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Dar es Salaam water supply expansion plan gets major boost

Plans to increase water supply in Tanzania's capital, Dar es Salaam, by an additional 150,000 cubic metres have moved a step forward after India announced a $178 million loan for the initiative. This brings the total funding for the project so far to $254 million as of October (2012).

India, through its Export/Import Bank, announced the financing facility a month after China, that through state-controlled company, Sinohydro Corporation, signed a $76 million for a water supply project in the city.

The Dar es Salaam water expansion plan is being undertaken in different phases and financed through various sources with the city's current average water supply standing at 300,000 cubic metres against a demand of 450,000 cubic metres.

India and China joins the independent US Government foreign aid agency, Millennium Challenge Corporation, in seeking permanent solution to persistent water shortages in Dar es Salaam that have been blamed on increasing non-revenue water, estimated at 54 percent, and increasing urban population that is currently estimated at 2.5 million people.

India in a statement through its embassy in Dar es Salaam, said the planned water supply initiatives in the city 'will substantially improve water supply in Dar es Salaam and Chalinize in the coast region'.

'The agreement further reinforces the commitment of the government of India to work with the government of Tanzania in improving the lives of the people and contribute to the development of Tanzania,' the statement added.

Previously, Dar es Salaam Water and Sewerage Authority, the sole provider of water supply and sewerage Services in Dar es Salaam city and parts of the coast region, had signed a $76 million deal with China's Sinohydro Corporation for the expansion of the Lower Ruvu water treatment plant and laying of a 57km water pipeline linking the plant to water storage tanks at Mlimani, 12km west of the city.

The 1.8m wide new pipelines will be used concurrently with old ones to convey an additional 90,000 cubic metres of water from the 180,000 cubic metres. The expanded water treatment plant will have a capacity of 270,000 cubic metres over the next 15 months.

'The intention is to expand all water sources to ultimately supply the city with 710,000 cubic metres bearing in mind that water uses increase day-by-day with the ongoing construction of industries and residential houses,' said DAWASA's acting Director General Boniface Kasiga. ● **Shem Oirere**

Royal HaskoningDHV to design drinking water system

The Dutch government's NL Agency has commissioned project management, consultancy and engineering firm Royal HaskoningDHV to design a drinking water preparation plant and distribution system for two districts in the Mekong Delta in Vietnam. The area lacks a central drinking water system and this causes health problems among the local population.

The system will supply clean drinking water to 168,000 people and 500 businesses in the districts of Chau Thanh and Chau Thanh A. They are located in the Vietnamese province of Hau Giang, a rural region of the Mekong Delta. It is an important region for the production and export of fruit, fish, rice and pork.

Royal HaskoningDHV will design the drinking water system for surface water obtained from the Mekong River and the required distribution network including the connections to homes and businesses. Distributing the water poses the biggest challenge, because users are scattered across the region.

The design phase must be completed in approximately eighteen months. Construction and installation of the drinking water system are scheduled to start mid-2014 and the work will take two years to complete.

The project is being co-financed by the Facility for Infrastructure Development (ORIO), which is funded by the Dutch Ministry of Foreign Affairs to encourage public infrastructure enhancement in developing countries.

This is Royal HaskoningDHV's sixth ORIO project in Vietnam. The firm is also working on the development of three drinking water preparation and distribution systems in the provinces of Ben Tre, Ba Ria Vung Tau and Hai Duong for a total of 235,000 inhabitants. Royal HaskoningDHV is further designing two wastewater treatment plants in the provinces of Ba Ria Vung Tau and Ninh Thuan. ●

water asset management INTERNATIONAL

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Bentley wins major Aguas de Portugal contract

Bentley Systems has announced that Águas de Portugal (AdP) Group has chosen Bentley's water software technology to streamline the operation and management of its water and wastewater systems while also making them more efficient and reliable.

AdP Group's water and wastewater collection and treatment systems and water supply networks serve 80% of Portugal's population. Through partnerships with the country's municipalities, AdP Group is responsible for managing multi-municipal systems, with its top priority being to increase water infrastructure's performance to service levels that comply with European best practices.

Among the many benefits AdP Group expects to achieve from its use of Bentley software is enhanced energy efficiency, including a 2% reduction in energy use at one AdP company that would provide annual cost savings of about €160,000 ($208,700). ●

Green Cross completes water and sanitation projects

To mark Global Handwashing Day, Green Cross has announced the completion of new rainwater harvesting and sanitation systems in remote Bolivian communities.

The official theme of this 5th Global Handwashing Day is 'Help More Children Reach Their 5th Birthday'. Green Cross's projects, which prioritize children and their school environment, are in line with this goal.

Green Cross has just equipped 16 schools with rainwater harvesting systems, ecological latrines and showers through its on-the-ground Smart Water for Green Schools project. Safe, secure water supplies are now being provided to more than 1200 people living in nine scattered hamlets of the Municipality of Vallegrande, and 1300 inhabitants of Gutierrez.

'These schools are second homes for children from 17 communities of two very deprived Bolivian areas,' said Marie-Laure Vercambre, Director of Green Cross's Water for Life and Peace Programme. 'People there live in water poverty, and suffer from water scarcity and contaminated supplies, because of their socio-economic background, climate and remoteness.'

Faride Tirado, Vice President of the Green Cross Bolivian chapter, said: 'Waterborne diseases, such as cholera, diarrhoea, typhoid, tuberculosis, hepatitis, polio and amoebiasis, pose real dangers to children living in these communities. Now thanks to the Smart Water for Green Schools project, parents can feel confident their children will have a much greater chance of not falling ill to such conditions.'

There are other benefits. Additional water plus compost made with collected waste are helping communities grow fruits and vegetables in the school gardens. Six more projects providing water supplies are being completed in Bolivia's Chaco de Santa Cruz semi-arid area. ●

EBRD supports water infrastructure modernisation

The European Bank for Reconstruction and Development (EBRD) is continuing to support the modernisation of water infrastructure in Romania with an up to €13.9 million ($18 million) loan for a project, co-financed by the EU regional investment programme.

The funds will help improve water and wastewater services for residents of Valcea county in the centre of Romania, in line with EU directives.

The EBRD loan is being made to SC APAVIL SA Ramnicu Valcea, a regional water utility in Valcea county. The county, which has about 413,000 inhabitants, is planning to extend and modernise water and wastewater services.

The work will drive down water losses and costs in the agglomerations of Ramnicu Valcea, Dragasani, Calimanesti, Olanesti, Babeni, and Balcesti.

The loan will co-finance a regional investment programme approved by the EU under Romania's Cohesion Fund Programme. The EBRD financing will consist of an EBRD loan of €8.6 million ($11.1 million) coupled with an envisaged loan of up to €5.3 million ($6.9 million) for green energy investments. This project is part of the EBRD's regional EU Cohesion Fund co-financing framework.

The investment will help the county improve the quality of its water supply, wastewater collection and treatment services in line with EU directives, and will allow the company to considerably reduce water losses and operating costs. ●

IADB approves loan for sanitation work

The Inter-American Development Bank (IADB) has approved a $9 million loan to Uruguay to support completion of sanitation and drainage works in the town of Ciudad de la Costa, Montevideo's main urban satellite.

The investments are part of an integrated sanitation programme for the town, which is being carried out by the National Water Supply and Sanitation Administration (OSE).

Projects funded by the programme include the construction of a new wastewater treatment plant and pump station, and expansion of the sewage and storm drainage network in sections of Ciudad de la Costa.

Under the programme, OSE will connect 2483 homes to the sewerage system, thus reducing the use of trucks for transporting sewage to the existing treatment plant.

Investments in stormwater infrastructure will reduce the risk of flooding in ten vulnerable areas, which will directly benefit about 11,000 people, IADB said in a statement. ●

Asset management and sustainability: planning for the unknown future

Sustainability has become an important topic in urban water management and asset management, and decision makers have to balance environmental and social impacts, risks and investment costs. Manfred Kleidorfer, Christian Urich, Günther Leonhardt, Robert Sitzenfrei and Wolfgang Rauch discuss the increasing demand for a holistic and integrated consideration, suggesting further linking-up of existing and forthcoming research projects in order to benefit from different approaches, solutions, and results.

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Urban areas and their development strongly depend on the two key tasks of urban water management: supply of high quality potable water and disposal of wastewater and stormwater. These services are central for human wellbeing as well as for economic development. Thereby, urban water management depends on a reliable infrastructure of water supply networks, separate or combined sewer systems, wastewater treatment plants and stormwater treatment facilities. In modern cities these assets have been constructed and maintained by past generations over decades. Of course adaptation to new conditions and changing needs is always occurring and in the same way the assets evolve with evolving technology. However, large parts of current water systems which are still used were built in former times. That this is possible shows that regarding future developments and adaptation of existing structures is not new in the asset management of the water industry. Engineers always built for future generations and hence had (and of course still have) to try to predict future conditions. Nowadays such a planning is often called 'sustainable'.

'Sustainability' has become 'one of the most widely used buzzwords of the past two decades' (Scoones, 2007) and 'incorporates a plethora of meanings' (Marshall and Toffel, 2004) resulting in a 'nebulous term that is currently used to mean a range of things' (Marlow, 2008). One of the most quoted definitions for sustainability is given in the report from the Brundtland Commission (WCED 1987): 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

In this report, sustainability is mainly linked to environmental aspects focusing on anthropogenic impacts. In the meantime, sustainability also incorporates social and economic thinking. But it is more than questionable how this definition of sustainability today fits into the common use of labelling anything that is desirable as sustainable (e.g. products that are more socially or environmentally friendly than others) (Marshall and Toffel, 2004). However, although a standard definition is elusive, Ashley and Hopkinson (2002) clearly say that 'in principle it means looking into the future well beyond normal business cycles and considering the needs of future generations and the relationship with current patterns of economic, social and environmental impacts'.

Although sustainable planning is not new in urban water management this topic becomes more and more important. External drivers as adaptation requirements in a changing environment, rehabilitation of aging infrastructure, changing environmental and socio-economic needs of urban water systems as well as increasing financial pressures require a careful prospective planning of system extensions and an optimization of existing systems. This includes consideration of impacts of climate change and city development (e.g. land use change, demographic change), social behaviour (e.g. decrease or increase of water demand), energy efficiency, institutional changes in the water authorities, and more.

Asset management and costs

The costs of urban water systems are key to future sustainable development. Limiting costs and appropriate pricing are not only requirements due to limited public funding (boosted by the financial crisis) but also essential for social equity (see for example Rogers et al., 2002). Cashman and Ashley (2008) evaluate the current and future (year 2015 and 2025) required annual expenditure on water infrastructure as a percentage of the gross domestic product (GDP). Some examples of results are shown in Table 1 and it is interesting to see that the investment requirements are considerably higher than for the energy, telecommunication and transport infrastructure sectors.

A sustainable financing of the water infrastructure means that this amount of money is invested each year to maintain current service levels. Limited national budgets and austerity packages in the financial crisis endorse the threat

Table 1: Estimated annual investment requirements for the water sector (from Cashman and Ashley, 2008)

Country	Projected expenditure as % of GPD by 2015	Projected expenditure as % of GPD by 2025	Average annual investment (billion $) by 2015	Average annual investment (billion $) by 2025
USA	0.75	0.64	101.65	167.63
China	1.50	1.90	182.10	247.18
India	0.74	2.50	74.80	108.31
Germany	0.75	0.83	23.38	35.84
France	0.75	0.83	16.86	25.84
Italy	0.75	0.92	16.83	25.23
Austria	0.75	0.89	2.59	3.91
The Netherlands	0.75	1.08	5.43	7.88
Czech Rep.	1.90	0.85	3.12	2.83

that budgets for water services are cut. This would contradict sustainable development as this would mean a shift of today's rehabilitation needs to future generations.

One approach to optimize costs is presented by Thomasius and Sympher (2011). They optimize the rehabilitation strategy of the sewer system of Berlin (Germany). Therefore, they determine life cycle costs of assets, including costs of repair, renovation and replacement based on sewer condition inspection and extrapolation for non-inspected sewers. Different risk scenarios are also taken into account to minimize operational costs and extend service life.

Another approach to reduce operating costs is presented by Sichla and Podewils (2011). They focus on the energy use of wastewater treatment plants in Germany, Poland and Croatia. For 24 analysed plants they found on average the potential for a reduction in energy use of about 30% (maximum about 40%) in relation to a model-based ideal value. This corresponds with findings of Wett et al. (2007) who estimate an average energy saving potential of about 30-50% in central Europe (based on data from Switzerland, Germany and Austria). Furthermore, they present the case study of a wastewater treatment plant in Strass (Austria) which has a positive energy balance (i.e. produces more energy than it uses).

Asset management and climate change

With the challenges posed by climate change, a point will be reached where adaptation of urban water infrastructure and management is critical for the sustainable future development of urban areas. Adaptation is a vital part of the response to the challenges of climate change to which the world is already committed. Furthermore, it offers an opportunity to adjust economic activity in vulnerable sectors and support sustainable development (Stern et al., 2006). One objective of adaptation is to reduce vulnerability of the water infrastructure to climate change and variability, thereby reducing their negative impacts. Hence adaptation, together with mitigation, is an important response strategy.

Numerous studies have been published which show the impact of climate change on urban water systems (e.g. Butler et al., 2007; Kleidorfer et al., 2009), often shown together with potential response strategies (e.g. Ashley et al., 2005; Semadeni-Davies et al., 2008; Arnbjerg-Nielsen and Fleischer, 2009). Thereby, not only adaptation of infrastructure systems is required but also design criteria have to be revised to incorporate, for example, an increase in rainfall intensity, which is not covered by statistical evaluations of historical events. For example, Arnbjerg-Nielsen (2008) evaluated climate change factors for the design of urban drainage systems in Denmark and estimated an increase in design intensities by 10-50% depending on duration, return period and anticipated technical lifetime of sewer systems. Another study was published by Mailhot and Duchesne (2010). They integrated climate projections for extreme rainfall, acceptable level of risk and expected lifetime of the infrastructure to define new design criteria of urban drainage systems.

Another aspect of the conjunction of urban water systems and climate change is the impact urban water infrastructure has on climate change. Such an impact is caused by greenhouse gas emissions from energy used by the system / the infrastructure (Wu et al., 2010). Rothausen and Conway (2011) review the greenhouse gas emission from energy use in the water sector. For example, in the United States about 5% of greenhouse gas emissions are water-related. However, it is important to mention that this includes end-use (heating) as well as irrigation. Heating is regarded as the most energy-intensive process (Griffiths-Sattenspiel and Wilson, 2009).

Genzowsky et al. (2011) developed a carbon footprint model for the water sector which not only incorporates greenhouse gas emissions from energy use but also direct emissions, for example in the wastewater treatment process or after sludge disposal or indirect emissions due to maintenance measures. The model incorporates different infrastructure facilities of the urban water system, such as wastewater treatment plants, water supply systems, pumping stations and sewer systems, as well as emissions from river basin management and dams.

Integrated approaches

Climate change is only one point to be regarded when adapting urban water infrastructure for a sustainable future. Cities and their infrastructure are dynamically evolving complex systems. Additionally, society continuously changes and impacts on the behaviour of inhabitants. For example, urbanization can lead to an increase in total population, population density and impermeable covering of urban areas. Changes in societal behaviour as the increase of single-person households and decrease or spatial displacement of family households lead to an additional demand of domiciles, and hence to a further change in urban land use, water demand and wastewater quantity and quality.

Urban water infrastructure is already adapting to a changing environment, driven by the retrofitting of existing infrastructure systems and changing guidelines, guiding rules and legal frameworks. Hence, the impact of climate change on an urban environment has to be analysed in conjunction with both city development based on societal change and in a dynamic context of a continuously evolving system. These points might on the one hand have additional negative impacts on urban water infrastructure, but they are on the other hand a chance for sustainable adaptation.

In recent years different research projects have been conducted and research centres founded to tackle the challenges of integrated approaches in urban water infrastructure. This shows the importance of adaptation needs in an international context. For example, in Australia the 'Centre for Water Sensitive Cities' was founded, aiming to make Australian cities resilient to current and future challenges. This is done by supporting the transition to a water sensitive city in which urban water management is incorporated into urban planning (Brown et al., 2009). In the United States recently the 'Engineering Research Center for Re-inventing America's Urban Water Infrastructure' was founded by researchers and industry partners. It is funded by the National Science Foundation to face the challenges of urban growth, climate change and economic stress. Also in Europe, several research projects have been funded to investigate potential adaptation pathways in an integrated approach by combining urban development, climate change and societal change.

The SWITCH project

The SWITCH project (Howe and Steen, 2008) was funded by the European Union in the Sixth Framework Programme. A consortium of 33 partners focused on sustainable integrated urban water management for the cities of the future. Therein, the entire water cycle (potable water, stormwater, wastewater, rivers and aquifers) was investigated. Impacts of global change pressures as climate change, urbanization and aging infrastructure were also considered.

The dynaklim project

The dynaklim project (Dynamic Adaptation of Regional Planning and Development Processes to the Effects of Climate Change) is a regional climate adaptation project funded by the German Federal Ministry of Education and Research. The main objectives of the research are to investigate the impact of climate change on the regional water balance and to improve the ability of the project region to adapt for changes in population, economy and environment. Panglisch et al. (in press) describe the potential impact of climate change on the potable water supply in the Ruhr region (quantity and quality). Here the drinking water supply of about five million people could be affected by climate chance induced low water levels in rivers during dry weather periods or flooding after extreme rainfall events. Consequently, the resilience of the current water treatment process to climate change induced risks is analysed. Hueben et al. (2011) present the potential impacts of global change on stormwater and wastewater infrastructure. Potential impacts can be increased rainfall intensities due to climate change, decreasing dry weather flow due to demographic changes (decrease of population) or changes in the water demand of the local industry. Risk and vulnerability maps underpin this analysis of adaptation strategies.

The PREPARED project / DAnCE 4 Water

The project 'PREPARED – enabling change' is funded by the European Union under the Seventh Framework Programme. A consortium of 35 partners (both from industry and the tertiary sector) is addressing required strategies for adaptation of water systems to a changing environment. As part of work area 6 an integrated scenario-based urban water tool (DAnCE 4 Water – Dynamic Adaptation for eNabling City Evolution for Water) was produced for assessing the dynamics of the urban water infrastructure (Kleidorfer et al., 2011). DAnCE 4 Water is a strategic planning tool for urban planners, government, watershed managers, and local councils that integrates urban development, infrastructure development and social transition (Urich et al., 2011, Bach et al., 2011). As it is based on a generic tool for a dynamic infrastructure assessment (Sitzenfrei et al., 2010) the dynamics of water system evolution can be taken into account. The model project pays special attention to decentralized solutions (Wong and Brown, 2009) and to the social system (de Haan et al., 2011; Ferguson et al., 2011). A common criticism of the definition of sustainability by WCED (1987) (see above) is the requirement of the prediction of needs of future generations, but these needs are unknown. Although the implementation of a social-transition model does not solve the problem that future needs cannot be predicted, this aims to improve the sustainability concept by considering the social system.

Figure 1 shows a first example of the integration of the population module (based on UrbanSim – Waddell et al., 2008) and the infrastructure module. Here, a city and its combined sewer system are developed into the future from 2010 to 2030. In time-steps of one year population projections and corresponding infrastructure development are evaluated. Sewer system performance (surcharge) is calculated by means of hydrodynamic simulation. As an adaptation strategy on-site infiltration systems of roof runoff for new or redeveloped buildings are tested. Due to the consideration of the dynamic effects the impact of different renewal rates can be evaluated and tipping points (Lenton 2011) in the system behaviour can be identified. Further information on this first test-case is available from Urich et al. (2011).

The TRUST project

'TRUST - Transition for the Urban Water Services of Tomorrow' is another project funded by the European Union in the Seventh Framework Programme. It is investigating transition pathways for the urban water cycle and is aiming to improve management of urban water services.

Measuring sustainability

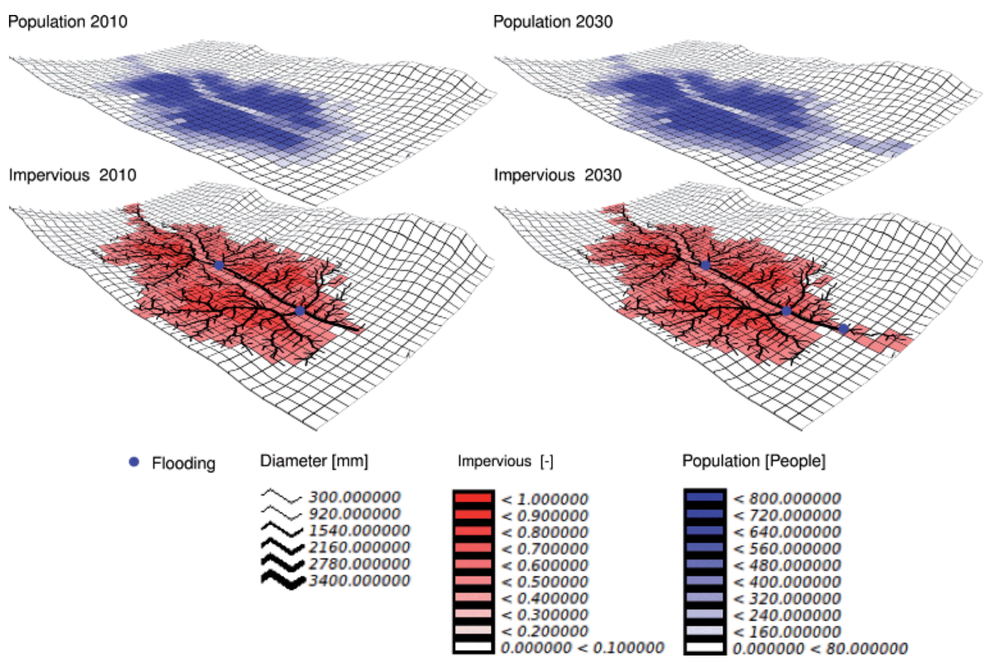
As mentioned in the introduction the term sustainability is used in many different meanings. Hence, defining performance indicators for urban water systems which reflect potentials for future development is of high interest. Ashley and Hopkinson (2002) review different frameworks for assessing performance of water service providers and see a tension between different areas of performance (economic, customer needs, and ecological). They conclude that it is most concerning that current institutional systems and regulatory targets encourage adoption of less sustainable solutions and that they 'tend to support the principle of existing customers "living off" past investments, and "using up" infrastructure capital which will not be available to forthcoming generations'. Hence, new performance indicators reflecting sustainable development are required. Lundin and Morrison (2002) also see the problem of lacking performance indicators for sustainability and combine environmental sustainability indicators (Harger and Meyer, 1996) with life cycle assessments to measure sustainability.

Milina et al. (2011) present the implementation of sustainable objectives in the management strategies of the water service provider of Oslo (as suggested by Ashley and Hopkinson, 2002). Thereby, sustainability is considered as 'financial and technical ability to renew the water and wastewater systems in a timely manner' incorporating environmental aspects, system age, renewal rate, and financial renewal with current revenue.

An uncertain future?

Regardless of the exact definition of sustainability it is clear that sustainable planning requires a prospective thinking and an assessment of future situations with regard to the needs of forthcoming generations. Furthermore, it is clear that any

Figure 1 **Population development, sewer system development and sewer system performance 2010 and 2030**



projection into the future contains uncertainties of different types. According to Walker et al. (2003) and Refsgaard et al. (2007) there are statistical uncertainties, scenario uncertainties, qualitative uncertainties, recognised ignorance and total ignorance. Plannning engineers are usually used to dealing with statistical uncertainties and scenario uncertainties which are common in urban water management (e.g Prudhomme et al., 2003; Deletic et al., 2012; Dotto et al., 2011). Assuming the impact of climate change would be perfectly known without uncertainties, climate change adaptation would be only one additional point to be regarded in the design of water infrastructure systems. This means reorganisation strategies and infrastructure development plans could be adapted not only to meet requirements for a changing society but also for climate change adaptation. Unfortunately future conditions are not clear, neither for climate change nor for demographic or societal change. Hence, more complex forms of uncertainties have to be considered or at least kept in mind. For example 'total ignorance' can never be considered in any adaptation process as this reflects the state of complete lack of awareness about imperfect knowledge. Such an uncertainty could be, for example, the ignorance about the technological progress or the economic development. Hence, sustainable solutions have to be able to be adapted to currently unknown situations. This means 'adaptation' needs to be continuously adapted and implemented technical solutions should not prevent transition to alternative systems.

Summary and conclusion

Sustainability has become an important topic in urban water management and asset management. Thereby, decision makers have to balance environmental and social impacts, risks and investment costs. Very high investments might not be sustainable in times of shortening of public financial resources and too little investments could result in unacceptable risks for local communities and prevent a sustainable development as this is the equivalent of shifting current investment requirements to forthcoming generations.

A large number of research projects show the importance of this topic in the water sector. It is interesting how the topic of sustainability is approached from different sides with all coming to a similar conclusion, which is the increasing demand for integrated approaches. Therefore, the entire urban water cycle should be investigated, taking into account social and economic aspects. Further linking-up of existing and forthcoming research projects would be desirable to benefit from different approaches, solutions, and results. ●

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Using valve manipulation to manage discolouration risk in drinking water distribution networks

There are several methods to reduce the risk of discolouration in drinking water distribution networks due to the accumulation and mobilisation of particles, such as flushing the network, controlling sediment entering the network and preventing sediment accumulation through regular resuspension.

To test this third option, valve manipulation was carried out in the networks of four Dutch water companies and compared with reference areas. Mirjam Blokker, Henk Vogelaar, Karel Goos and Jan Vreeburg discuss the results of this research.

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The goal of drinking water companies is to supply their customers with good quality drinking water 24 hours a day. With respect to water quality, the focus has for many years been on drinking water treatment. Recently, interest in water quality in the drinking water distribution system (DWDS) has been growing. On the one hand, this is driven by customers who expect water companies to ensure the best water quality by preventing such obvious deficiencies in water quality as discolouration and (in many countries) by assuring a sufficient level of chlorine residual. On the other hand, since '9/11' there is a growing concern about (deliberate) contaminations in the DWDS. Consequently, there is an interest in the behaviour of both dissolved and particulate substances in the DWDS (Blokker et al. 2008; Powell et al. 2004).

Discolouration is the main reason for customers to complain about their water quality (Vreeburg and Boxall, 2007). Vreeburg and Boxall (2007) concluded that the mechanisms leading to discolouration events are complex and poorly understood. Their basic concept of the cause of discolouration is that particles are attached by some means to the pipe wall. In normal flow conditions the particles stay in their place and do not affect the aesthetic quality of the water. If flows are increased above normal, scouring forces and shear stress increase and the particles may be mobilised, sometimes leading to customer complaints. Vreeburg (2010) has suggested that one of the measures to reduce the discolouration risk is the prevention of the accumulation of particles in a DWDS by building self-cleaning networks. Regularly occurring high velocities and a unidirectional flow will ensure that particles are mobilised regularly and are then removed from the distribution network in small quantities through the consumers' taps. Thus, the particle accumulation will be kept within limits. In practice, the self-cleaning DWDS concept leads to a branched distribution system with sufficiently small pipe diameters. The diameters are selected based on a design velocity of 0.4m/s and the expected demand, which is determined with the so-called q√n method (Vreeburg et al. 2009). This method calculates the maximum demand through a square root relationship with the number of homes on a branch. These design principles

Table 1: Lengths of research and reference areas of (a) WML, (b) Water company Groningen, (c) Pidpa, (d) Brabant Water

a)

Pipe diameter	Material	Research area		Reference area	
		km	%	km	%
Ø 100 mm	DI			0.17	(5%)
Ø 100 mm	AC	2.45	(78%)	2.48	(77%)
Ø 150 mm	AC	0.71	(22%)	0.58	(18%)
Total		3.16		3.22	

b)

Pipe diameter	Material	Research area		Reference area	
		km	%	km	%
<Ø 100 mm	CI	0.4	(19.9%)	0.5	(24.1%)
Ø 100 mm	CI	0.7	(35.3%)	1.1	(50.8%)
Ø 150 mm	CI	0.6	(28.8%)	0.4	(19.1%)
Ø 200 mm	CI	0.3	(16.1%)	0.1	(5.9%)
Total		2.0		2.2	

c)

Pipe diameter	Material	Research area		Reference area	
		km	%	km	%
Ø 50 mm	CI	0.0	(0%)	0.1	(3.4%)
Ø 80 mm	CI	6.0	(100%)	4.2	(94.0%)
Ø 250 mm	CI			0.1	(2.7%)
Total		6.0		4.4	

d)

Pipe diameter	Material	Research area		Reference area	
		km	%	km	%
≤Ø 60 mm	PVC	2.4	(19.7%)	1.3	(8.8%)
Ø 100 mm	PVC	7.2	(59.0%)	7.4	(50.3%)
Ø 150 mm	PVC	1.6	(13.1%)	2.7	(18.4%)
≥Ø 180 mm	PVC	1.0	(8.2%)	3.3	(22.4%)
Total		12.2		14.7	

ensure unidirectional flows with high maximum flow velocities.

Laboratory tests (Ackers et al., 2001; Husband et al., 2008; Ryan et al., 2008; Slaats et al., 2003) and field tests (Blokker et al., 2009; Blokker et al., 2010b) have shown that typical DWDS sediment can be resuspended at a velocity of 0.2 to 0.25m/s. If this velocity occurs once every other day, this flow may be able to mobilise the sediment instantaneously and keep the pipe clean. Self-cleaning networks can be achieved in practice.

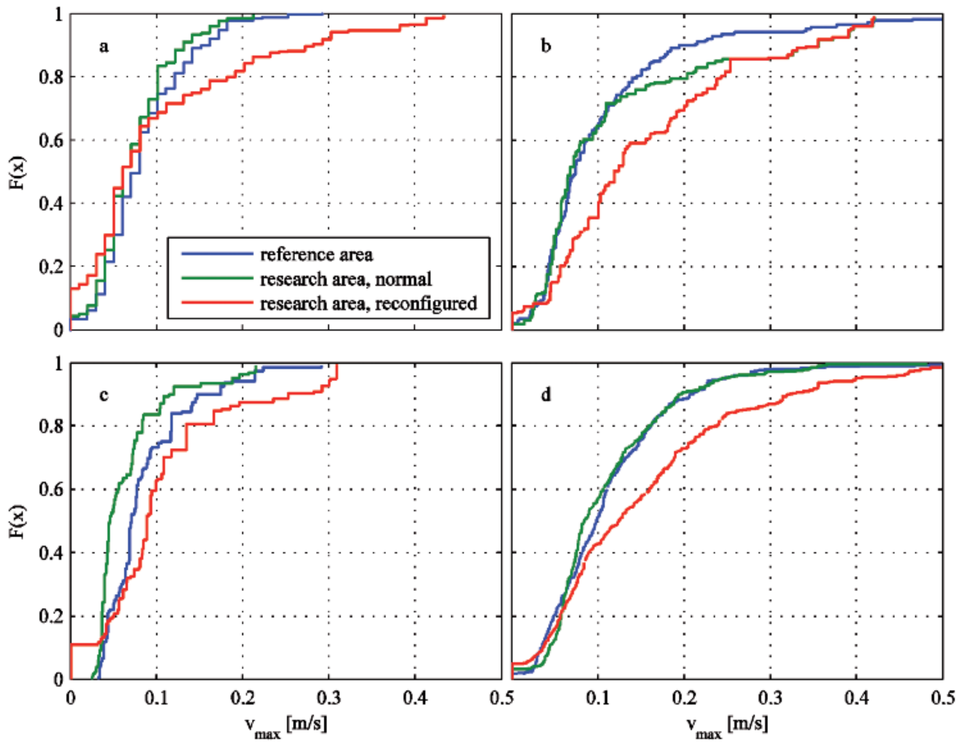


Figure 1
Cumulative frequency distribution of maximum velocity per pipe segment for (a) WML, (b) Water company Groningen, (c) Pidpa, (d) Brabant Water. The used time step was 1 min for (a) and 10 sec for (b), (c) and (d).

In existing networks, discolouration is typically prevented by timely flushing. An alternative option would be to enforce a unidirectional flow by closing carefully selected valves (valve manipulation). This would result in fewer flow direction reversals, with higher flow velocities in some pipes, whilst other pipes see lower flow velocities. This paper investigates the effect of valve manipulation on the fouling rate of real networks. The effect of unidirectional flow and the effect of a change in flow velocities are studied. Some of the practical issues are also discussed.

Valve manipulation

Hypothesis

Valve manipulation leads to the reconfiguration of a network. The network will experience unidirectional flows as much as possible. This will lead to shorter residence times because no flow directional reversals will occur. It will also lead to higher velocities in some pipes and may lead to lower velocities or even stagnant water in some other pipes. Regularly occurring high velocities and a unidirectional flow will ensure that particles are mobilised regularly and are then removed from the distribution network in small quantities through the consumers' taps. Thus, particle accumulation will be kept within limits. The hypothesis is that even though not all pipes will experience a regular velocity above the self-cleaning velocity, the whole network will have a lower fouling rate in a unidirectional flow condition and high velocities in part of the network.

Selection of test areas

Four water companies from the Netherlands and Flanders participated in the test. Each water company selected a research area (where some valves would be closed during the test period) and a reference area. The selection of the test areas was done by the water companies with the following selection criteria:

A. The two areas are comparable:

- The two areas experience the same incoming water quality. This can be reached by choosing adjacent areas that receive water from the same pumping station through the same transport mains.
- The two areas have a similar fouling rate in the normal configuration. The fouling rate is believed to be determined by flow velocities and residence times in the network. Thus, there will be a relation between the number of served households and pipe lengths and diameters. The two areas will be

Table 2: Characteristics of test areas (a) WML, (b) Water company Groningen, (c) Pidpa, (d) Brabant Water.

	a) Research area	a) Reference area	b) Research area	b) Reference area	c) Research area	c) Reference area	d) Research area	d) Reference area
Total length (km)	3.2	3.2	2.0	2.2	6.0	4.4	12.2	14.7
# Households	500	500			109	130	1480	1430
Hydraulic model time step (s)	60		10		10		10	
# Valves closed	8	x	3	x	9	x	17	x
# RPM locations	4	4	4	4	4	4	9	6
RPM disturbance time (min)	5		5		8 - 12		15	
Measurement period (months)	6		7		7		14	

compared on maximum flow velocities in a hydraulic network model with realistic water demand patterns.

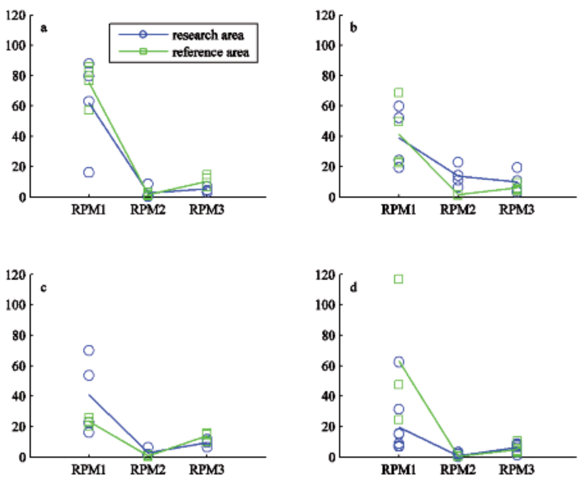
B. The fouling rate is measurable in a limited time period, i.e. six to 14 months. The test areas are selected based on discolouration complaints or previous Resuspension Potential Method measurements (Vreeburg et al., 2004).

C. With the selection of the valves that need to be closed in the test period, the water company will respect the network requirements on minimum pressure and hydrant capacity as much as possible.

D. The effect of the valve manipulation will be determined by comparing the maximum flow velocities in a hydraulic network model with realistic water demand patterns.

The two test areas of the four water companies were rated according to the criteria in Table 3; some background information on the test areas is found in Table 1, Table 2 and Figure 1. The research and reference areas of the four water companies are comparable between each other but not between the different water companies. The network characteristics are different (Table 1), and the measurements are also slightly different in measurement period and RPM set-up (Table 2).

Figure 2 **RPM results of (a) WML, (b) Water company Groningen, (c) Pidpa, (d) Brabant Water. The time between RPM1 and RPM2 is less than 2 months; the time between RPM2 and RPM3 is 6 to 14 months (Table 2).**



Estimation of effect of valve manipulation on flow velocities

In order to investigate the influence of the velocity on the fouling of pipes, a detailed hydraulic network model with realistic demand patterns was required. The stochastic demand model SIMDEUM (Blokker et al., 2010c) was applied. This model was used to allocate the stochastic water demand patterns to demand nodes in the hydraulic network model (Blokker et al., 2010a; Blokker et al., 2011b). For water company (a) an InfoWorks hydraulic model with a pattern time step of one minute was used, whilst for water companies (b), (c) and (d) an EPANET hydraulic model with a pattern time step of ten seconds was used. Figure 1 shows that the research and reference areas per water company are comparable with respect to the maximum flow velocities in the network. It also shows that the reconfigured research area had higher flow velocities and that the number of pipes that experience a maximum velocity above the self-cleaning velocity of 0.2 to 0.25m/s increased noticeably for most water companies.

Resuspension Potential Method

The build-up of material was analysed using the Resuspension Potential Measurement (RPM) (Vreeburg et al., 2004). This consists of a five to 15 minutes disturbance of an extra flow velocity of 0.35m/s followed by at least ten minutes measuring protocol. This means the turbidity is measured and logged every minute. The RPM gives the discolouration risk at a particular location in the network. The RPM is represented by the average turbidity during the first 15 minutes after the initial disturbance. In the result graphs (Figure 2), the RPM of each location within the test areas is shown along with a line through the averages of the RPM values per test area. Water companies (a), (b) and (c) each selected four RPM locations in each area; water company (d) had nine RPM locations in the research area and six in the reference area (Table 2).

Results of the valve manipulation

The RPM at RPM1 (Figure 2) show that there was a considerable variation across the networks; parts of the network may have fouled a lot where other parts may be much cleaner. They also show that the research and reference areas had not fouled to the same extent previous to RPM1. It is unknown if this is because there was a difference in fouling rate between the two areas or that events such as the use of hydrants have taken place pre-RPM1 that can explain the difference. The RPM2 in the research area of water company (b) is not very low; something probably went wrong with the cleaning of this area. This makes it impossible to draw conclusions on the effect of the valve manipulation on the fouling rate.

The differences between RPM2 and RPM3 are not very high for any of the water companies; especially for water company (d), where the fouling rate was so low that it was not possible to draw any conclusions on the effect of valve manipulation. The test period of this water company was the longest (14 months) but still not long enough. Water companies (a) and (c) showed an improved fouling rate for the research areas compared to the reference areas. It is not possible to quantify the improvement based on only these two test areas. One reason is that the fouling rate of the research and reference areas may not be equal (see comments on RPM1). A test where the research area is its own reference area by doing the same tests consecutively may be more suitable for that (Blokker et al. 2011a). Another issue is that the relation between RPM and discolouration complaints is unknown.

It was possible to reconfigure the selected test areas with the help of valves into networks with as much unidirectional flows as possible and with an increased maximum velocity (Table 3). In practice this did not lead to any pressure complaints or other issues. The water companies were concerned about the occurrence of some pipes with stagnant water – Dutch water companies do not distribute chlorinated water and the effect of

Table 3: Suitability of test areas (a) WML, (b) Water company Groningen, (c) Pidpa, (d) Brabant Water

		(a)	(b)	(c)	(d)
A1 – Equal incoming water quality?		Yes as areas are adjacent. Based on hydraulic models feed is from the same side.			
A2 – Comparable network characteristics?	Length (Table 1)	Yes	Yes	Reference area shorter	Reference area shorter
	Diameters (Table 1)	Yes	Research area larger diameters	Yes	Reference area larger diameters
	# Households (Table 2)	Yes		Yes	Yes
	Statistical distribution vmax (Figure 1 before reconfiguration)	Yes	Reference area lower velocities	Yes	Yes
B – Measurable fouling rate during measurement (Figure 2) ?	RPM1	High	High	High	High
	RPM2	Low	Research area too high, not cleaned well	Low	Low
	Δ RPM2-RPM3	Measurable, but low	Measurable, but low	Measurable, but low	Hardly measurable
C – Do requirements of water companies lead to changes in reconfiguration plan?		No	No	No	No
D – Potential of reducing fouling rate based on % vmax > 0.2 m/s (Figure 1 after reconfiguration)	Research area	2 →18%	20→30%	5 →12%	11→26%
	Reference area	2%	10%	5%	11%
Suitability of test areas		+	+/-	+	+/-

stagnancy on the water quality is unknown. Another practical issue is that it is difficult to keep track of valves that need to stay closed and ensure that these will remain closed even after works have been done. For these reasons the test period was kept to a minimum.

To overcome these practical issues we suggest using the valve manipulation (after cleaning an area) as a temporary solution in an area with many discolouration complaints. When the measure proves to be effective in reducing the number of complaints the reconfiguration may be made permanent. In the permanent situation some pipes will be removed ensuring no pipes with stagnant water and no permanently closed valves that need to be managed.

Conclusions

It is possible to reconfigure an existing network through valve manipulation in such a way that it will experience more unidirectional flows and higher flow velocities in parts of the network. Regularly occurring high velocities and a unidirectional flow will prevent particles from accumulating, resulting in self-cleaning pipes. The hypothesis that the entire network will have a lower fouling rate even if not all pipes experience a velocity above the self-cleaning threshold of 0.2 to 0.25m/s was confirmed in two out of four test areas; the other two test areas were inconclusive. This makes the hypothesis plausible, but not yet proven.

Because valve manipulation may decrease the sediment accumulation rate (after cleaning an area) this method can be used as a trial solution in an area with unacceptable discolouration problems. When the measure proves to be effective, i.e reducing the number of complaints, the reconfiguration may be made permanent. In the permanent situation the practical issues concerning stagnant water and proper valve registration can be addressed. ●

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Towards sustainable urban water systems and services: how to measure progress - the case of Oslo, Norway

Oslo city's water resources portfolio consists of 40 lakes, which are drained by eight watercourses that flow into the Oslo fjord. Setting the city's water sector on the path of sustainability will facilitate greater adhesion of urban water management to the city's planning and an integrated assessment of the city's sustainability. Oslo Water and Sewerage Works is both the responsible body and the provider of the water and wastewater services. Jadranka Milina, Øivind Ryenbakken, Erland Eggen, Rashid Elmi and Per Kristiansen discuss how moving along the path towards sustainability poses new challenges and demands for the utility.

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Within the framework of several institutional and legal arrangements, different strategies for sustainable urban development have been adopted. The city of Oslo, Norway, has developed its 'Strategy for Sustainable Development with Urban Ecology Program 2002-2014' and urban development master plan 'Oslo towards 2025' based on a range of thematic plans for the different fields and sectors: climate change, local transport, green areas, air quality, noise pollution, solid waste, water supply and wastewater treatment, and land use. The city has a parliamentary political system which stretches across a broad network of politicians, staff from the municipal departments, agencies and services as well as private sectors, state departments, research institutions and non-governmental organisations (NGOs).

The city's Water and Sewerage Works (VAV) has overall responsibility for urban water systems and associated services except for the operation of two wastewater treatment plants. The utility is one of the city's technical departments that have been reformed and continue to evolve as pressure for a more efficient and effective government and operational sustainability increases. Embedding of key drivers of sustainability into the utility has been boosted by the adoption of the ISO 24500 series for activities related to drinking water and wastewater services. The series of standards addressing water services include a service-oriented (ISO 24510:2007)

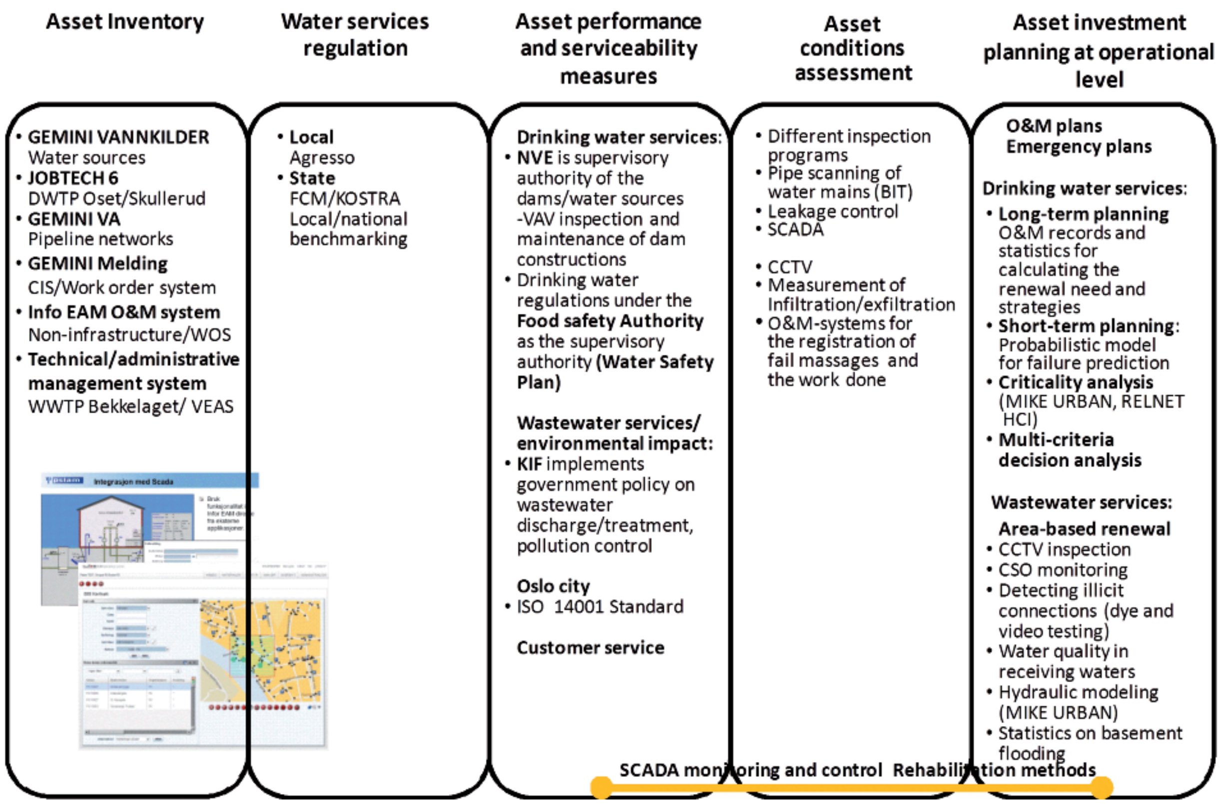


Figure 1 A schematic representation of VAV asset management building blocks, tools and plans.

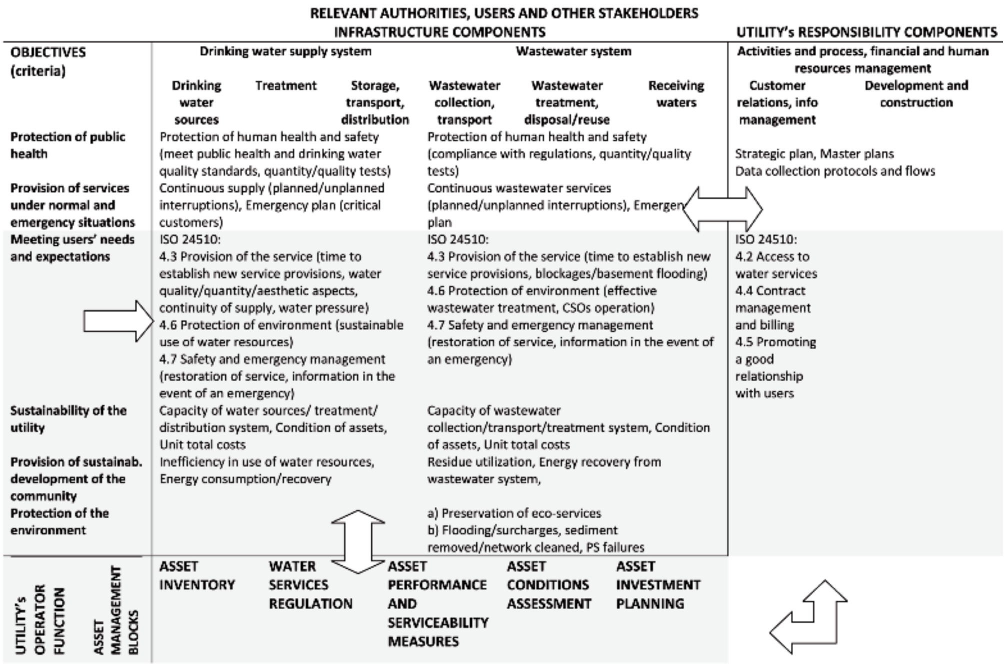


Figure 1
Objectives, including performance assessment criteria relating to the infrastructure components and the management components of the Oslo Water and Sewerage Works

and two management-oriented standards (ISO 24511:2007 and ISO 24512:2007). The objectives of the standards are to meet the users' needs and expectations under sustainable economic and social conditions. They can serve to capture the essence of the utility and its management components' sustainability, and to propagate practices of sustainability across the users and infrastructure owners, relevant authorities, operators, communities, financial institutions, scientific and technical organizations, and laboratories.

This paper describes how sustainable objectives are embedded into the physical components of the water and wastewater system, and management components of the utility's dual function as the responsible body and the operator for water and wastewater services. Linking of sustainability objectives with the practical level of the utility's asset management concept, and also with a wider set of sustainable development drivers, is presented.

Balanced scorecard for the main objectives of VAV

VAV is a municipally-owned, self-financing company within Oslo municipality. The utility provides drinking water supply and sanitary services for 600,000 people. Oslo city's water resources portfolio consists mainly of surface water. The city receives its water from surface sources in the 330km^2 of forest surrounding the city. The area includes 40 lakes drained by eight major watercourses into the Oslo fjord.

VAV is responsible for operation, maintenance and renewal of all units of the drinking water supply system as well as the city's wastewater collection and transport system. It oversees the Bekkelaget WWTP, which is run privately, and covers Oslo's share of the costs of VEAS WWTP, which is run by an inter-communal sewage company.

VAV acts under a system of technical self-regulation and has established main objectives and a service policy in accordance with legal requirements and the guidance given in NS-ISO 24510, NS-ISO 24511, NS-ISO 24512. The objectives related to the infrastructure components and the management components of the utility are shown in Table 1. Main components of the utilities asset management system are presented in the last row of the table, while other managerial components are lumped together and presented in the last column of the table. The key elements of the asset management system are illustrated in Figure 1.

The NS-ISO 24500 framework identifies two sustainable objectives: one addresses 'Sustainability of the utility' and the other addresses 'Provision of sustainable development of the community'. Many of the criteria relevant for utility sustainability assessment are linked to the utility's asset management framework, its techniques, decision making tools and plans (Milina et al., 2009; Sægrov and Hathi, 2009). The asset management framework provides both interconnections and feedback loops which play an important role in operation of sustainable management.

However, the requirements to address a wider set of integrated societal sustainability objectives associated with urban water services make demands for broader decision support concepts (Marlow et al., 2010; UKWIR 2010).

Sustainability of the utility

Asset management block: water services regulation and benchmarking

The Norwegian water and wastewater service sector is regulated by the full cost model (FCM). The method is based on a calculation of operating costs and capital costs (depreciation and interest). Any surplus or deficit is counterbalanced against a restricted cost recovery fund. According to the state guidelines for cost recovery, fee revenue should be adjusted so that within a three to five year period it is in balance.

As a municipal department VAV has to obey a complicated financial and audit system. The local enterprise resource planning system (ERP Agresso) is coupled to national information system KOSTRA for reporting from the municipal to the state level. KOSTRA provides financial, technical and service data on drinking water and wastewater services.

The Norwegian standard for drinking water and wastewater service levels is based on the principles described in the international standards ISO 24510, 24511, 24512 and utility data reported to KOSTRA information system. A rolling benchmarking framework developed by the Norwegian water association, Norsk Vann, provides comparison of water utilities and drives process improvement. The service assessment criteria related to sustainability of the utility include water losses, age of infrastructure,

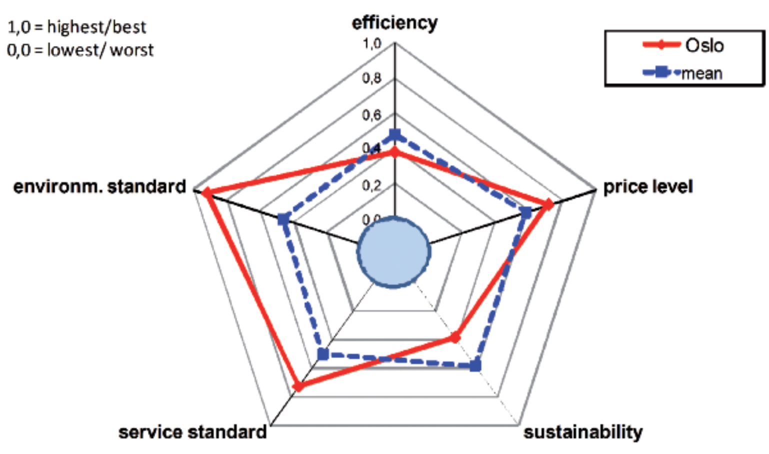


Figure 2
Effometer benchmarking: The balanced scorecard summarizes VAV's performance in key dimensions.

criteria related to water sources, compliance with standards / regulatory requirements, costs of the water services as well as serviceability to customers (unplanned interruption to water supply, blockages, basement flooding). Addressing the utility's contribution to sustainable development of the community by efficient consumption of energy and energy recovery from water and wastewater systems is not yet included in the reporting system.

In 2010, VAV carried out a more detailed review of its management processes using the Effometer benchmarking model (Eggen, 2010). The model, which is widely used in the Norwegian hydroelectricity sector, estimates a utility's performance using a set of indicators. Figure 2 shows VAV's performance in 2009 in the five dimensions. Results are measured against the other nine participants in the benchmarking. 'Price level' is the result indicator for unit price per customer (low price gives high score). The dimension 'sustainability' indicates VAV's financial and technical ability to renew the water and wastewater systems in a timely manner. Sustainability is the sum of financial and physical sustainability; physical sustainability is a result of system age and the current rate of renewal, and financial sustainability is the ability to finance renewal with current revenue. Financial sustainability is calculated as the ratio between depreciation and calculated financial expenses and replacement value; i.e. the ability to make reinvestments in the system. Physical sustainability is the number of years it will take the utility to attain average asset age of the group of comparators given the current age and renewal rate.

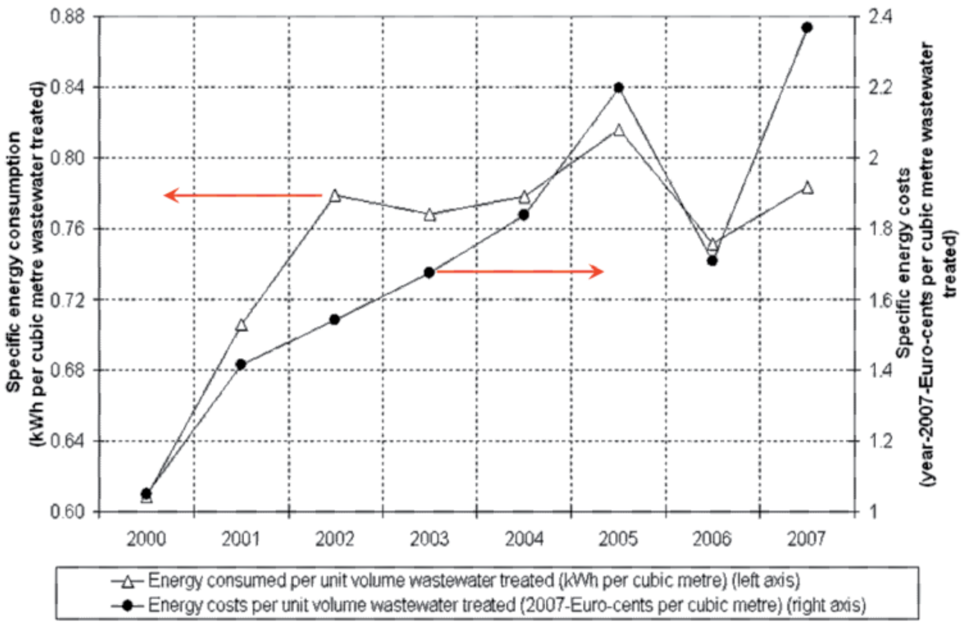


Figure 3 Wastewater treatment plants: specific energy consumption and costs.

To understand how VAV compares to some of the best practice utilities, and to find reasons for differences in performance, VAV benchmarks its processes against the Scandinavian 6-Cities benchmarking framework and European Benchmarking co-operation (European Benchmarking cooperation: International Benchmark 2009, 2010).

Asset management block: asset conditions assessment – energy and chemicals consumption

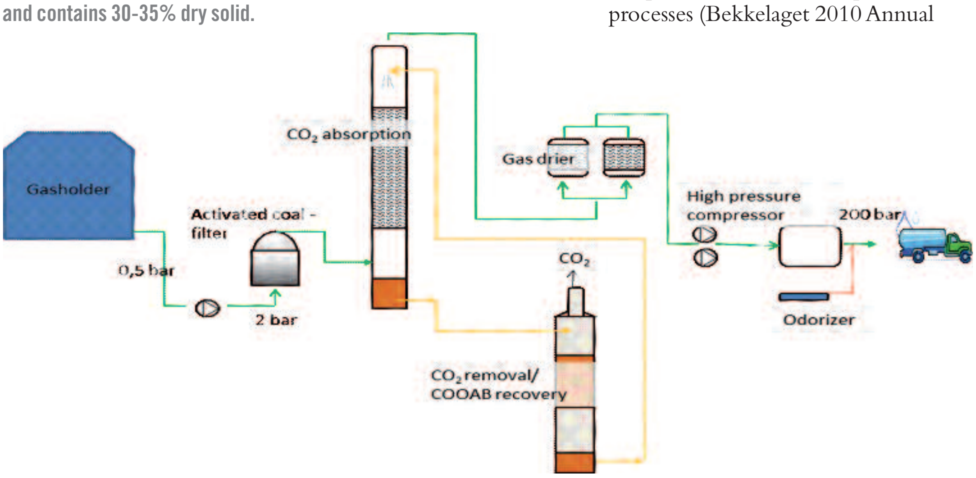
VAV has performed a comprehensive investigation of energy and chemicals consumption patterns of water and wastewater facilities, their potential environmental impacts and costs (Venkatesh and Brattebø, 2011). The VAV's main targets include advanced equipment controls in order to design and implement pump and motor efficiency programmes and to optimize the treatment plants' processes (Bekkelaget 2010 Annual report; VEAS 2010 Annual report).

VEAS WWTP treats 63% and Bekkelaget WWTP treats 37% of total wastewater flow originated from Oslo. Both plants operate in activated sludge mode (VEAS WWTP – primary clarifier, activated sludge process, secondary clarifier, sludge digestion and handling; hydropower from grid, biogas for heating. Bekkelaget WWTP – primary clarifier, activated sludge process, secondary clarifier, sludge digestion and handling; hydropower from grid, biogas for engine fuel and heating). The electricity purchased from the grid is around 30 GWh, while in-house produced electricity from the biogas accounted for 24.3% of the total electricity consumed in 2007. Specific energy consumption and costs in Oslo's wastewater treatment plants are shown in Figure 3 (Brattebø, 2010). The chemical consumption decreased from 22.5 million kg in 2000 to 15 million kg in 2007.

In-depth UWCS (Urban Water Cycle Services) metabolism model analysis with actual flows of clean and wastewater and related flows of energy, chemical and materials (i.e. stock of assets), will be carried out for Oslo as model city in the 7th Framework Programme project TRUST (Transition to the Urban Water Services of Tomorrow, Theme ENV.2010.3.1.1-1, Grant agreement no. 265122).

Figure 4

Energy recovery in Bekkelaget WWTP – upgrading of biogas to biomethane, COOAB process – CO2 absorption (Johansen et al., 2009). The plant is designed for biological treatment of an average flow of 150,000m³/d. In addition, 100,000m³/d can be treated chemically. The discharge consent for phosphorus removal is 90%, and it is 70% for nitrogen and BOD5 removal, respectively. The sludge is treated through a thermophilic anaerobic digestion process whereby the incoming sludge is pre-heated before entering the digester. The thermophilic digestion has proven to be a good process that gives a short retention time (at 55°C in 12 days), increased pathogenic removal and considerable increase in biogas production. The final product is pasteurized and dewatered in centrifuges with polymer and contains 30-35% dry solid.



Promotion of sustainable development of the community

Bekkelaget WWTP – cutting greenhouse gas emissions

Oslo City Council has an ambitious goal to cut 50% of greenhouse gas (GHG) emissions by the year 2030. Private and public transportation is the major contributor to GHG emissions in the city. To make a positive contribution to reducing the climate footprint of the city, VAV has upgraded its biogas

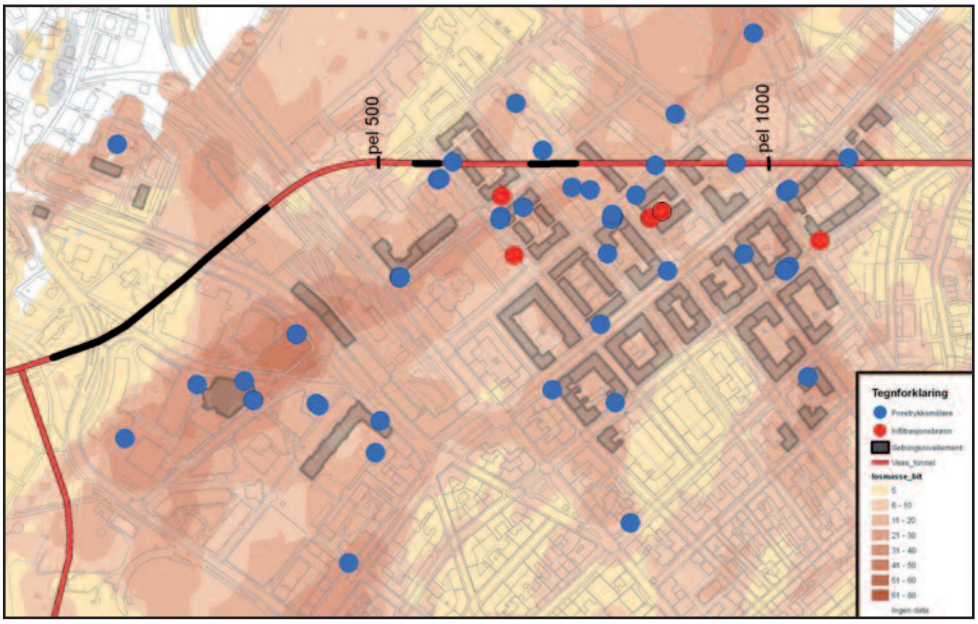


Figure 5
The wastewater tunnel section in the Majorstuen area in Oslo to be sealed (red-black line): active sites for monitoring pore water pressure (blue), subsidence (grey houses), water infiltration (red); thickness of the sediments (yellow-brown).

plant at Bekkelaget WWTP to biomethane. Today it produces about 3.6 million Nm^3 of biogas, of which 60-70% is upgraded to biomethane (Figure 4). The amount of biomethane produced corresponds to 2.2 million litres of diesel equivalent. This is enough to replace 80 buses powered by diesel with 80 buses powered by biomethane or around 20% of the total number of buses operating in Oslo. The switch to biomethane reduces particular matter emissions by 98%, nitrogen oxide by 78% and noise by 92%. The goal is to upgrade 90% of the biogas to methane.

Managing urban groundwater balance

Rapid urban development and the accompanying underground mining associated with extensive traffic and wastewater tunnel constructions resulted in a decline in pore-water pressure in the clay/silty clay soils as well as in the system of cracks in fractured rocks, and the compaction of surficial deposits (Milina, 2010). As a consequence, significant subsidence has become a serious problem at some locations in Oslo. In order to control the problem related to subsidence-related damage of the blocks of flats from the nineteenth century, which are founded on wooden rafts which 'float' in the clay, a monitoring system of groundwater level and pore-pressure fluctuations was established in the critical area in the early 1970s. The decline in artesian head was halted and reversed by artificial recharge using infiltration wells.

The history of wastewater tunnel sealing in the Majorstuen area shows that the well-known injection techniques alone will not provide sufficient radial density. The leakage measurements after injection of a cement-based agent in tunnel sections presented in Figure 5 showed a reduction in infiltrated flow. However, the pore pressure did not show the desired response. To restore the pore water pressure to its natural level will cost €9.2 million ($11.9 million).

Various studies have been carried out in order to better understand the details of the processes involved, and to prevent future problems related to water level falls caused by excavation and drainage activities. This triggered the use of new technology and new requirements in construction and maintenance of the city's new wastewater tunnel system in the Bjørvika area (subsidence 25mm/year) and conservation of the cultural stratums which lie at a depth of 2.5-4.5 metres under surface in the Medieval park in Oslo's Gamlebyen (Old Oslo).

Conclusions

The introduction of the ISO 24510 series has provided pointers to objectives related to sustainability of water utility and services, and its contribution to sustainable development of the community. The implementation of the standards gives grounds for changes which are needed to operationalize sustainability. To make the transition, the 'rules-in-use' will have to change to enable inventory, valuation, benchmarking, and monitoring of different categories of sustainable solutions. The Oslo case has shown that sustainability objectives require adaptation of the utility's asset management system to new premises and a broader platform for the implementation of a wider set of integrated societal sustainability objectives. ●

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Optimising asset investment definition and planning for urban water and wastewater services in low and middle income countries

In order to optimise asset investment decisions for urban water and wastewater services when there are limited financial resources, a cyclic and holistic approach to investment provision within the context of strategic asset management is needed. David C Logan and Jan G Janssens discuss the application of serviceability risk-based decisions that take into account whole-life-cost using technical and financial modelling, and how it can be rolled out for use in low and middle income countries.

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Urban water and wastewater utilities have enormous social, economic, environmental and political implications for the cities and countries served. Whether public or private, they are long-term, monopolistic activities which require sustainable, long-term business plans. The provision of these services is dependent on high cost infrastructure, being assets which usually have long lead-in and implementation times, long service lives and significantly high operating costs. These assets are the essential working tools for service delivery and their serviceability, which is their ability to function effectively, conditions the service provider's capacity to meet its legal, regulatory, environmental and contractual obligations, referred to hereafter as 'service obligations'.

General principles

Limited financial resources impose the need for priorities and technical and financial choices

Over the years, the assets need to be provided, maintained, upgraded, replaced and added to. This is because demand for the service grows, because service quality requirements evolve, the assets themselves age and deteriorate, raw (water) resources sadly degenerate and new constraints such as tighter environmental considerations are introduced. Investment is also triggered by technological advances that present the opportunity for efficiency and service improvements.

Limited financial resources, whether generated from service sales, provided externally, or both, impose the setting of capital investment priorities and making the most appropriate technical and financial choices to best meet the service obligations. The optimisation of those priorities and choices with respect to their overall cost implications and service effectiveness is strongly dependent on the approach used both to determine them and the timing of their implementation. Their optimisation is also very strongly tied to service organisation, data availability and management and to operational performance.

Whilst the principles discussed in this paper are applicable whatever the institutional, regulatory and contractual arrangements, and are unavoidably shaped by them, they are also highly dependent on sector management efficiency by the public authorities at each of those levels.

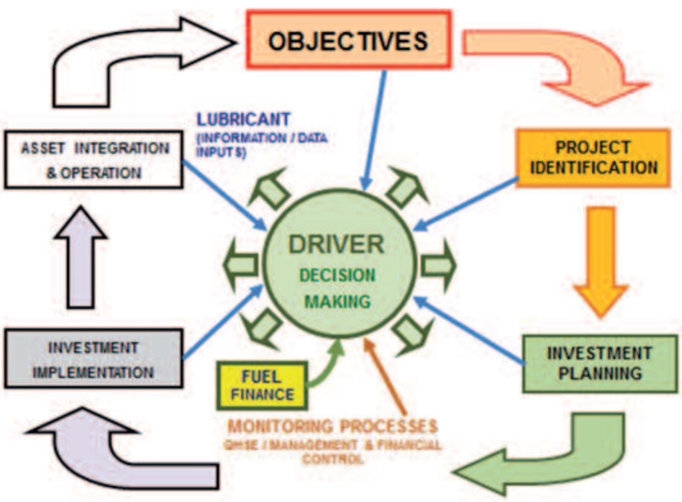


Figure 1
The asset provision cycle

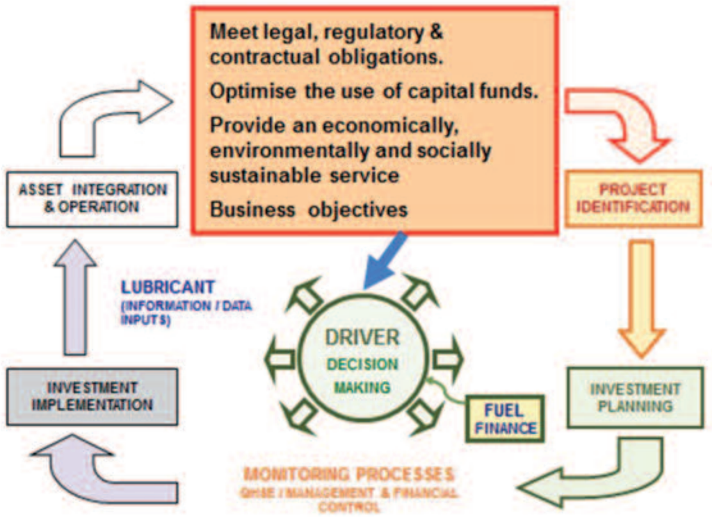


Figure 2
Objectives prime the decision based process

Asset investment definition and planning are data-fed management processes

Capital investment should be perceived and organised on a process basis, within the overall management and operation of the assets. It needs to be seen as an integral part of strategic asset management (SAM) for the service as a whole. This applies whether asset holding and operations are combined within the same, or separate, entities.

The overall organisation and operations of a utility need to favour data acquisition and flow within clearly defined management processes. This includes the collection, recording, updating, validation and communication of all the management, technical, operational, commercial and financial data that is essential for reporting, decision making, efficient planning, operations and investment. Such a process-based approach lends itself ideally to the application of quality management as a system for safeguarding and monitoring efficiency and is essential for transparency and good governance.

Capital expenditure (CAPEX) comprises both capital maintenance involving the replacement of existing equipment such as pumps or major repairs and asset creation or enhancement, such as the provision of new infrastructure or the upgrading or extension of existing facilities. The two are embraced within a global approach together with the operating cost implications of the investment options available. This implies that the uneasy and traditional trading of CAPEX against operational expenditure (OPEX) is replaced by a new, TOTEX (total expenditure) logic. Rather than the traditional, individual project-based approach to new investment, a holist and whole-life-cost approach is thus introduced. This takes into account the impact of the proposed investment on the system and service as a whole through modelling and simulation, alongside other investment proposals. They are integrated into the global business model to reflect expected service and commercial improvements and to ensure that they do not jeopardise the financial balance of the business or indeed the sector, before an investment decision is made.

A cyclic approach to investment definition and planning

The asset provision process can be considered as a continuous, decision driven cycle, rather than as a series of individual linear processes. At each step the options are tested and the optimised choice validated, to feed the decision whether or not to launch the next stage in the process. A new or improved asset, when integrated into the systems, contributes to the service as well as providing technical, cost and operational data which in turn feed the databases and models and contribute to further decision making in the cycle. This is illustrated in Figure 1 and discussed later.

Investment decisions involving technical and financial choice and timing must be based on reliable data, cost and performance projections, within a global vision of the service. The decision maker needs to be assured that the choice is the best adapted to the needs of the service and business, implying that alternative options will be modelled and simulated at the project identification and planning stages and may even be reviewed later in the cycle.

Risk, serviceability, 'optioneering', knowledge and control

Current trends are for decisions to be made on the basis of service and / or financial risk. The question: 'What is the impact and cost of service failure?' will guide the choice of action. All relevant service obligations, but also business considerations, will be expected to contribute to that choice.

A modern asset management system will include asset condition grading with a methodology for assessing this as well as serviceability. With respect to serviceability, the current trend is to include a notion of acceptable service risk alongside the ability of a particular asset to perform. Rather than a traditional age- or even condition-based approach to capital maintenance planning, a serviceability risk-based approach is thus introduced, focusing on real priorities and optimising resources.

The term 'optioneering' has been coined to describe the testing of options to arrive at the best adapted time-related technical and financial solution in terms of acceptable risk to the service. This usually includes the 'defer' and 'do nothing' options for comparative purposes and may even be the solution adopted if the implications are deemed to be the most acceptable. The process however ensures that if the situation becomes unacceptable in terms of risk, it will be reintroduced into the cycle.

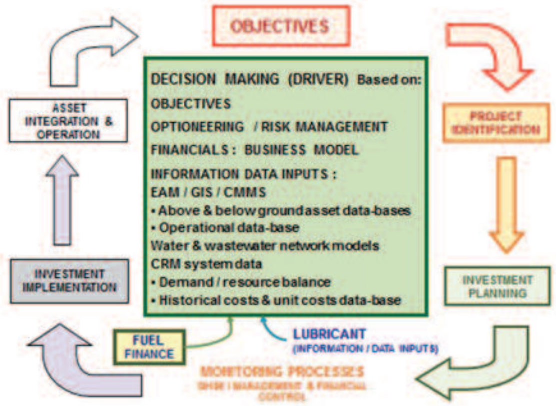
The above approach implies having a thorough understanding and control of the systems, with reliable data on assets, demand, actual usage and operations. It also relies on having a realistic business plan and being able to optimise time-related technical and financial choices within the overall context of the service.

Specific considerations for low and middle income countries

Capital investment funding

Revenue from water and wastewater services for capital expenditure is limited and asset provision in LAMIC is often dependent on external sources such as loans from international finance institutions (IFIs: World Bank, African Development Bank, etc.). The servicing of these loans is usually at least partially dependent on service revenue. Investment by IFIs in utility infrastructure is invariably conditioned

Figure 3
Decision making and information



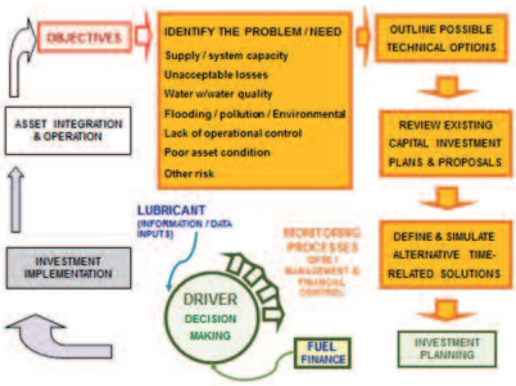


Figure 4
The product identification stage

on programmed financial and service performance improvements. This frequently implies the restructuring of the sector and the reorganisation of the utility, often with private sector involvement which can take many forms of public-private partnership (PPP). Incentives for improvement are usually driven through phased-in performance targets and obligations which can be regulatory and / or contractual. An element of performance-related remuneration can be introduced for the operating company, and when appropriate, financial aid can be partially linked to performance through output-based aid (OBA). Each case should be studied individually within its context to determine the best adapted package.

Typical context in LAMIC

In LAMIC, fast urban growth often far exceeds system expansion and many areas can be left either un-served or inadequately served. Insufficient revenue, lack of data and means, poor organisational and management efficiency and inadequate maintenance often lead to the premature degradation of existing systems and to unacceptable levels of technical and commercial losses. These significantly impact service levels and revenue, thus establishing a vicious circle. Due to a lack of knowledge and resources, maintenance and repair or replacement are frequently reactive rather than planned, leading to longer service discontinuation than necessary. This is compounded if replacement parts are not on hand, or easily obtainable off-the-shelf, or if funds are not readily available for their acquisition.

A lack of detailed technical system data and of historical performance data means that investment decisions cannot be optimised in terms of technical and financial choice and timing within the context of the overall system and service. The result is often that investment choices are promoted on the basis of superficially perceived rather than studied and validated needs. Ill-guided or ill-timed investment decisions, such as focusing on early and over-ambitious capacity expansion rather than balancing timely expansion with system optimisation, leads to the inefficient use of precious funding, unnecessarily high operating costs, and can compound already excessive losses. For example, doubling water production capacity to increase customer supply when loss levels are at 50% will deliver more water, but is likely to more than double those losses, as there will be additional pressure in the systems. Reducing losses to 75% will substantially save on both CAPEX needs and on OPEX.

There is often a dichotomy however in the case of LAMIC, as best adapted investment decisions need to be made as early as possible in an improvement programme for the services, whilst reliable data for optimised decisions is frequently insufficient at this stage. In view of the long lead-in times for capital investment and the length of time required to gain sufficient data, understanding and control of the systems, as well as to install the necessary management tools, etc., a broad and phased approach is required. The proposed approach, which is described in the following sections, is not only applicable to LAMIC, but in principle to all water and urban water and wastewater services.

Project identification and investment planning for low and middle income countries

Overall view of the asset provision cycle

As discussed and illustrated earlier, the provision of infrastructure and other related capital assets is a process that can be presented as a decision-driven continuous cycle. The cycle is primed by a decision to meet service-related objectives which are either not met, or are no longer expected to be met if no action is taken. The cycle progresses from need or problem identification, through project identification, investment planning to investment implementation and finally the integration and operation of new or improved assets.

The right hand side of the cycle defines the annually approved, rolling capital investment programme (CIP) which determines the optimised investments to be made and when. This therefore determines the financial decisions to be made and is the subject of this paper. The actual implementation of the CIP and the integration and operation of the new or improved facilities are not discussed further here, but the importance of integrating technical, financial and performance data from these into the relevant databases is strongly stressed.

The objectives

Whatever institutional, regulatory and contractual arrangements are in place, and in the respect of State sector policy, the following objectives must clearly apply:

- To respect regulatory (including legal and environmental) and contractual obligations
- To optimise the use of limited capital funds
- To provide an economically, environmentally and socially sustainable service.

These objectives are necessarily both present and long-term to ensure that the stability of the economic activity and service are achieved and maintained. They may include other financial and business objectives, depending on the policies for the sector and the direct involvement of the private sector. Typical objectives are indicated in Figure 2.

The objectives prime the decision-based process of asset provision or improvement and impose a high level of transparency, with clear interfacing

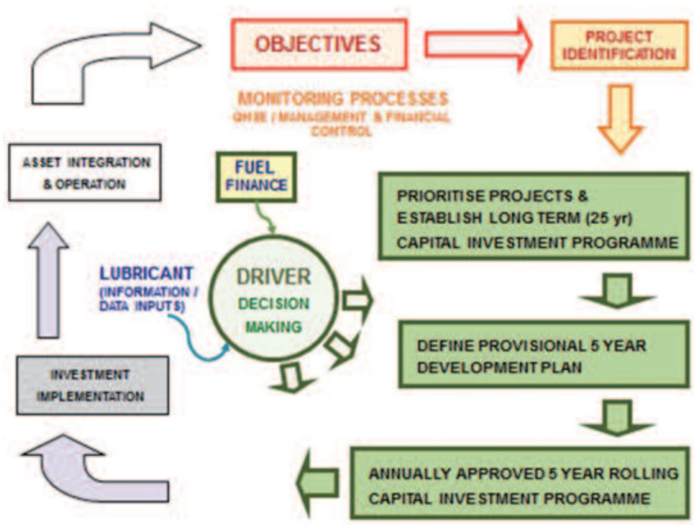


Figure 5
The investment planning stage

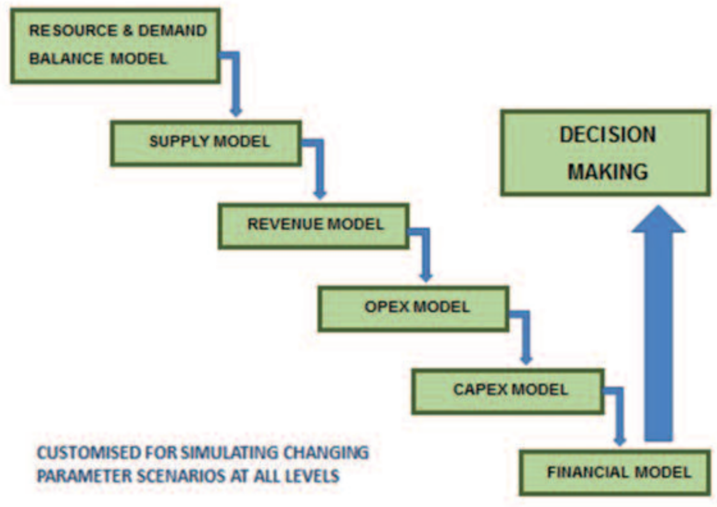


Figure 6
The global business model

between each of the activities and respective parties involved.

Decision making as the 'driver' of the process

Well informed decisions must be able to be made at each step of the process by the appropriate level of management concerned, within a clearly structured set of guidelines.

With respect to existing assets needing renewal or replacement (capital maintenance), the decision to act will be based on risk and its implications. This will take into account serviceability risk based on asset condition grade, actual operational performance and the likelihood of failure, as well as the service and cost implications of asset failure. With respect to asset expansion / enhancement or new assets (asset creation), decisions to act will be based on regulatory and contractual obligations, (including a political decision to extend the service), the implications of the 'defer' or 'do-nothing' options and possibly on the economic opportunity of such investment. The decision basis will include the legal, regulatory and contractual implications of failure and possibly political and commercial considerations in terms of corporate reputation.

In all above cases, the decisions will be based on the whole-life-cost of the proposed investment and the technical and financial solution adopted will be based on 'optioneer-ing', using modelling and simulation to define the most cost effective option, including the 'defer' and 'do-nothing' options. 'Optioneering' will embrace all relevant existing and proposed assets, to ensure that a global approach is maintained with respect to the impact of each proposal on the rest of the systems.

Information and data management, an essential prerequisite for sound decision making

An essential prerequisite to the whole process of sound investment decision making is the availability of sufficient and reliable data. This includes technical, condition and historical performance data for the assets, cost data for new or replacement works, current and projected demand figures including consumption data for all categories of customers (users), detailed technical, administrative and operating and maintenance costs for the installations and the costs of managing the service.

The following data-bases are normally required:

- EAM (enterprise asset management) system for above ground asset data (treatment plants and pumping stations, etc.)
- GIS (Geographic Information System) for below ground (network) asset data
- CMMS (Computerised Maintenance Management System) for asset maintenance information and planning
- CRM (customer relations management) for customer administrative, management and service performance data, including meter reading, billing and revenue collection information.

All these systems should be integrated within an overall corporate enterprise resource planning (ERP) system architecture. They will feed the system models, etc., and will themselves be fed with up-to-date data from activities on the ground. Relevant data will then be introduced into the business plan. A mature, fully integrated system will include a computerised operational control centre, a customer call centre, SCADA (Supervisory Control and Data Acquisition) for key installations and LIMS (Laboratory Information Management System), with communications links, electronic recording tools and well-defined processes to allow real-time management of field activities and data flow. It is important that data knowledge and acquisition be no longer dependent on individual operative's memories and ad-hoc recording on personal note books or paper scraps.

The well-developed system will include a single central database of each type, above, with access on clearly defined user and need based protocols. Asset database ownership will logically reside with the asset owner but their control will be in the hands of the party using and up-dating the data, that is, the operator of the assets. These arrangements allow all requisite transparency over operational and asset management performance, notably to the regulatory body and the client authorities. The driving position of decision making with its principal data sources is illustrated in Figure 3.

It should be recognised that whilst some water and wastewater services in higher income countries are less developed than we have described above in terms of data and management systems, the objectives given here are not utopic. It is a fact that services in LAMIC often received specific funding aid for the installation of information technology and are able to make a dramatic leap forward with respect to these systems. The key consideration must be to apply the very optimisation and planning principles that are described in this paper to those system investments as well.

Control systems

Two main control systems need to be installed to monitor and ensure (by subsequent correction) the respect of decisions and procedures:

- QHSE (quality, health & safety and environment) management, which is itself a cyclic, continuous improvement process which when fully developed, will embrace every activity within the service.
- Management and financial control, itself subject to quality management and which essentially monitors and regularly reports through 'dash-boards' on internal corporate performance against management and financial targets, as well as on the respect of the relevant procedures.

In addition, within a regulated environment with complex performance and reporting obligations, a performance manager is usually appointed to act as the interface with the regulatory authorities and to ensure regulatory compliance.

Project identification
Project identification is a stepped process deriving from the identification of a problem or need. This can be actual or projected insufficiency of supply or system capacity, unacceptable levels of losses, non-compliance with respect to water or wastewater service levels or quality, flooding or pollution, or a lack of operational control of the systems. It may be the opportunity to improve service and economic efficiency through the introduction of new technology. There are many possibilities (see Figure 4).

Fed from both asset and operational data, possible technical options are outlined in consultation with the operations and maintenance department(s). Existing capital investment plans and proposals are reviewed in terms of possible impact and alternative, time-related solutions are tested through integration into the relevant models and simulated to 'optioneer' the best time-related technical and financial solution.

Investment planning
The retained option, above, are prioritised in terms of importance of impact to constitute the draft long-term (typically 25-year) CIP. The draft 25-year CIP is then integrated and tested by simulation in the business plan for the assessment of the financial impact on the service. Once balanced, the long-term CIP is submitted and defended for approval at the requisite management level.

After approval, further refinement of the technical and financial options is made through 'optioneering' to validate or if necessary redefine projects and their priorities for the first five years of the CIP. This defines the provisional five-year asset development plan which when approved is updated and rolled forward annually as the approved five-year (rolling) CIP. The approved five-year CIP triggers annual investment decisions and project development, which is outside the scope of this paper, but for which the basic principles of testing and 'optioneering' continue to apply (Figure 5).

The global business model
The global business model reflects the business of operating the existing and planned future systems and services, incorporating performance obligations and targets in terms of current and projected:

- Resource and demand (balance)

Table 1: Typical Global Action Plan for the implementation of optimised asset definition and planning for water and wastewater services in LAMIC

	Table 1: Typical Global Action Plan for the implementation of optimised asset definition and planning for water and wastewater services in LAMIC	Yr 1	Yr 2	Yr 3	Yr 4
1	**Review regulatory and contractual arrangements, requirements and obligations**				
2	**Review and survey existing systems to be operated**				
	Examine existing plans, data and models etc.				
	Site investigations and surveys, including valves, flow meters and pressure gauges, etc.				
	Technical audit of key installations				
	Review historical operating data on performance, complaints and incidents				
	Selective sample CCTV surveys on a prioritised basis				
3	**Review existing O&M organisation / means and implement**				
	Review, recommendations and implementation				
4	**Take control of the systems**				
	Select key, 'pilot' areas / zones				
	Renew defective or add essential bulk measurement equipment on installations				
	Renew defective or add essential network equipment (valves and meters, etc.)				
	Targeted leak detection and repair work				
	Water and wastewater quality monitoring and management				
	Create and develop asset databases				
	Implement condition ranking, criticality and serviceability analysis				
5	**Master demand and improve customer management**				
	Review recorded consumption, demand and resources				
	Organise and implement physical and administrative survey of customers / connections				
	Mapping and geographic referencing of customer connections				
	Update customer database				
	Systematic customer metering and connection improvement				
	Define and implement improved organisation & procedures				
6	**Select and install IT systems**				
	Select ERP, design system architecture, select suitable packages, and implement systems				
	GIS, EAM (asset databases)				
	CMMS (maintenance management)				
	Water and sewerage system modelling including quality				
	CRM and call centre				
	Supply chain management / unit cost database, etc.				
	Other systems required, (laboratory: LIMS; etc.)				
7	**Strategic asset management**				
	Review on-going, committed and planned schemes on the basis of information available				
	Identify critical and high priority schemes on basis of information available				
	Review and recommend justified high priority schemes for early implementation				
	Review current asset management organisation, procedures and practice as a whole				
	Recommendations for improvement to a modern SAM approach				
	Introduce the proposed project identification and investment planning process using the data and systems available and develop and review this as the data bases and systems evolve				
	Integrate key project proposals in the business plan for impact testing				
	Implementation of the new overall SAM system				
8	**Develop / up-date business plan**				
9	**QHSE**				
	Review existing processes, confirm or redefine and phase in QHSE management processes				
10	**Training programme, including training of local trainers**				
	Staff evaluation and definition of needs				
	Design training programme, modules, equipment and facilities required				
	Programme and implement training including the training of local trainers				

- Operating and commercial performance
- Income and expenditure from the service

This feeds into the financial business model with current and projected:
- Cash flow
- Income and expenditure accounts
- Capital expenditure, amortisations and depreciation
- Borrowing and debt servicing
- Balance sheets

These allow the assessment of projected overall financial performance.

The time-related investment proposals are fed into this model, which is customised to simulate changes in key parameters, thus testing its sensitivity to varying options and performance projections, to bring comfort to decision making in business terms (Figure 6).

Practical application to LAMIC

Recapitulation of the requirements

It is clear from the above approach to asset investment identification and planning that the effectiveness of whole process is very dependent on the existence or development and continuous maintenance up-to-date of the following:
- A clear and efficient regulatory and contractual framework with well defined, realistic, measurable and attainable performance indicators and targets
- Accurately recorded information on the systems: above (EAM) and below ground (GIS) asset databases, including condition grades and historical performance data, and water and wastewater system models, ideally including water quality
- Control of the systems and their operation and maintenance, with: efficient zoning, with bulk, district and sub-area metering and valves; flow meters and pressure sensors, both permanent and mobile; and an efficient computerised maintenance management system (CMMS)
- Accurate knowledge of current customer service requirements, consumption and performance, and projected future demand, including: an up-to-date technical and administrative customer database; full customer metering; a well-adapted customer relations management system (CRM); and clear details of trade effluent consents and discharges
- A well designed overall management information system, integrated within an ERP architecture
- This will include QHSE, regulatory compliance, financial management and accounting, HR management, appropriate IT packages for supply chain management with a unit cost database, laboratories, etc.
- A well-adapted corporate organisation and procedures within the framework of a suitable QHSE system
- A well-structured and suitably customised business model

Typical implementation in LAMIC

In LAMIC it is rare for all the requirements listed above to be available. It is therefore important to define a phased action plan to acquire the requisite knowledge and control of the systems and build up the management information systems, database and models, where these are lacking or insufficient.

A hypothetical action plan, which covers all likely requirements, is illustrated below. In practice, it would need to be adapted to the specific situation and context of the service being considered, in terms of activities listed and their durations. The time factors in particular will depend on the size of the services in terms of population served, the number and extent of the urban areas concerned and the state of the infrastructure and service at the starting date of the contract. This is often referred to as the 'starting point', which can often not be determined immediately, because of the lack of data availability at the beginning of the contract.

Where external support is to be sought for its implementation, this could be mobilised through the early stages of a management contract, or through an initial service type contract, both necessarily with a service provider who has sound experience in both strategic asset management and in service operations. A well-adapted training programme with training of local trainers should be included to assure the long-term sustainability of the process.

The typical action plan which follows assumes the case of a four-year management type contract with a three-year definition and implementation period and a final year to consolidate the organisation and systems and hand over responsibility to local managers. For extensive and complex service areas, particularly those that are very weak at the start, contract periods of up to six years may be required. It may also be necessary to precede this contract with some technical assistance to obtain the minimum required data and knowledge of the systems and define a viable framework and terms for the future contract. ●

AM DIARY

A listing of upcoming asset management-related events and conferences. Send event details to WAMI for inclusion.

Stormwater & Urban Water Systems Modeling Conference
21-22 February 2013, Toronto, Canada
Web: www.chiwater.com/Training/Conferences/conferencetoronto.asp

The Future of Utilities and Customer Operations in Utilities
19-21 March 2013, London, UK
Web: http://marketforce.eu.com

5th IWA International Conference on Benchmarking and Performance Assessment (Pi2013)
9-12 April 2013, Medellin, Colombia
Web: www.iwabenchmarking.com/pi2013

Asset Management for Enhancing Energy Efficiency in Water and Wastewater Systems
24-26 April 2013, Marbella, Spain
Web: http://iceam2013.es

3rd International IWA Conference on Water, Economics, Statistics and Finance
24-26 April 2013, Marbella, Spain
Web: http://iceam2013.es

Regional Utility Management Conference - Improving Performance in Emerging Economies
13-15 May 2013, Tirana, Albania
Web: www.shukalb.org/utilityconf

7th International Conference on Sewer Processes and Networks
28-30 August 2013, Sheffield, UK
Web: www.shef.ac.uk/spn7

LESAM 2013 - IWA Leading Edge Conference on Strategic Asset Management
4-6 September 2013, Sydney, Australia
Web: www.lesam2013.org

13th International Conference on Urban Drainage 2014
7-11 September 2014, Sarawak, Malaysian Borneo
Web: http://www.13icud2014.com