Portugal*

**Corresponding author. E-mail: rita.amaral@live.com*

[b]*Urban Water Division, Hydraulics and Environment Department, National Civil Engineering Laboratory (LNEC), Av. do Brasil 101, Lisbon, Portugal*

Abstract

Over the last two decades, remarkable progress in the Portuguese drinking water and wastewater services sector has been achieved. Nevertheless, it faces a serious challenge in trying to ensure long-term sustainability. There is equally scope for considerable efficiency and effectiveness gains. The national strategic plan for the period 2014–2020 has assigned a prominent role to infrastructure asset management (IAM) in the paradigm shift required in water services. This paper discusses the progress made, the critical issues and the challenges faced by the Portuguese water sector regarding IAM, based on a comparative analysis of international and national contexts. Various worldwide initiatives are presented. The main drivers to start using IAM were quite diverse. In Portugal, legislation initially contributed to attracting the attention of the sector to IAM, but LNEC, a research institute, has played a leading role in this process. The water services regulator has also been playing a very important role. The highly fragmented structure, the politicised nature of municipal water utility management and the existing accounting procedures are some of the main barriers to the spread of IAM best practices. The sector's ongoing restructuring and the new tariff regulation will be key enabling opportunities and challenges in coming years.

Keywords: Infrastructure asset management (IAM); Literature review; Long-term sustainability; Portuguese water sector; Urban water services

Introduction

Drinking water and wastewater services are fundamental to sustaining societal quality of life. The infrastructures responsible for the provision of such services represent a major portion of the value of municipal physical assets and are expected to be managed for current and future generations.

doi: 10.2166/wp.2016.137

'Asset management' (AM) is a modern term for an old practice – managing infrastructure assets has been a continuous task for many thousands of years. Nevertheless, a more comprehensive and well-devised strategic approach has been evolving in the last few decades (Alegre, 2009). Water utilities are increasingly being forced to adopt a long-term approach and to manage the infrastructures in an optimal way, striking a balance between performance, risk and whole-of-life costs.

The ISO 55000 standard defines AM as the 'coordinated activity of an organisation to realise value from assets'. The concept of AM started to be applied in the financial sector and has evolved in other areas such as engineering, currently assuming many forms and meanings. For utilities, the focus is on the physical assets, and in particular on the physical systems directly supporting the service provision, which are at the root of the term 'infrastructure asset management' (IAM). The term IAM is herein used as including all the physical assets of the water systems, linear and vertical, buried and above ground.

The application of IAM principles in the water sector has significantly advanced in the last decades. Numerous initiatives have been carried out around the world. Most of the activity seems to be coming from developed countries, but an increased focus on the IAM challenges in many developing countries has been observed (GWRC, 2009).

In Portugal, over the last two decades, remarkable progress in the water sector has been achieved, namely in terms of quality of the services provided, investments made in new infrastructures, institutional and organisational framework, regulatory environment, management skills and scientific developments (for example Baptista *et al.*, 2014). Nevertheless, it faces a serious challenge in trying to ensure long-term sustainability. There is also scope for considerable efficiency and effectiveness gains. PENSAAR 2020, the national water services strategic plan for 2014–2020, warns of a clearly insufficient rehabilitation rate, lack of asset knowledge and difficulties to ensure cost recovery (MAOTE, 2015). For the current rehabilitation rates to be sustainable, pipes would need to last on average 100 and 200 years for water and wastewater networks respectively. Furthermore, over 3.5 million people, or 33% of the country's population, are served by utilities that do not ensure cost recovery. A large number of utilities are not able to quantify the true cost of their services. As a result, a new paradigm for the sector has been defined:

> '*the strategy should be less centred on new infrastructure to increase the population served and more focused on the management of the sector assets, its operation and the quality of the services provided with an overall sustainability'.*

This new strategy has assigned a prominent role to IAM in the paradigm shift required for the sector.

This paper discusses the progress made, the critical issues and the challenges faced by the Portuguese water sector with regard to IAM, based on a comparative analysis of the international and national contexts. After this introduction, the second section examines how IAM has evolved worldwide, identifying key drivers and initiatives. The third section presents an overview of the Portuguese water sector and the main steps taken in this field. The fourth section summarises international trends, analyses whether the key international drivers have also contributed to spreading IAM in Portugal, identifies the main future challenges and points out some recommendations based on successful experiences. In the fifth section some concluding remarks are presented.

Highlights of key IAM initiatives

Australia and New Zealand

Australia and New Zealand are broadly known as one of the world-leading schools in IAM (for example Schulting & Alegre, 2007; van Heck, 2008). Figure 1 presents a timeline with examples of key IAM-related initiatives conducted in Australia and New Zealand.

Changes in these countries started primarily from the reform of Local Governments in the mid-1980s and in the first half of the 1990s. The process stimulated the reassessment of councils' infrastructures and the national governments have strongly endorsed the concept of IAM (for example GAO, 2004; GWRC, 2009).

In Australia, there are different drivers being used to improve AM such as legislation, regulatory licence requirements and accounting standards. In the water industry, the way was led by Sydney Water and Hunter Water after the New South Wales government passed legislation to restructure water boards as 'state-owned corporations' (Jones *et al.*, 2014).

In New Zealand, the increasing requirements in terms of legislation have been the main driver for IAM development. The recent amendment to the Local Government Act which introduced the requirement to develop a 30-year infrastructure strategy (LGA, 2014) is noteworthy. The Office of the Auditor General has also been an important driver for AM improvements in New Zealand (IPWEA & NAMS, 2006).

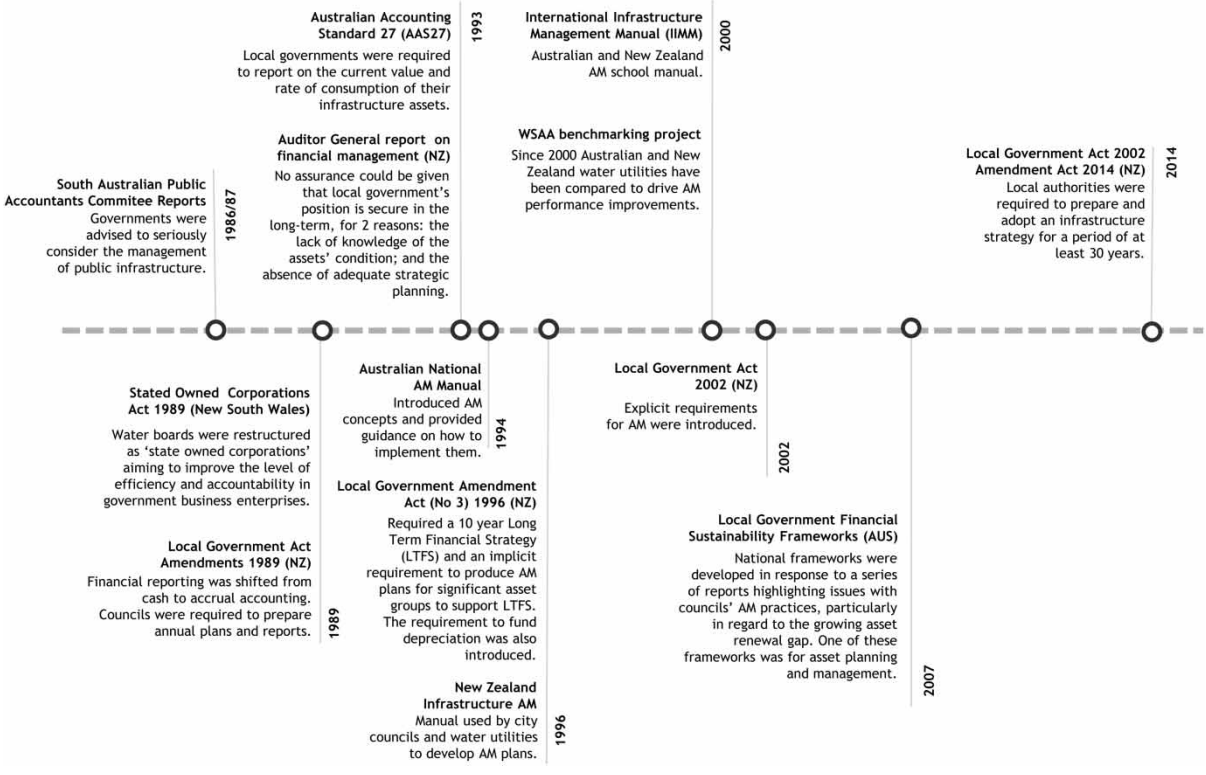

Fig. 1. Examples of key IAM-related initiatives in Australia and New Zealand.

In both countries, IAM manuals (IMEA, 1994; NAMS, 1996) were published and a range of training initiatives were carried out to assist with legislation or regulation compliance. Water utilities were to become commercially based and customer-focused (for example Kelly, 2005; IPWEA & NAMS, 2006). Utilities are required to report extensive AM related information and are externally audited. Benchmarking projects have also been used to drive AM performance improvements. The Water Services Association of Australia (WSAA) started these projects in 2000, with the International Water Association (IWA) co-sponsoring the programme since 2007. The WSAA's Aquamark Framework has been applied since 2004 for assessing AM process maturity. The 2012 project involved thirty-seven participants principally from Australia and New Zealand, but also from the USA, Canada and the Philippines. The Australian and New Zealand AM 'school' is synthesised in the International Infrastructure Management Manual (IIMM), revised and updated periodically (current edition: IPWEA & NAMS, 2015), which is dedicated to different types of public infrastructures and promotes the Total Asset Management Process. The 2015 edition has been driven largely by the introduction of the ISO 55000 standards and includes numerous new case studies. A supplement to the IIMM 2015 (IPWEA & NAMS, 2015) was also recently published aiming at providing a practical guide towards implementing ISO 55001 using the IIMM.

United Kingdom (UK) – England and Wales

In the water industry, the first comprehensive introduction of AM principles took place in the UK in 1989 (GWRC, 2009). At this time, water companies in England and Wales were privatised in response to the need for increased investment and in an attempt to achieve greater efficiency (Ofwat & DEFRA, 2006). In the period leading up to privatisation, it was necessary to provide investors with information about the condition of infrastructures and investment requirements associated with the process. Subsequently, the role of the water and wastewater services economic regulator (Ofwat), introduced by the British government at the time of privatisation, has been the main driver to AM improvement in the sector. The water companies are required to develop 5-year AM plans (AMPs) proposing and justifying the expenditure needs, the financing requirements and the implications for price limits and average bills. These plans are reviewed and approved by Ofwat. Ofwat also sets limits on the prices the water companies can charge their customers. The development of these plans is currently centred around the UK Common Framework for Capital Maintenance Planning and takes into consideration the guidelines periodically published by the regulator, aiming to promote a continuous improvement process. Developed through a UK Water Industry Research (UKWIR) project, the Common Framework is founded on risk-based principles and encompasses an economic approach which allows the trade-off between capital and operational cost options to be considered. It was launched in 2002, after the House of Commons Environmental Audit published in 2000 accused the water industry of 'intellectual neglect' (Anglian Water, 2015). Since then, several UKWIR projects have added knowledge to the Common Framework. Remarkable changes have been the introduction of total expenditure ('totex') in AMPs, combining both capital and operating expenditure, and the transformation to a more 'outcome-driven' regulation. With this in mind, the content of the Common Framework has been updated and this led to a new framework for expenditure decision-making. An overview of these developments is presented in Figure 2.

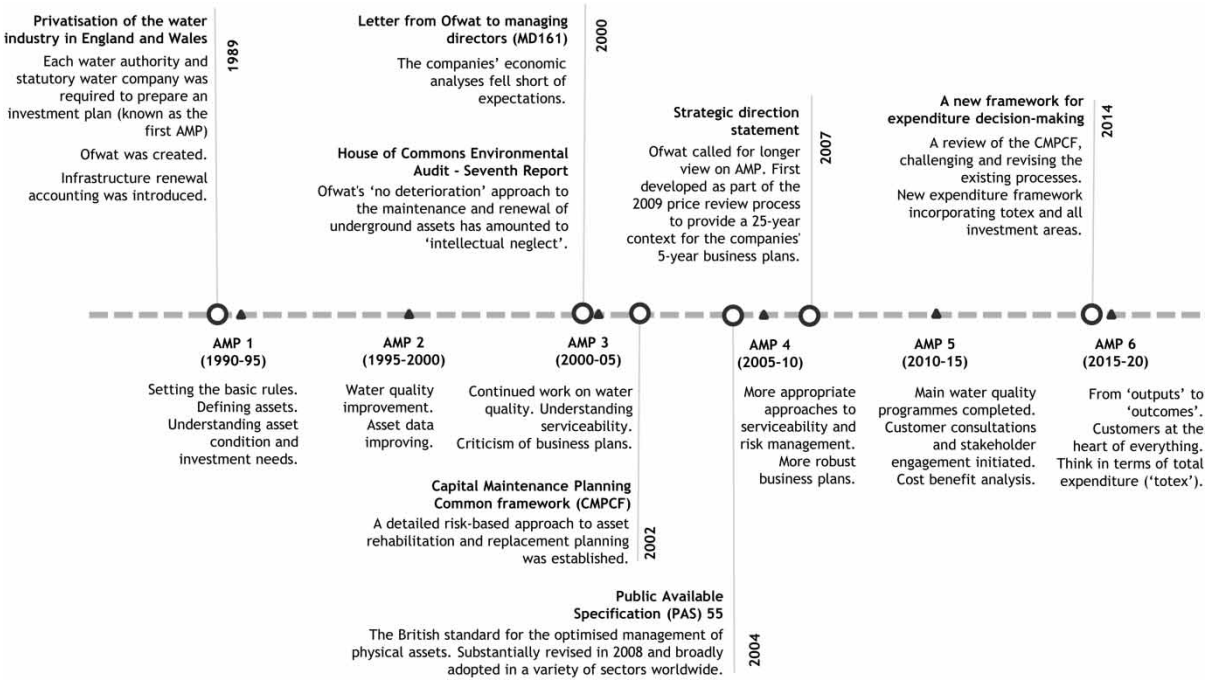

Fig. 2. Examples of key IAM-related initiatives in the UK (England and Wales).

United States of America (USA)

In the USA, IAM did not develop as fast as in the above-mentioned countries primarily due to the different structure of the water industry, which comprises many more organisations and a mix of private and municipal entities (Jones *et al.*, 2014). Nevertheless, some US water utilities, such as Seattle Public Utilities, began implementing a comprehensive AM approach in the early 2000s, in line with the Australian and New Zealand 'school' (Kelly, 2005). Since 2006, the speed of IAM uptake has been increasing, in a large part due to the Strategic Asset Management Communication and Implementation research programme (known as 'the SAM Challenge'), which has created an enabling environment at both national and utility level (Graf & Blankenship, 2011). This project was sponsored by the Water Environment Research Foundation (WERF) and included the participation of the UKWIR and the Global Water Research Coalition. The SAM challenge and other research programmes have strengthened the Sustainable Infrastructure Management Program Learning Environment (SIMPLE) as the leading reference for AM knowledge and guidance. Currently, SIMPLE provides guidance, decision support tools, practices and case studies structured to answer the so-called 'five-core question', set out in the guidance published by the US Environmental Protection Agency (USEPA, 2008), applying a ten-step method. McGraw-Hill Construction (2013) paints a picture of the state of IAM in the water industry in the USA and Canada.

Canada

The first AM concepts and guidelines were introduced in Canada from the mid-1990s. The National Research Council (NRC) Canada has played an important role in this regard, carrying out multiple

initiatives (for example the Infraguide and the Municipal Infrastructure Investment Planning projects – Vanier & Newton, 2005). The NRC's AM recommended approach can be viewed as 'the six simple questions' (Vanier, 2000). The Walkerton (Ontario) accident, which occurred in 2000 and resulted in the deaths of seven persons due to a drinking water system's contamination, had a profound impact on the management of water infrastructure in Canada. The Walkerton inquiry report (for example O'Connor, 2002) has been the basis of new legislation and regulatory changes, following a period of increased activity and development in AM practices. In 2007, the Public Sector Accounting Board introduced new accounting standards for public infrastructure in Canada (PSAB 3150), similar to the USA's Government Accounting Standards Board Statement 34 (GASB 34). This is having a national transformational impact on the evolution and development of AM practices in Canadian municipalities (Andres, 2012). The information provided by PSAB 3150 has triggered several AM key initiatives, such as the first national report card on the state of municipally-owned water, wastewater and road infrastructure (CCA *et al.*, 2012, 2014).

European Union initiatives

The twin decision support systems CARE-W (Computer-Aided Rehabilitation of Water Networks) and CARE-S (Computer-Aided Rehabilitation of Sewer Networks) were developed in the scope of EU-sponsored research projects (Sægrov, 2005, 2006). These projects were aimed at assisting water utilities in the establishment of a rational framework for rehabilitation plans of water and wastewater networks. The projects ended respectively in 2004 and 2005, and since then a number of applications have taken place in several countries. In technical and scientific terms, Portugal (LNEC) and Norway (SINTEF) launched AWARE-P (Advanced Water Asset Rehabilitation in Portugal (www.aware-p.org)), following the CARE path. This initiative allowed for the establishment of a sound and systematic IAM approach, which in the meantime became an international reference, publishing corresponding guidance manuals and software tools. More recently, the TRUST project (www.TRUST-i.net) was developed under the 7th Framework Program of the European Union with the participation of thirty partners from eleven countries. This was a 4-year project starting in 2011 with the aim of delivering knowledge to support Transitions to the Urban Water Services of Tomorrow, enabling communities to achieve a sustainable, low carbon water future without compromising service quality. In the scope of IAM, apart from technologies and analytical tools, TRUST results include an objective-oriented approach to IAM, the TRUST/AWARE-P IAM approach, designed to support a continuous improvement management process. It is an outcome-oriented IAM planning for long-term sustainability, embedding key ISO 55000 requirements, as well as the IWA guidance and recommended best practice on performance assessment, benchmarking and good management. This approach is incorporated in a series of IAM best practice manuals (for example Alegre & Covas, 2015). An e-learning course on this subject was also made available (www.trust-i.net/iam/).

Other relevant worldwide initiatives

Many other relevant initiatives around the world could be highlighted. Some examples include the following:

- In France, the renowned Scientific and Technical Association for Water and the Environment (ASTEE) has recently published two guides on AM for drinking water supply networks (ASTEE *et al.*, 2013, 2014).

- In the Netherlands, there are several platforms (for example the VVZBs, the cooperation of wastewater treatment managers, AM working group) focused on IAM and frequent congresses, courses and meetings in this regard have been held in recent years. AM policies are directed by service targets, much more than economic reasons. Dutch water companies in collaboration with the KWR Watercycle Research Institute have developed a national database (called USTORE) to store and analyse failure data (for example Vloerbergh & Blokker, 2010).
- As part of the Danube Water programme, the International Association of Water Supply Companies in the Danube River Catchment Area (IAWD) has recently finished a capacity building project, over a period of 18 months, with the main goal of creating greater awareness and improving AM practices for 17 water utilities from Bosnia and Herzegovina, Montenegro, Macedonia and Serbia (www.danube-water-program.org).
- In Japan, the Ministry of Health, Labour and Welfare (MHLW) established the 'asset management guidelines for water supply utilities' in 2009, in order to encourage utilities to adopt AM. Many utilities have established medium- to long-term infrastructure renewal and financial plans based on these guidelines (Sawai, 2013). In 2013, the MHLW provided a simplified support tool for AM, particularly aimed at small-scale utilities.
- The Korea Water Resources Corporation (K-water), South Korea's leading water related company, developed an AM roadmap as a first step of a process to strengthen its AM programme. AM terminologies were translated and an AM foundation appropriate for the Korean business culture was established, contributing to creating an AM path for all Korean organisations.
- In 2011, Rand Water, the largest water utility in Africa, started a paradigm shift from an engineering approach to an AM approach (Lange & Kasan, 2013). Several initiatives were carried out, including a restructuring of the SAM division, an AM maturity assessment and the implementation of guidelines provided in PAS 55.
- The Asian Development Bank (ADB) has published a guide about water utility AM, aiming to improve sustainability of operations and realise the full benefits of ADB loans for water supply (ADB, 2013). The guide presents an overview of AM and includes the experience of four utilities in Pakistan, the Philippines, Australia and Vietnam.

The Portuguese water sector

Brief historical background

Due to difficulties in response to the challenges posed by the entry into the European Union (EU), the Portuguese Government decided to start a profound reform in the water sector in 1993. This reform aimed at increasing the coverage levels and improving the quality of services as well as business efficiency. It comprised the formulation of a new national strategy and the revision of the institutional and legal framework, the governance models and the territorial organisation (Baptista *et al.*, 2011). Among other measures, the reform enabled the deverticalisation of the services, splitting the wholesale (bulk) and the retail (end-user) activities, the opening to private capital and, later, the establishment of a sector-specific regulatory authority (Marques, 2011). Until then, water services were under the exclusive responsibility of the local administration. With regard to bulk activities, it was stipulated that the

investment should be complemented by the central government through the creation of multi-municipal systems (controlled by the Águas de Portugal, or AdP, group), adopting business-like practices and management style. A regulatory authority (IRAR) was set up in 1998 to regulate multi-municipal and municipal concessions. Its designation has since changed to ERSAR (the Portuguese acronym for Water and Waste Services Regulation Entity) and it was given broader authority including economic regulation, quality of service regulation and drinking water quality control. A 2009 legislation, effective since 2011, extends the intervention scope of ERSAR to all operators, irrespective of the management model.

More than €4,300 million were invested during the 2000–2006 Strategic Plan for Water Supply and Wastewater Services (PEAASAR I) (MAOTDR, 2007). During the period covered by the following plan, PEAASAR II (2007–2013), there were investments above €2,600 million (MAOTE, 2015). A substantial part of these investments was backed by EU-allocated funds.

The massive investment effort, predominantly applied to bulk services, resulted in significant progress in the physical access to services (levels of 95%, 81% and 78% were achieved in water supply, wastewater collection and wastewater treatment services, respectively) (MAOTE, 2015). Drinking water quality and bathing water quality have also improved. Despite this, other parameters with regard to the quality of service provided need improvement (for example water losses, infiltration/inflow in domestic sewers). There are also serious problems of economic and financial sustainability. Against this background, a new paradigm for the sector was defined in PENSAAR 2020 (2014–2020):

> '*the strategy should be less centred on new infrastructure to increase the population served and more focused on the management of the sector assets, its operation and the quality of the services provided with an overall sustainability*' (MAOTE, 2015).

The investments envisaged for PENSAAR 2020 surpass €3,700 million, with a major part planned to be supported by the utilities. Other important actions are underway in the sector, including the definition of a new tariff regulation (with the change of a cost plus model to a revenue cap model, with more incentives for efficiency) and the restructuring of the AdP group (with a reduction from 19 utilities to just five regional utilities).

General characterisation

The reforms undertaken reshaped the market structure, which is now quite complex (Pinto & Marques, 2015). The responsibility of water services is shared by the state (multi-municipal systems) and the municipalities (municipal systems). The system owner may opt between three distinct management models: direct management, delegation and concession, and is able to promote public-public partnerships or public-private partnerships.

Table 1 presents an overview of water service utilities in 2013. The majority of bulk activity is ensured through AdP multi-municipal concessions. At retail level, municipalities are the most common governance structures, although the number of municipal companies and municipal concessions has increased in recent years. According to ERSAR (2015), in 2013 there were about 160 water supply systems (about 50% of total water supply systems) and 101 wastewater systems (38%) serving populations of less than 10,000, which clearly demonstrate the level of fragmentation in retail services that still prevails.

Table 1. Overview of Portuguese (mainland) water services' utilities in 2013 (ERSAR, 2015).

		Number of utilities (population covered[a] ×1,000)			
		Water supply		Wastewater	
Management model	Management submodel	Only bulk	Retail	Only bulk	Retail
Concessions	Multi-municipal concessions	11 (4,916)	1 (11)	16 (6,922)	–
	Municipal concessions	1 (144)	27 (1,902)	2 (402)	22 (1,646)
Delegations	State-owned companies	1 (1,778)	1 (548)	–	–
	State/municipalities partnerships	1 (253)	1 (340)	1 (253)	1 (341)
	Municipal and inter-municipal companies	1 (49)	23 (1,793)	–	24 (1,835)
	Parish or users' association	–	92 (61)	–	–
Direct management	Municipalised and inter-municipalised services[b]	–	20 (2,316)	–	18 (2,308)
	Municipalities (municipal department)	–	189 (3,100)	–	199 (3,930)

[a]Number of inhabitants potentially supplied by those utilities in mainland Portugal.
[b]Structure with some degree of financial and administrative autonomy.

There is a small number of utilities with vertical integration (interpreted as the incorporation, within the same operator, of the bulk and the retail services) in mainland Portugal. There is also a reduced degree of horizontal integration (interpreted as the integration of several municipalities into one single operator), mainly in retail services, with a total of 367 utilities in water supply services and 283 utilities in wastewater services in a country with about 10 million inhabitants. The utilities mostly provide water and wastewater services together, especially in the retail activity. Thus, there is a great potential for use of scale economies, economies of process and economies of scope, in order to further reduce costs and to guarantee greater structural efficiency in service provision.

Table 2 summarises the extent of the water asset base in mainland Portugal.

Quality of service assessment

Within the scope of quality of service regulation, a fully audited annual assessment and comparison process has been performed by ERSAR on all water utilities operating in mainland Portugal since 2011. The quality of service assessment is currently based on 16 indicators for each service (drinking water supply, wastewater management and municipal waste management). The results of this evaluation process have public disclosure in the *Annual Report on Water and Waste Services in Portugal* series, aiming to push utilities to increase efficiency and to consolidate a culture of concise, reliable and easily interpretable information for all. Since 2014, this information is also available through a freely downloadable mobile ERSAR app, selected by the Organisation for Economic Co-operation and Development (OECD) as one of the show cases of Stakeholder Engagement for Inclusive Water Governance (OECD, 2015).

The global results for relevant IAM indicators are presented in Table 3. Despite significant progress in recent decades in terms of quality of service provided, there are clear opportunities for improvement. A large part of the utilities, mainly in wastewater retail services, does not ensure cost recovery. In addition to operating inefficiencies, this can be explained by the fact that price-setting is often influenced by political interests, which do not reflect a rational logic. A great number of utilities are unable to report the true cost of their services, failing to respond to this indicator. There is a low adequacy of treatment

Table 2. Water asset base in mainland Portugal (ERSAR, 2015).

Water supply		Wastewater	
276 / 5,878	Surface/groundwater water abstraction facilities	2,598	Treatment plants[a]
252	Treatment plants	1,671	Collective septic tanks
3,317	Other treatment facilities[b]	26	Long sea outfalls
2,407	Pumping stations	6,432	Overflows
8,623	Reservoirs	4,842	Pumping stations
102,714 km	Water mains	5, 825 km	Sewer mains

[a]Septic tanks are not included.
[b]Facilities that only perform disinfection and/or aggressive correction operations.

capacity, mainly due to an underutilisation of the treatment plants. High rates of non-revenue water, mains failures and sewer collapses can be observed in many utilities, which is associated with a clearly insufficient rehabilitation investment. It should also be noted that a significant number of utilities have revealed difficulties in information reporting, particularly in retail services.

Further analysis of some of the indicators and index reported by ERSAR (2013a) was performed, exploring relationships between them. Illustratively, some results are presented in Figures 3–5.

Figure 3 presents an asset knowledge and management index (AKMI) in retail water and wastewater services. This index is calculated according to the existence and the degree of detail of the asset register, the information available about work orders and the level of IAM, as presented in ERSAR (2013b). The lack of asset knowledge by a significant number of utilities is rather concerning, in particular with regard to retail systems (Figure 3). The situation is especially critical in wastewater services.

Figure 4 presents the relationship between the non-revenue water indicator (presented in ERSAR, 2013b) and the AKMI in retail systems. It appears that the utilities with greater AKMI tend to present

Table 3. Quality of service provided in mainland Portugal (ERSAR, 2015).

	Weighted average [minimum; maximum]	
Sector and performance indicators	Bulk	Retail
Water supply		
AA06 – Coverage of total costs (–)	1.1; [0.8; 1.4]	1.0; [0.2; 1.9]
AA08 – Non-revenue water (%)	4.7; [0.6; 13.8]	30.9; [7.9; 80.5]
AA09 – Adequacy of treatment capacity (%)	31; [0; 87]	57; [0; 98]
AA10 – Mains rehabilitation (%/year)	0.3; [0; 4.6]	1.0; [0; 7.3]
AA11 – Mains failures (n °/(100 km.year))	11; [1; 45]	40; [0; 487]
AA13 – Real water losses (l/(connections.day))	–	139; [0.4; 997]
AA15 – Standardised energy consumption (kWh/m^3.100 m)	0.38; [0.30; 0.69]	0.48; [0.32; 9.38]
Wastewater		
AR05 – Coverage of total costs (–)	1.0; [0.9; 2.3]	0.8; [0; 5.8]
AR07 – Adequacy of treatment capacity (%)	59; [3; 96]	45; [2; 88]
AR08 – Sewer rehabilitation (%/year)	0.9; [0; 3.0]	0.4; [0; 13.0]
AR09 – Sewer collapses (n °/(100 km.year))	1.3; [0; 3.1]	1.8; [0; 242.6]
AR11 – Standardised energy consumption (kWh/m^3.100 m)	0.49; [0.30; 0.73]	0.56; [0.30; 11.39]

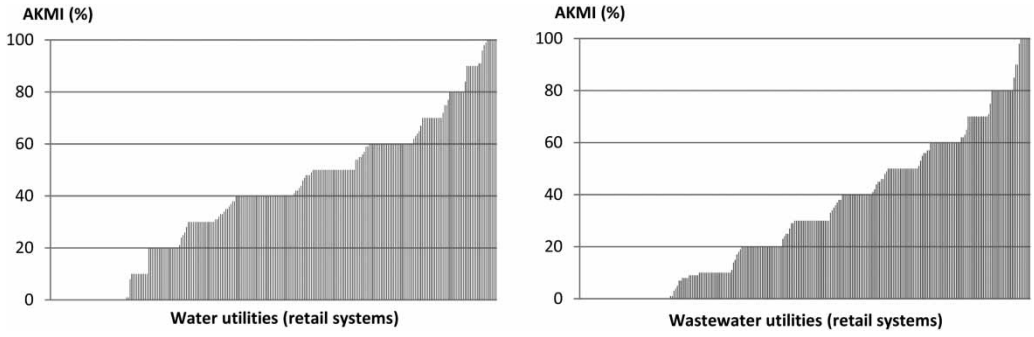

Fig. 3. Asset knowledge and management index (AKMI) in water and wastewater utilities – retail systems.

lower rates of non-revenue water and vice-versa. Salvetti (2013) has reported a similar trend in the French water sector.

In general, lower AKMI, poorer infrastructural performance and lower cost recovery, in either water supply and in wastewater services, are more frequently found in utilities directly managed by municipalities (municipal departments). With regard to better performing utilities, it was not possible to identify a management model that clearly stands out from the rest (for example Figures 4 and 5).

IAM-related initiatives

Important developments in IAM have taken place in recent years in Portugal. The National Civil Engineering Laboratory (LNEC) has taken a leading role in research, development, training and awareness of this issue. The specific activity in IAM began under the research programme 'Water Infrastructure Asset Management' (Alegre, 2008). Since then, several relevant research and collaborative projects followed, at national, European and international level (for example the AWARE-P project, the TRUST project, the iGPI initiatives, igpi.aware-p.org, and a project financed by WERF and USEPA – Coelho *et al.*, 2015). An integrated IAM methodology was developed and materialised in the

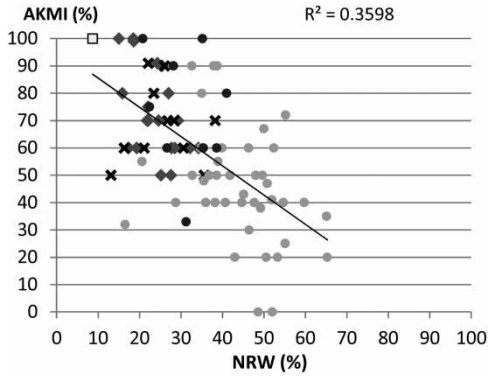

Fig. 4. Non-revenue water versus AKMI – retail systems. *Note:* charts only include data from utilities that have responded to AA06, AA08 and AA10 indicators with acceptable or good reliability level (** or *** in terms of ERSAR's classification, as presented in ERSAR (2013b)).

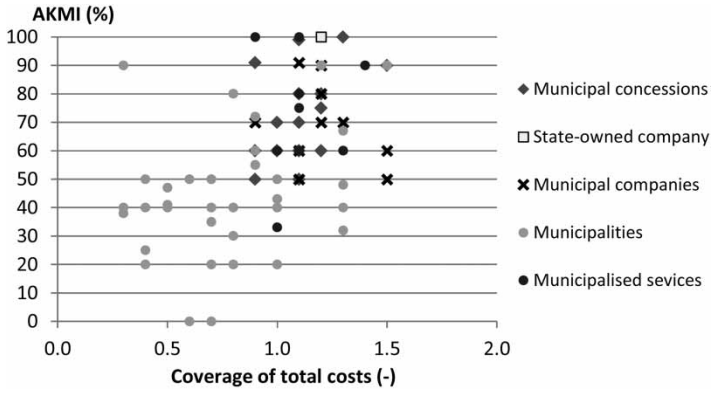

Fig. 5. Coverage of total costs versus AKMI – retail systems. *Note:* charts only include data from utilities that have responded to AA06, AA08 and AA10 indicators with acceptable or good reliability level (** or *** in terms of ERSAR's classification, as presented in ERSAR (2013b)).

publication of two technical guides by ERSAR. An innovative IAM decision support software was also developed and tested in several utilities.

Numerous conferences, workshops, courses and meetings have been organised in Portugal (for example IWA LESAM 2007; IAM workshop in IWA World Water Congress 2014). Academic training has also taken place, with several master and doctoral dissertations being developed in recent years.

Regarding the water utilities, a growing interest in IAM principles has been noted, especially after the introduction of national legislation (Decree-Law no. 194/2009), which requires all water supply and wastewater utilities (in the sphere of municipal ownership) serving a population of 30,000 and above to promote and maintain an IAM system. Some utilities, such as EPAL and the AGS private holding companies, have been effectively implementing IAM programmes. EPAL, the largest water company in Portugal, started the process in the middle of the 2000s which culminated in the development of an Integrated Asset Management Model (Capela *et al.*, 2014). AGS has been participating in various research and innovation projects, which enabled the establishment of an AM policy inside the group and the implementation of a collaborative programme to support utilities on developing IAM plans (Feliciano *et al.*, 2014).

Trends, critical issues and challenges

Legislation

Legislation has been the principal driver of IAM in countries such as New Zealand. There is a growing number of increasingly specific requirements. As a result, the development of IAM plans is now common practice. If at first it favoured a logic of planning and reporting in the short- and medium-term and was more focused on financial management improvements, more recently there has been a tendency towards long-term planning and a greater focus on improving infrastructure management. Examples are the recent requirements to develop a long-term infrastructure strategy in New Zealand and a strategic direction statement in the UK. In Portugal, it is believed that, in general, legislation has contributed to raising awareness of water utilities to the IAM issue, specifically through reference to IAM systems (Decree-Law no. 194/2009), but it has

not been an important driver in the spread of its effective implementation. The legislation is not, on the whole, as demanding or as specific as in these countries; on the contrary, it is considered vague and lacking. In relation to municipal systems, some IAM practices are recognised in the legislation as duties of water utilities. In particular, in relation to water utilities serving more than 30,000 inhabitants, it is recognised that they must promote and maintain an IAM system, however it does not refer to specific requirements that are associated with an IAM system. There is no verification of compliance with these duties, with them becoming, in practice, a set of recommendations that are not followed in many water utilities. It is believed that in order to demonstrate that they have performed these duties, they must be required to develop plans which, as in other countries, would be subject to certification by independent audit. In addition to helping ensure compliance with these requirements, audits have a further advantage of fostering a process of continuous improvement. The main aspects to be detailed in these plans, including the frequency of their revision and delivery (for example every 5 years), must be clearly stated. In relation to multi-municipal systems, a technical report about the performance and condition of the infrastructures and the future rehabilitation and renewal requirements is now required to be delivered every 5 years. These reports are subject to certification. The authors consider that there is space for improvements in these reports. Following international trends, the delivery of a long-term plan that reflects organisations' planning at a strategic level should additionally be demanded. It should be noted that ERSAR is currently making efforts in order to make the legal requirements more specific (and thus increase legal effectiveness by allowing easier identification of any breaches of duty, etc.), namely through the development of new asset knowledge and management indices. These indices will be audited annually as part of the quality of service assessment process. Another incentive mechanism that has started to be used is to require minimum values of the current AKMI to assign certain kinds of EU funds.

Regulation

The role of the regulator in countries such as England and Wales has been the principal driver for the development of IAM processes. In Canada, the regulatory response to the accident in Ontario also had a profound impact in terms of IAM implementation. In Portugal, ERSAR has also been playing an important role in promoting the implementation of IAM best practices in the sector. The recent enlargement of the scope to regulatory intervention to all water utilities has encouraged the improvement in utilities' information management and accounting systems, which are fundamental bases to IAM. The dissemination of service quality information and the distinguishing, annually, of utilities of excellence, has also contributed to fostering competitiveness in the sector. However, there is no financial incentive and/or penalty system for utilities, as happens, for example, in the UK. The recent strengthening of ERSAR's powers, which translates into defining the sector's tariffs and into allowing the application of fines and the enforcement of debts, will constitute an important challenge to achieving a significant improvement in service quality and to ensuring full cost-recovery. Additionally, ERSAR has had an important role in the circulation of technical guides and in the promotion of and support to IAM projects.

Structure of the sector

The structure adopted in each country for the water sector is an important factor in the degree of ease of IAM implementation. For example, according to Jones *et al.* (2014), this was the main reason for IAM not

having been developed as quickly in the USA as it was in the UK, Australia and New Zealand. In some countries where IAM has been developed more quickly, there has been a trend towards reducing the number of utilities in the sector. In England and Wales, for example, in 1945 there were 2,600 utilities involved in water supply and wastewater management (Ofwat & DEFRA, 2006); currently there are only thirty-four utilities in the sector. Whatever the ownership and management of services, internationally there are examples of success of several types and it is impossible to clearly highlight the most advantageous IAM solution. In Portugal, the water sector is, as mentioned above, very fragmented and a number of management models coexist. There is a very large number of small utilities, often run-down, and a high number of utilities without the scale to ensure adequate levels of service quality and operating economies. This situation greatly complicates the technical and economic management of the systems. The recent territorial and corporate reorganisation of the state-owned systems, which included, among other measures, the reduction from 19 water supply and wastewater management systems to five regional systems, is a major challenge for the sector in the coming years and it is expected to achieve a significant improvement in the level of IAM. Regarding retail services, where municipal management is prevalent, in which the level of fragmentation is exceptionally high and where the most serious service provision performance problems are found, the situation is much more complex, there being serious impediments to the proliferation of IAM practices.

Accounting standards

The introduction of important alterations in accounting standards was a key initial driver of IAM in international terms. Examples are the AAS27 in Australia, the GASB 34 in the USA or, more recently, the PSAB 3150 in Canada. In Portugal, it is considered that existing accounting procedures and practices constitute a strong barrier to the proliferation of IAM in the sector, a deep-rooted review being required. One of the aspects worthy of analysis is the accounting of the value of infrastructures. The existence of a great variety of management models, with specific rules and a variety of peculiarities, make this analysis complex and force accountants, financers and engineers to sit at the same table. This is a pressing challenge and is extremely important for the boosting of IAM practices in Portugal.

Research and innovation

In countries such as the USA, the role of research institutions was decisive in creating a favourable environment for the rolling out of IAM, at both a national and utility level. In Portugal, LNEC has similarly taken a leading role in the field of IAM. As well as developing its research activity, already internationally recognised, it has promoted training and capacity building projects for water utilities, and has organised specific IAM discussion forums and sessions dedicated to this theme in several national and international congresses. Through these projects several utilities have developed strategic and tactical IAM plans and established networking between professionals in the sector, with the sharing of experiences between utilities. It could be said that LNEC was primarily responsible in Portugal for creating awareness of IAM in the utilities and in the water sector in general, currently placing it at the top of the list of priorities.

Studies assessing investment needs and sources of funding

Some countries have been addressing the challenges of aging water infrastructures, in particular carrying out studies to assess the condition of the infrastructures, estimating investment needs and assessing the funding gaps. Some of these studies have been developed specifically for the sector (for example CSA, 2014) while others are included in studies with a broader scope, which also include the evaluation of other types of infrastructures, such as transport, energy and others. An example of the latter one is the 'Report Card' (for example CCA *et al.*, 2012), conducted periodically in countries such as the USA, Australia, New Zealand and, more recently, Canada, aiming at attributing a rating to the state of different sectors' infrastructures, assessing investment needs and making recommendations. These studies have contributed to alerting and raising awareness in governments about the growing investment needs and have encouraged the search for adequate solutions. For example, in England and Wales, a need for investment that was higher than the amount the government was willing to finance contributed to the decision to privatise the sector. In the USA and Canada, awareness of the funding gap problem has led to developments in IAM. In Portugal, estimates of overall investment needs in the water services infrastructure have been made as part of the strategic plans for the sector. There are no known classification systems for the condition of the infrastructure, like those that exist in the above-mentioned countries, either at industry or multi-sector level.

In the last two decades, a large part of the investment in the sector has been subsidised by funds allocated by the EU. On the one hand this continued support with EU funds has allowed the leveraging of investments at lower costs and ensured sustainable cost recovery at economically more affordable prices (MAOTE, 2015), but on the other hand it has led in practice to the tariffs not covering total costs, in the expectation of continuing to benefit from subsidies from external entities. These expectations have been a barrier to the change of attitude required for the journey towards IAM. These aspects pose important challenges to the sector that need to be addressed.

Water services associations

The benchmarking projects undertaken by WSAA are an example of success in the promotion and development of IAM in Australia and New Zealand and demonstrate the importance that this type of organisation can have in this field. More recently, utilities in other countries such as the USA or Canada have also been participating in these initiatives. The Portuguese water supply and wastewater association (APDA) has created an AM working group, which has begun to focus on developing a best practices manual. Other working groups in holding companies such as AGS and the AdP group have also been working in this area. Like the international experience, it is considered that the work to be done by these groups can be an important driver for improving IAM processes in utilities. In particular, benchmarking projects focused on the analysis of IAM processes, such as those carried out internationally, are an opportunity that must be explored in the sector.

Business strategy and customer focus

There has been a trend in countries such as Australia, New Zealand and the UK for water utilities to become increasingly commercial and to have a much greater focus on their customers. In the UK, for example, the utilities are increasingly encouraged by the regulator to engage with their customers, seeking

to obtain their opinion about levels of service and the tariffs charged (known as the 'willingness to pay surveys') (Jones *et al*., 2014). The involvement of stakeholders is indeed one of the areas under development in IAM. In Portugal, some initiatives that show a greater proximity to customers are beginning to appear, although not to the same extent as the above-mentioned countries. In this way challenges have been set to the sector, which are aimed at promoting measures that encourage utilities to follow this trend.

Corporate structure and organisational culture

Several utilities which have successfully implemented IAM programmes internationally have realised the importance of having a structure and positions in the organisation dedicated to IAM (for example Sydney Water). It is widely recognised that the effective implementation and development of IAM requires the developing of an IAM culture in the organisation (for example Waugh, 2005). This organisational culture must be supported by top management. Portugal is no exception. The cases of greatest success in IAM programmes surveyed by LNEC were utilities where support from the top was clear and effective. EPAL and, more recently, the other companies in the AdP group are also following the path of incorporating IAM into the organisations' corporate structure. The holding companies (for example AdP group and AGS) have also set up IAM work groups and programmes to support their companies. The results achieved have been very positive. These initiatives have helped inform and create awareness in employees, disseminating best practices in the group and fostering an IAM culture in the organisations. The biggest challenges are faced by smaller utilities, where technical resources are scarce. Participation in collaborative projects and in working groups, such as those promoted by APDA, could be an important asset to these utilities.

Concluding remarks

The importance of the application of IAM principles in the water industry is now widely recognised, having become one of the main discussion topics in international and national terms.

This paper aimed to discuss the progress made, the critical issues and the challenges faced by the Portuguese water sector in regard to IAM, based on a comparative analysis of the international and national contexts.

An overview of various initiatives and developments around the world were presented. The main drivers to start using IAM were quite varied, resulting in different views and frameworks. In leading-edge countries such as Australia, New Zealand and the UK, IAM has significantly evolved over the last three decades owing to pressures from governments, regulators, shareholders and other stakeholders to ensure cost-effective and sustainable water services.

In Portugal, the introduction of IAM principles in the water sector was more recent. After an extended period of significant investment in the construction of new water and wastewater systems, a new period more focused on the management of the existing assets has started. The results of the performance evaluation system have shown clear improvement opportunities, emphasising the need for effective solutions.

The explicit reference to IAM systems in legislation has decisively contributed to attract the attention of the utilities and the water sector in general to this issue. LNEC has developed an integrated IAM methodology and has led several collaborative and research projects for the benefit of the water

sector. The regulator has also been playing a very important role in promoting the implementation of IAM best practices, either through the quality of service assessment system or through the publication of technical guides and in the promotion of and support to IAM projects. Several utilities have already developed strategic and tactical IAM plans.

The Portuguese water sector has already taken important steps to embrace sound IAM, but has still a long way to go. The highly fragmented structure, the politicised nature of municipal water utility management and the existing accounting procedures and practices are some of the main hurdles to the spread of best practices in IAM. The ongoing restructuring of the sector and the implementation of the future tariff regulation will be key enabling opportunities and challenges in coming years.

Acknowledgements

The authors would like to thank the Foundation of Science and Technology, Portugal (FCT), which supported this work through a PhD studentship.

References

ADB (2013). *Water Utility Asset Management: A Guide for Development Practitioners.* Asian Development Bank, Mandaluyong City, Philippines.

Alegre, H. (2008). *Gestão Patrimonial de infraestruturas de abastecimento de água e de drenagem e tratamento de águas residuais (Water Infrastructure Asset Management).* Research Program, Series 'Theses and Research Programmes', LNEC, Lisbon, Portugal, p. 385.

Alegre, H. (2009). *Current Drivers, Challenges and Trends of Infrastructure Asset Management.* Keynote at the Seminar on Asset Management Program, Japan Works Association, 28 July, Tokyo, Japan.

Alegre, H. & Covas, D. (2015). *Integrated planning of urban water services: a global approach*. TRUST Manual of Best Practice, Vol. 1, retrieved from http://www.trust-i.net/downloads/index.php?iddesc=146 (accessed 22 February 2016).

Andres, R. (2012). Impact of new accounting rules for managing assets in Canadian Municipalities and the link to sustainable infrastructure. In: *Global Perspectives on Sustainable Infrastructure Conference*, *Washington*.

Anglian Water (2015). Capital Maintenance Planning. From a historical and future Perspective, July, retrieved from http://www.anglianwater.co.uk/_assets/media/Long_term_investment_-_Final.pdf (accessed 22 February 2016).

ASTEE, AITF & ONEMA (2013). *Gestion patrimoniale des réseaux d'eau potable. Elaboration du descriptif détaillé des ouvrages de transport et de distribution d'eau (Infrastructure Asset Management for Drinking Water Supply Systems. Establishment of Detailed Specifications for Water Supply Networks).* Association Scientifique et Technique pour l'Eau et Environnement; Association des Ingénieurs Territoriax de France; Office National de l'Eau et des Milieux Aquatiques, Paris (in French).

ASTEE, AITF, FNCCR & ONEMA (2014). *Gestion patrimoniale des réseaux d'eau potable. Politiques d'investissement et gestion des immobilisations: cadre et bonnes pratiques. Une vision à la croisée des approches techniques, comptables et financières (Infrastructure Asset Management for Drinking Water Supply Systems. Investment Policies and Asset Management: Framework and Best Practices. A Vision at the Crossroads of Technical, Accounting and Financial Approaches).* Association Scientifique et Technique pour l'Eau et Environnement; Association des Ingénieurs Territoriax de France; Fédération Nationale des Collectivités Concédantes et Régies; Office National de l'Eau et des Milieux Aquatiques, Paris (in French).

Baptista, J. M., Maçãs, F. & Pereira, C. (2011). *Contribuições para a reorganização dos serviços de abastecimento público de água, de saneamento de águas residuais e de gestão de resíduos urbanos em Portugal (Contributions to the Reorganisation of Water and Waste Services in Portugal).* ERSAR, Lisbon, Portugal.

Baptista, J. M., Alves, D. & Andrade, I. (2014). O acesso à água e ao saneamento como direitos humanos em Portugal (Access to water and sanitation as human rights in Portugal). In: *Public Interventions in 2014*, Series 'Public Interventions'. ERSAR, Lisbon, Portugal.

Capela, M., Serranito, F. & Luis, A. (2014). Embedding information management into Asset Management – the journey of a water supply utility. In: *Proceedings of the IWA World Water Congress 2014*, *Lisbon, Portugal*.

CCA, CPWA, CSCE & FCM (2012). *Canadian Infrastructure Report Card. Municipal Roads and Water Systems (Vol. 1)*. Available at: http://www.canadainfrastructure.ca.

CCA, CPWA, CSCE & FCM (2014). *Canadian Infrastructure Report Card. Asset Management Primer*. Available at: http://www.canadainfrastructure.ca.

Coelho, S., Vitorino, D., Jurkovac, B., Alegre, H., Kerr, D. & Brito, R. (2015). *Visual Tool for Supporting Asset Management Performance, Risk and Cost Analysis. Project INFR-2012*, WERF, Alexandria, VA.

CSA (2014). *Exploring the Issues Facing New Zealand's Water, Wastewater and Stormwater Sector.* Castalia Strategic Advisors. Local government New Zealand, Wellington.

ERSAR (2013a). *Relatório Anual dos Serviços de Águas e Resíduos em Portugal 2012 (Annual Report on Water and Waste Services in Portugal 2012).* ERSAR, Lisbon, Portugal.

ERSAR (2013b). *Guia de avaliação da qualidade dos serviços de águas e resíduos prestados aos utilizadores – 2.ª geração do sistema de avaliação (Quality of Service Assessment System for Water and Waste Services – 2nd Generation of Quality of Service Indicators).* Series 'Technical Guides'. ERSAR, Lisbon, Portugal.

ERSAR (2015). *Relatório Anual dos Serviços de Águas e Resíduos em Portugal 2014 (Annual Report on Water and Waste Services in Portugal 2014).* ERSAR, Lisbon, Portugal.

Feliciano, J., Almeida, R., Santos, A. & Ferreira, A. (2014). Infrastructure asset management program in a multi-utility organisation. In: *Proc. of the IWA World Water Congress 2014*, *Lisbon, Portugal*.

GAO (2004). *Water Infrastructure: Comprehensive Asset Management has Potential to Help Utilities Better Identify Needs and Plan Future Investments*. GAO-04–461, United States General Accounting Office, Washington, DC.

Graf, W. L. & Blankenship, L. L. (2011). WERF's research helps utilities improve the strategic management of their assets. In: *Proceedings of the LESAM 2011*, *Mülheim an der Ruhr, Germany*.

GWRC (2009). *Compendium of Best Practices in Water Infrastructure Asset Management* (Bhagwan, J. ed.). Global Water Research Coalition, London.

IMEA (1994). *National Asset Management Manual*. Institute of Municipal Engineering Australia, Sydney, Australia.

IPWEA & NAMS (2006). *International Infrastructure Management Manual (IIMM).* 2006 Edition. Institute of Public Works Engineering Australasia, Sydney and National Asset Management Steering Group, Wellington.

IPWEA & NAMS (2015). *International Infrastructure Management Manual (IIMM).* 2015 Edition. Institute of Public Works Engineering Australasia, Sydney and National Asset Management Steering Group, Wellington.

IWA LESAM (2007). IWA Leading Edge Conference on Strategic Asset Management, IWA and LNEC, Lisbon, 17–19 October.

IWA World Water Congress (2014). Pre-Congress Forum on Infrastructure Asset Management in the Water Sector, Lisbon, 21–26 September.

Jones, M., Williams, W. & Stillman, J. (2014). The evolution of asset management in the water industry. *Journal American Water Works Association (AWWA) 106*(8), 140–148.

Kelly, E. S. (2005). What's so different about Australian asset management? In: *Proceedings of the AWWA/WEF Joint Management Conference*, *Atlanta*, pp. 1–12.

Lange, L. W. & Kasan, H. C. (2013). Paradigm shift from engineering to asset management : Rand water, largest water utility in Africa. In: *Proceedings of the LESAM 2013*, *Sydney, Australia*.

LGA (2014). *Local Government Act 2002 Amendment Act 2014*, New Zealand.

MAOTDR (2007). *PEAASAR II Plano Estratégico de Abastecimento de Água e de Saneamento de Águas Residuais 2007–2013 (PEAASAR II Water Supply and Wastewater Services Strategic Plan 2007–2013).* Ministry of Environment, Spatial Planning and Regional Development, Lisbon, Portugal.

MAOTE (2015). *PENSAAR 2020. Uma nova estratégia para o setor de abastecimento de águas e saneamento de águas residuais (PENSAAR 2020. A New Strategy for the Water and Wastewater Sector).* Vol. 1. Ministry of Environment, Spatial Planning and Energy, Lisbon, Portugal.

Marques, R. C. (2011). *A regulação dos serviços de abastecimento de água e de saneamento de águas residuais. Uma perspectiva internacional (Regulation of Water and Wastewater Services. An International Perspective)*, Vol. 1., Series 'Studies'. ERSAR, Lisbon, Portugal.

McGraw-Hill Construction (2013). *Water Infrastructure Asset Management: Adopting Best Practices to Enable Better Investments*. SmartMarket Report, Bedford, MA, USA.

NAMS (1996). *New Zealand Infrastructure Asset Management Manual.* National Asset Management Steering Group, Association of Local Government Engineering NZ Inc. (INGENIUM), Thames, New Zealand.

O'Connor, D. R. (2002). *Report of the Walkerton Inquiry: The Events of May 2000 and Related Issues. Part One: A Summary*. Ontario Ministry of the Attorney General, Queen's Printer for Ontario.

OECD (2015). *Stakeholder Engagement for Inclusive Water Governance.* OECD studies on water, OECD Publishing, Paris.

Ofwat & DEFRA (2006). *The Development of the Water Industry in England and Wales.* Office of Water Services, Birmingham and Department for Environment Food and Rural Affairs, London.

Pinto, F. & Marques, R. (2015). Tariff recommendations: a Panacea for the Portuguese water sector? *Utilities Policy 34*, 36–44.

Sægrov, S. (2005). *Computer Aided Rehabilitation for Water Networks: CARE-W.* IWA Publishing, London.

Sægrov, S. (2006). *CARE-S: Computer Aided Rehabilitation for Sewer and Stormwater Networks.* IWA Publishing, London.

Salvetti, M. (2013). The network efficiency rate: a key performance indicator for water services asset management. In: *Proceedings of the 7th IWA International Conference on Efficient Use and Management of Water*, *Paris, France*.

Sawai, T. (2013). Good practices and tools in asset management implemented by Japanese Water Supply Utilities. In: *Proceedings of the LESAM 2013*, *Sydney, Australia*.

Schulting, F. L. & Alegre, H. (2007). Global developments of Strategic Asset Management. In: *Proceedings of the LESAM 2007*, *Lisbon, Portugal*.

USEPA (2008). *Asset Management : A Best Practices Guide.* US Environmental Protection Agency, Washington, DC.

van Heck, G. J. (2008). Asset Management Frameworks for (drinking water) infrastructures around the world. A (not exhaustive) overview of different initiatives and developments. In: *Proceedings of the NGI Conference*, *Rotterdam*.

Vanier, D. J. (2000). Asset management 101 : a primer. In: *Seminar of the APWA International Public Works Congress*, *Louisville, KY, USA*.

Vanier, D. J. & Newton, L. A. (2005). *MIIP Report: Open Forum on Opportunities for Research in Asset Management in Canada*. National Research Council Canada.

Vloerbergh, I. & Blokker, M. (2010). Sharing failure data to gain insight into network deterioration. *Water Asset Management International 6*(2), 9–14.

Waugh, R. (2005). New Zealand Asset Management – review and lessons learnt. In: *Proceedings of the IPWEA Conference*, *Adelaide, Australia*.

Received 7 March 2016; accepted in revised form 16 July 2016. Available online 6 October 2016