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Sanitation and Water for All report charts progress towards commitments

At the second Sanitation and Water for All (SWA) High Level Meeting in April 2012, developing countries, donors and development banks made commitments to address barriers to delivering sustainable water and sanitation services. The 2013 Progress Update on the 2012 SWA High Level Meeting Commitments, launched by the Sanitation and Water for All partnership, tracks achievements made against the commitments so far.

'The monitoring report shows exceptional achievements and illustrates that that political will and strong leadership can drive action, even in the toughest environments,' says H.E. John Agyekum Kufuor. 'I am immensely impressed that countries were able to translate commitments into action on the ground. This report shows that SWA High Level Meetings add value.'

All 15 developing countries that made specific commitments to tackle open defecation have made notable progress in scaling up community-based approaches to sanitation. Nine countries reported significant budget increases for sanitation and water and many leaders have given the water, sanitation and hygiene (WASH) sector higher political visibility. Others report progress in creating stronger information systems from which important decisions can be made. Improved planning and coordination processes is another theme highlighted in the report.

While notable progress has been made, the report shows that much work remains to be done to address commitments aimed at improving the effectiveness and sustainability of service delivery. Slower progress has been made in terms of strengthening institutional arrangements and financial systems, addressing human resources gaps and using better information in planning processes. Change in these areas will take a considerable amount of time and progress needs to be monitored over several years, says SWA.

In April 2014, SWA will be holding the third High Level Meeting, when developing countries, donors and development banks will report on progress since 2012 and table new and more ambitious commitments. ●

World Bank approves $178m for Mozambique water supply expansion project

The World Bank, through its International Development Association, has approved $178 million for a water supply expansion project in Mozambique.

The bank said on July 25 that the funding will finance implementation of the Greater Maputo Water Supply Expansion Project to enhance water access in the capital Maputo under which at least 100,000 families will benefit.

'The government of Mozambique has made steady progress in building a sustainable water system to provide access to clean water for many households in its quickly growing urban areas,' said Laurence C Clarke, World Bank Country Director for Mozambique.'We are happy to support this project that will bring improved health and water security to over 100,000 families living in the Greater Maputo Area.'

The new funding paves the way for the construction of a 60,000 cubic metres/day water treatment plant, which will draw water from the Corumano dam. The project also entails construction of a water supply pipeline 92 kilometres, reservoirs and pumping stations.

The Maputo water supply project is the largest component in the country's National Urban Water Supply and Sanitation Strategy. The strategy contributes directly to Mozambique's third Poverty Reduction Action Plan of 2011-2014, which, among other things, seeks to 'improve access to, and use of water to enable access to safe sanitation.'

'Mozambique is vulnerable to periodic tropical cyclones during the summer months that periodically flood the intake system and water treatment plant of the existent waterworks,' said Jamal Saghir, Director for Sustainable Development in the Africa Region. 'This project will support the creation of a water system that is climate resilient and that brings clean water for drinking, cooking and cleaning for the families in the Greater Maputo Area.'

Part of the World Bank funding will be used in providing technical assistance to Mozambique's state-controlled water utility, Water Supply Asset Holding and Investment Fund (FIPAG), and enhancing the capacity of the country's water sector regulator, the Water Regulatory Council.

'Approximately 17 percent of under-five deaths in Mozambique are the result of diarrhoeal diseases, primarily caused by poor water and sanitation,' said Luiz Claudio Martins Tavares, Task Team Leader for the project.

'The funds approved today will transport clean, treated water directly to households in the Greater Maputo Area, bringing families an opportunity for improved health, and more time in each day for busy women and girls.' ●

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EDITORIAL

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Sri Lanka announces water supply projects

Sri Lanka's National Water Supply and Drainage Board and Coca-Cola Beverages Sri Lanka have signed a memorandum of understanding for a project to provide safe drinking water to areas affected by chronic kidney disease.

Coca-Cola will provide resources for constructing an RO treatment plant and the infrastructure to house it. The plant will treat around 1500 litres/hour of water and will operate for 20 hours a day, providing water to over 1100 homes in the villages of the Padaviya DS division.

The plant will be maintained by a community-based organisation, in collaboration with the National Water Supply and Drainage Board.

Padaviya, in the north of the Anuradhapura district, has a high number of patients with chronic kidney disease, which is believed to be caused by heavy metals in agrochemicals, with diffusion in water contributing significantly to intensifying the disease.

Sri Lanka has also announced the launch of the R22,000 million ($151 million) Kilinochchi water supply scheme.

This project will rehabilitate a 3800m^3/day water supply system that rebels destroyed during the country's long insurrection.

The Sri Lankan government will provide R740 million ($5.6 million) for the project, with the balance being provided by the Japanese government. ●

Utility publishes white paper on sustainability and resilience planning

American Water Works Company has published a new white paper on sustainability and resilience planning for water utilities, which is intended to address the increasing number of extreme weather events that the country is facing.

With hurricane season already under way, CEO Jeff Sterba explained: 'Water and wastewater systems are built for resiliency and sustainability of operations during weather events or other circumstances that could potentially interrupt service, but the increasing frequency of significant events in recent years, caused by climate change, has created a renewed focus on business continuity planning and emergency response for water utilities.

'When events that were historically considered to be 100-year events happen more and more frequently, utilities must prepare for a new normal.'

American Water's white paper warns that climate change is having a profound effect on how communities can reliably access clean water, causing poor water quality and scarcity and putting significant stress on the water infrastructure. In 2011 and 2012 alone there were 25 climate-related extreme-weather events in the US that each caused about $1 billion in economic damages.

The white paper highlights American Water's approach to mitigation, including risk assessment through engineering planning studies, risk management through prudent investment into its systems, integrated water resource management and the use of innovation technology. ●

IADB approves grant to improve capital's drinking water services

The Inter-American Development Bank (IADB) has approved a $35.5 million grant for a programme to expand and improve drinking water services in the Haitian capital, Port au Prince.

The grant will support the second phase of a programme launched in 2010 with support from the IADB and the Spanish Fund for Cooperation in Water and Sanitation in Latin American and the Caribbean (FECASALC).

At present, about 70% of the three million people in the metropolitan region consume water provided by CTE-RMPP, the capital area's utility.

The programme will be carried out by Haiti's national water and sanitation agency, DINEPA, and CTE-RMPP.

Goals for the second phase include further reducing losses caused by leaks, clandestine connections and unpaid bills, as well as to improving revenue in order to cover operational expenses.

CTE-RMPP will also start implementing a master plan of investments to expand coverage and improve the quality of service. ●

ADB warns that Pakistan is on the brink of water scarcity

The Asian Development Bank (ADB) has warned in a report that Pakistan is on the brink of being classed as 'water scarce'.

The country has not constructed any major water reservoirs in over 40 years, and only has a limited storage capacity.

The Asian Development Outlook 2013 report notes that: 'Water demand exceeds supply, which has caused maximum withdrawal from reservoirs. At present, Pakistan's storage capacity is limited to a 30-day supply, well below the recommended 1000 days for countries with a similar climate.'

The report adds that climate change is affecting snowmelt and reducing flows into the Indus river, the country's main source of water.

The ADB has recommended increases in storage capacity to better manage periods of low snowmelt and low rainfall, as well as rehabilitation of the distribution system to reduce losses.

The report cautions that without proper water management Pakistan's agricultural sector will also suffer badly.

The authors note that 'anecdotal evidence suggests that agricultural productivity could be doubled with appropriate reform,' and add: 'Improved water management is critical to deliver sufficient water to the 80% of farmland in the country that is irrigated.' ●

Decision making model for the replacement and upgrading of sewer pipes in Colombia's Aburrá Valley

Given that the sewer network is a relatively expensive infrastructure, utilities have to ensure that they only replace and modernize those parts that need it, at the right time and using the best technique; minimizing not only the direct costs but also the socio-environmental costs. Using the case of Colombian utility Empresa Pública de Medellín, Luz Ángela Hernández Chavarriaga and Carlos Mario Ángel Montoya discuss the use of a decision making model to assist sewer repair and replacement investment works.

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Sewer pipes can suffer from problems such as a lack of hydraulic capacity and degradation, which ultimately lead to structural damage, pollution of the receiving streams, flooding, and traffic disruption due to works and citizen complaints.

The main causes of these problems are a combination of various factors, such as:

- Ageing infrastructure
- Inappropriate use of the network by users disposing of substances which can deteriorate the quality of the pipe's materials
- Flow rates that are higher than the designed rates, which cause pressure stresses that diminish the pipes' structural capacity
- Unsuitable construction processes
- Low quality materials
- The depth of the installation
- The foundation soil
- The tightness of the joints
- Other external and internal aspects

The main purpose of this paper is to present a methodology for decision-making regarding the replacement and rehabilitation of pipes applicable to our environment, in order to improve the structural, hydraulic, and environmental functionality of the sewer system.

Investment planning

The sewer system of Colombian utility Empresa Pública de Medellín (EPM) consists of all the wastewater, stormwater and combined water sewer pipes and treatment systems. As a whole, the system's function is to collect water from the secondary pipes (combined, wastewater and stormwater), transport it through the collectors and interceptors, and deliver it to wastewater treatment plants.

The previously poor state of the utility's network led to claims and complaints, with consequences such as: delays in customer service; partial, non-comprehensive solutions; deterioration of the utility's public image; low responsiveness; and failure to meet operational goals and objectives. Also, due to new requirements arising from the implementation of technological improvements, such as increased preventive inspections of the pipes with CCTV and the popularization of hydraulic modelling of the network, the number of problems in the system became worse in the short-term, increasing the future requirements for replacing the pipes.

Therefore, it became necessary to implement a methodology based on the existing data for the network, its operation and the historical maintenance data, using a Geographic Information System (GIS). The use of GIS to plan replacement activities in order to determine the scale of investment became vitally important, as these tools are used worldwide and enable the interaction of various databases that can be linked and integrated, using data analysis spatial queries. Similarly, having a better view of the system with the identification of prioritized sites means that they can be a focus for people who carry out field research.

Using the information that exists in the databases and information systems, an initial determination was made of which sections of the system most urgently needed intervention. By then performing a more detailed analysis on the basis of a series of assumptions, the sections of the network that were in the most critical condition were identified.

Components of the model

The model integrates the following components:

- Structural and environmental index
- Hydraulic index
- Degree of deterioration by inspection

Structural and environmental index

The structural condition of a pipe section basically depends on its properties (material, diameter, age, etc.), the construction techniques, the external

Table 1
Weights and criteria of the indicators used at EPM

INDICATOR	WEIGHT	CRITERION	COMMENTS
Age	10	Pipe Age/(Material Useful Life*)	*Useful life: 60 years for PVC or polyethylene; 40 years for pipes of other materials
Material	1	Plastic: 0.40 Concrete: 0.60	
Depth	1	Crown Depth of the section/1.90	Crown Depth > 0.8 m
		0.80/Crown Depth of the section	Crown Depth <= 0.8 m
Diameter	1	Diameter < 600 mm: 0.8 Diameter >= 600 mm: 0.2	If diameter <= 150 and it does not come out of a spillway, it is replaced.
Number of Connections	1	$\frac{\text{Average length of the system}}{\text{Average distancebetween axes}} \times \frac{\text{Distance between connection axes}}{\text{Length of the section}}$	
Obstruction	1	$\frac{\text{Average length with obstructions}}{\text{Average obstructions per section per year}} \times \frac{\text{Section obstructions per year}}{\text{Section Length}}$	
Damages	2	$\frac{\text{Average length with repairs}}{\text{Average repairs per section per year}} \times \frac{\text{Section repairs per year}}{\text{Section Length}}$	

Table 2
Weight of the indicators used in EPM

Indicator	Weight of the indicator (1 to 10)	Criterion
Minimum Velocity	2	$\text{minimum velocity criterion} = \begin{cases} 0.1 \text{ if meets the criteria} \\ 0.9 \text{ if meets the criteria} \end{cases}$
Maximum Velocity	2	$\text{maximum velocity criterion} = \begin{cases} 0.1 \text{ if meets the criteria} \\ 0.9 \text{ if meets the criteria} \end{cases}$
Hydraulic Capacity	1	$\text{maximum hydraulic depth criterion} = \begin{cases} 0.1 \text{ if hydraulic depth} \leq 85\% \\ 0.9 \text{ if hydraulic depth} > 85\% \end{cases}$

loads (depth of the installation) and the characteristics of the flow it carries (flow, type of water, sediments).

According to existing methodologies, a structural analysis is usually based on the results of CCTV inspections. In general, the condition of a pipe is classified according to its structural damage, in order to determine the degree of urgency of the rehabilitation and to calculate its cost.

In the absence of sufficient CCTV data it becomes necessary to use other methods to determine a structural and environmental index for each section, based on the properties of the pipe, its environment and the damage and obstructions which have occurred. In order to carry out a detailed assessment of a sewer section, the literature recommends using a set of indicators, which are similar across different papers.

In general, the following indicators are recommended for structural assessment: age, diameter, depth, thickness, material, water table level, soil, loads, type of water transported, coding of the results of the CCTV inspection and special construction characteristics. The recommend indicators for the environmental assessment are damage and obstructions in the system.

The choice of indicators should also:

- Represent relevant aspects of the network's operation and of the service provided
- Be clearly identified, with a specific and unambiguous meaning for each indicator
- Be measurable, which also makes them useful for regulators
- Take into account the existence of data

For its initial application at EPM, the parameters chosen for the structural and environmental assessment were age, depth, obstructions, structural damage, material, diameter and installed connections, which will be subsequently supplemented in the next phases of the model's development by including other indicators such as the properties of the subsoil and water table level, among others.

Hydraulic index

To conduct the hydraulic assessment, we recommend using hydraulic modelling computer tools, which today include programmes that have reached a high level of reliability as the software uses equations for gradually varied flow in its calculations. From the hydraulic point of view, the recommended indicators for its assessment are capacity, flow and sedimentation.

The parameters that were assessed in EPM in order to get this index were:

- Minimum speed
- Maximum speed
- Hydraulic depth

Once the hydraulic models have been put into operation, an application will be implemented to make it possible to get the results automatically.

Degree of deterioration determined by inspection

The diagnosis of the pipes using a CCTV camera provides a real time look at their constructive, operational, hydraulic and structural condition.

In 2010, EPM implemented a coding, rating and classification methodology for the diagnoses made with a CCTV camera, entitled 'Methodology for diagnosing and assessing sewer pipes with CCTV', which can then support decision making and planning of maintenance and rehabilitation programmes for the sewer system.

This methodology builds upon the structural and operational aspects of the inspected pipes, depending on the defects found during the inspection. Each observation is coded and rated using a rating system and subsequently assessed and directly related to a classification, which then establishes criteria in order to determine the degree or level of deterioration of the assessed network section with regards to its likelihood of collapse. The following damage classifications are taken into consideration for the structural conditions: crack; fracture; break; gap; deformity; collapse; joint; and deteriorated surface.

It should be noted that the diagnosis of a network using CCTV provides input data for making decisions on maintenance, repair or rehabilitation but does not determine this. To reach this determination, there must be prior knowledge of the pipes and some additional variables that have a direct influence on the final decision to rehabilitate and the technique that will be used. Some of these variables are: network diameter; depth; water table level; pipe age; type of soil on which the network is anchored; pipe material; maintenance events and care

Table 3
Section rating level according to CCTV

Diagnosis	Recommendation
Level 1: No defects were found or the few defects that were found are not significant and do not endanger the structural and / or operational stability of the section.	Level 1: We recommend conducting a new inspection within seven to ten years, to verify the structural and operational condition of the section.
Level 2: The defects that were found have greater significance, but do not compromise the short-term structural and / or operational stability of the inspected section.	Level 2: We recommended conducting maintenance actions in order to correct the damages that were found and perform a new inspection within five to seven years to analyze the structural and / or operational risk.
Level 3: The defects that were found generate isolated structural and / or operational problems. Corrective or preventive actions must be taken in order to minimize the likelihood of a failure.	Level 3: Must perform maintenance actions that will correct the defects, prioritizing them according to the severity or rating. We recommend conducting a new inspection within three to five years to verify the result of the actions that were performed and check that the structural and / or operational risk has not increased.
Level 4: The isolated defects or sector defects that were found are highly significant and compromise the structural and / or operational condition of the inspected section.	Level 4: Preventive or corrective measures must be taken, performing maintenance actions that prevent the damage from spreading. Prioritizing the defects according to their severity or rating, schedule a new inspection within one to three years to analyze the result of the actions that were taken.
Level 5: Has highly significant defects in the entire section which require an immediate structural and / or operational intervention.	Level 5: Perform the urgent structural and / or operational maintenance actions in order to leave the affected section operational. The possibility of replacing or refurbishing the section should be analyzed.

provided; types of roads; traffic flow; network location in parklands and / or walking trails, among others.

Integration of the model's components

With the help of a decision tree that can be incorporated into a GIS, all the selected indicators were calculated in order to calculate the indices for each of the network sections located in the sector where the work was being conducted.

In the event that not much of the network has been inspected, the structural and environmental indices and the hydraulic index can be used to select a reliable sample of sections to inspect in order to subsequently input them into the model.

Application of the decision making model

In the case study in question one of the most critical sectors in the city of Medellín was selected, which, because of its operational needs, requires an early intervention. The selected area is located within the Santa Elena sanitation basin, and covers the pipes of the entire sector north of the ravine that shares that name. This sector was delimited, covering the discharges from the northern side of the sanitation basin and all those pipes that offload into the Santa Elena collector, which has a sampling and measurement point in the outlet into the Medellín river.

The sanitation basin covers a total area of 14km^2, of which 87% of the basin lies within the urban area with a high population density. The sector selected in the use case includes 5km^2 of the northern side of the basin. The area's boundaries are defined to the north by the basins of the Los Ataudes and El Ahorcado ravines, to the south by the Santa Elena ravine, to the east by the basins of the La Castro and San Antonio ravines and to the west by the Jesús Nazareno and Villanueva neighbourhoods. The number of sewer sections of the sector is 4298 (approximately 141km of pipe).

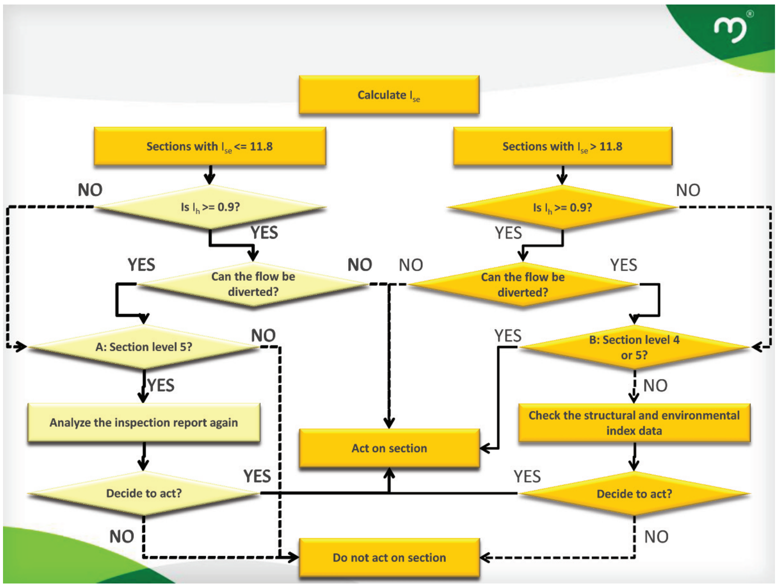
Structural and environmental index (I_{se})

First, the indicators, their weights and the calculation formulas were selected. Once each one of the criteria was calculated at the network section level, they were aggregated into the formula for the index, where they were weighted by assigning weights according to the incidence of each variable in the network's behaviour.

Structural and Environmental Index
= Σ weight x criterion

Table 2 shows the weights assigned to the criteria for each variable for

Figure 1
Decision tree with the EPM data and criteria



the case of EPM's sewer network. The limit values for the structural and environmental indices that determine whether the section can be rated as good, fair, critical or very critical were established by EPM depending on the value of the investment assigned for the replacement and modernization of the pipes, for a period of ten years. The ranges obtained were as follows:

- Good section: Index ≤ 11.21 (with an age less than or equal to 85% of its useful life or with fewer than one repair or two obstructions per year)
- Fair section: Index between 11.21 and 11.8 (with an age between 85% and 100% of its useful life or with fewer than one repair two obstructions per year)
- Critical section: Index between 11.8 and 14.3 (with an age between 100% and 125% of its useful life or with more than one repair or two obstructions per year)
- Very critical section: Index > 14.3 (with an age more than 125% of its useful life or that has had more than one repair, or more than two obstructions per year)

For the case of the Santa Elena sector study, the following data for this index was obtained:

- Good section: 3183 sections
- Fair sections: 273 sections
- Critical sections: 367 sections
- Very critical sections: 475 sections

Hydraulic Index (I_h)

Similar to the structural and environmental index, the hydraulic index is calculated for each section using the following formula:

Hydraulic Index
= Σ weight x criterion

Table 3 shows the weights assigned to the criteria for each variable. In the case of EPM, the hydraulic parameters for each network section were determined from the hydraulic modelling results, using the SewerGEMS software from Bentley.

The minimum velocity is 0.45 m/s for wastewater networks and 0.75 m/s for stormwater and combined networks. The maximum velocity is 10 m/s for plastic pipes and 5 m/s for other types of materials. The maximum permissible hydraulic depth value is based on the pipe's diameter; it is between 70% and 85% of the actual internal diameter of each sections.

For this index you have to verify if the section satisfies the hydraulics criterion and analyze if the section with I_h >= 0.9 can transport less flow.

In the above case 426 critical sections that did not meet hydraulic conditions, with hydraulic indices above 0.9, were found.

Degree of deterioration determined by inspection

According to the criticality of the pipe inspection done in the field, which is related to the characteristics of the damage and its location, the level of deterioration for each section is assigned. For the sewer operated by EPM, the levels of deterioration that were determined are shown in Table 3.

Decision tree for the use case

With the indices obtained for each section and their level of deterioration, the sites where an intervention will take place are determined using the decision tree that is shown in Figure 1 as an aid, with the values and criteria used by EPM.

It is important to note that if there is no information on the level of deterioration it can be obtained with the help

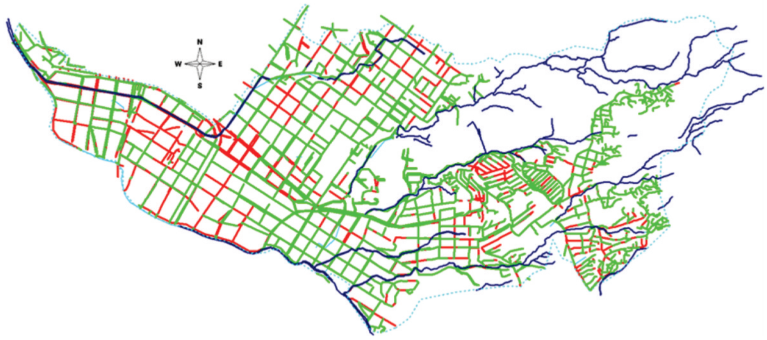


Figure 2
Schematic of the sections to replace and upgrade, showing the areas of greatest deterioration

of the structural and environmental index and the hydraulic index. Before running the model, inspect all the sections that meet the following condition:

(I_{se} > 11.8) and [(I_h < 0.9) or (I_h > 0.9 that will allow flow diversions)]

In addition, the same number of non-critical sections that meet hydraulic capacity must be inspected as critical sections, divided by the sector's total sections.

(I_{se} ≤ 11.8) and [(I_h < 0.9) or (I_h < 0.9 and that will allow flow diversions)]

In the EPM case:

- The percentage to be applied to the non-critical sections is found with I_{se}
- Sections with critical I_{se}: 842 sections
- Sections with non-critical I_{se}: 3456
- Total sections 4298
- Percentage: 19% (842/4298)
- Sections with I_h > 0.9 = 426
- Sections that meet (I_{se} > 11.8) and [(I_h < 0.9) or (I_h > 0.9 that will allow flow diversions)] = 760
- Sections that meet (I_{se} ≤ 11.8) and [(I_h < 0.9) or (I_h > 0.9 and that will allow flow diversions)] = 3115
- Sections to inspect: 760 + 3115 x 19% = 1351 sections (44.6km approximately)

Results

Once these sections have been inspected, the model is run for the selected sections and the level of deterioration scores obtained in this activity are entered.

We conducted a case study for a section in the Santa Elena basin and obtained: 426 sections to upgrade that do not meet the hydraulic conditions; and 727 sections to replace and upgrade that are not structurally and environmental sound, which comes to 1153 sections (around 38km) that need replacing and upgrading.

As a result of applying the model, a GIS with a map similar to the one shown in Figure 2 was obtained, which includes the sites to replace and upgrade (sites in red) in a consolidated manner.

Conclusions

The decision making model for replacing sewer pipes is based on knowing the variables that govern the network's hydraulic, structural and environmental behaviour and the rate and weight they each have in order to include them in a decision model. This tool is very useful for the planning and budgeting phases of the projects to be implemented in the short- and medium-term.

The decision making model can be applied using a template in a GIS. For the moment this has been applied for just pipes located within the metropolitan area of Medellín, but the model may be used in other sectors. Likewise the criteria can be used and the calculations undertaken using Excel spreadsheets.

By applying the decision making model we obtained an estimate of the criticality of the sections, including structural, environmental, and hydraulic parameters. The combination of these parameters allows us to establish network replacement plans, assessment, and inspections, from various perspectives. Currently, EPM is developing a replacement plan on the basis of the decision making model for the next ten years. This is a period during which we expect to update our information, and we hope to establish a network modelling contract and make good progress inspecting the system using CCTV inspections in order to improve the model's results.

The decision making model is a dynamic model, based on the information available in the system. The criteria were established so that they were all dimensionless in order to be able to weight them all in the same equation, and based on the multi-objective analysis, weights were assigned to each variable in order to rate them according to the variables' influence on the network's behaviour. It is important for the information to be spatial, as well as the results, as this allows us to identify work fronts or work areas which will lead to the least possible impact on the community.

The ideal case for the use of this methodology would be to have CCTV inspections of the entire system. For now this is not possible due to the large extent of the pipe network. EPM is currently developing a project to conduct an inspection of all the pipes in the coming years. The decision making model does not exempt EPM from inspecting the entire system, as the model infers the network's status, and on several occasions it has been found that 80% of the model's results match reality.

Together with the large amount of pipework that exists in the Aburrá Valley, the decision making model is a helpful tool for prioritizing the sectors that require prompt intervention, the formulation of replacement plans, and the prioritization of CCTV inspections. ●

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This paper was presented at the 5th IWA International Conference on Benchmarking and Performance Assessment of Water Services in Medellín, Colombia, held 9-12 April 2013.

Asset management capacity development using a structured framework

Asset management has been developing over the past decades and is being increasingly used to form a structural framework to meet regulations and improve business efficiency. George Illaszewicz and Roland Bradshaw provide an overview of asset management development, with examples of application in Canadian communities.

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Asset management is the set of coordinated activities an organization uses to realize value from tangible and intangible assets in the delivery of its objectives. In other words, it is the practice of investing the appropriate resources in deliberately identified activities to achieve, as best as possible, the desired results. The measured approach itself promotes alignment of the asset management processes with the organizational strategy and objectives.

Asset management is not a new concept. The practice of asset management, as presently envisioned, began in the 1980s. In this time, efforts have been undertaken by multiple organizations and entities worldwide to advance the asset management body of knowledge. Within Canada alone, a selection of guiding materials and mandated requirements exist for asset management. This includes: a partnership between the Federation of Canadian Municipalities, the National Research Council and Infrastructure Canada to develop case studies, tools and best practice reports for asset management; InfraGuide, which is full accrual accounting requirements for Tangible Capital Assets mandated through the Public Sector Accounting Board standard PS 3150; and most recently participation in the development of the international standards for asset management systems, ISO 55000.

As the understanding and acceptance of asset management as a powerful business process spreads, organizations, municipalities and governments are growing increasingly interested in improving their capacity for engaging in asset management in-house. With the wide range of requirements and guidelines, and occasionally conflicting information, the focus drifts from understanding the concepts to trying to understand how the pieces fit together. A structured framework spanning the breadth of asset management disciplines offers a powerful tool for clarifying these relationships, while returning the emphasis to development or improvement of organizational asset management capacity.

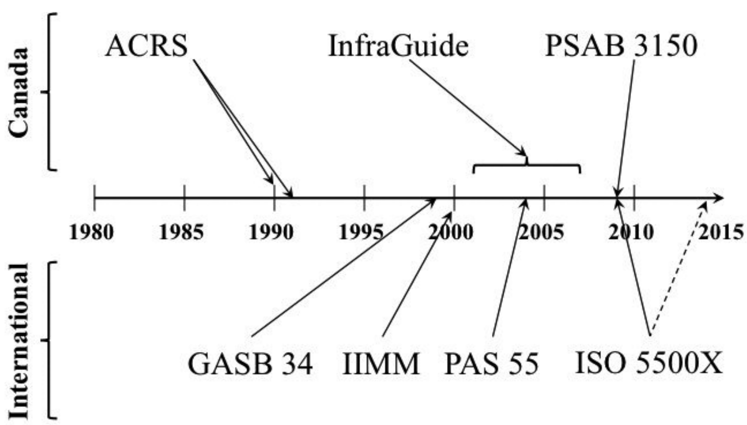

Figure 1
An abridged history of asset management development

Definitions

Framework (conceptual / structured)

One definition of frameworks proposed by Rapoport is that: 'Conceptual frameworks are neither models nor theories... models describe how things work, whereas theories explain phenomena. Conceptual frameworks do neither; rather they help to think about phenomena, to order material, revealing patterns – and pattern recognition typically leads to models and theories' (Rapoport, 1985, as cited by Cuthill & Fien, 2005). Accepting this distinction between theories, models and conceptual frameworks, a structured framework would then imply an intermediate point between a prescriptive model and a conceptual framework.

In general, a framework represents an organization's understanding of the world. To enable capacity development, a framework must exist to provide the frame of reference. To be useful, the framework must allow an organization to locate itself on the framework, understand the opportunities that may be available to it (e.g., either for increasing or decreasing organizational capacity), and make informed decisions and corresponding changes (e.g., capacity development) as need be.

Capacity / capacity development

For the purposes of this discussion, the authors consider capacity to represent the degree to which an organization can identify needs, and plan and implement decisions to achieve desired outcomes. Capacity development therefore represents 'transformations that empower individuals, leaders, organizations and societies' (UNDP, 2009). The outcomes are largely unique to the organization, but are typically oriented around delivering the expected levels of service from infrastructure assets for the system users. The asset management framework presented herein does provide a measure of 'maturity' of the associated processes, but does not inherently imply a level (high versus low capacity) or quality (good versus bad) related to the capacity development.

When considering capacity and capacity development, it is also important to consider the difference between the concepts of competence and capacity. While these constructs work hand-in-hand to achieve the organization's desired objectives, the authors consider competence to be a subset of capacity at an individual level whereas capacity represents the organizational collective ability to reach their objectives.

Asset management

A variety of definitions exist for infrastructure / physical asset management, though the concepts are largely analogous. InfraGuide considers asset management to be '[the] combination of management, financial, economic, engineering, operational and other practices applied to physical assets with the objective of providing the required level of service in the most cost-effective manner' (FCM, 2005). This is similar to international perspectives. For example, the British Standards Institute (BSI) defines asset management as the 'systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan' (PAS 55-1:2008). Similarly, the IIMM defines it as '[the] systematic and coordinated activities and practices of an organization to optimally and sustainably deliver on its objectives through the cost-effective lifecycle management of assets' (IIMM, 2011).

While the definitions suggest similar intentions behind asset management, practice suggests a wide range of motivations. Canadian industry is largely condition-driven, with the belief that assets are designed to fulfil the requisite needs and condition reflects their ability to achieve the desired levels of service. In contrast, the heavily regulated municipal environment in the UK is primarily concerned with performance; assets may be in terrible condition, but that is irrelevant as long as they are achieving the required outputs. Other industries have a more risk-centric approach to their asset management practices. Considering the diverse spectrum of approaches for asset management practices, an asset management framework must retain the flexibility to address each philosophy and avoid an overtly prescriptive viewpoint.

Maturity

To achieve process improvements, a system must be available to measure the current and target capacity. A variety of systems are available, such as benchmarking, total quality management, the Deming Cycle, or Capability Maturity Models. As previously indicated, an asset management 'maturity' scale was adopted for the framework to provide a means to measure the development of individual processes. While this scale was adopted to provide a mechanism for measuring the current and desired capacity level of an organization, it is highly emphasized that the 'scores' do not imply a value corresponding to the maturity level. In other words, the achievement of an 'implemented' level of maturity may be sufficient for an organization; there is no implication that a level of 'excellence' must be achieved for every component of the framework and in many cases, advancement beyond a specified point may be undesirable.

Guidelines, standards and reporting requirements

This section identifies some of the key guidelines and standards currently recognized in the asset management field, as well as several of the reporting frameworks. The list is not considered exclusive or comprehensive, but rather intended to give an impression of the breadth of the material currently available.

Asset management
- InfraGuide Guidelines
- Ontario Ministry of Infrastructure Building Together Guide for Municipal Asset Management Plans
- International Infrastructure Maintenance Manual (IIMM)
- Publicly Available Specification 55 (PAS 55)
- ISO 55000 / 55001 / 55002

Performance / condition assessment
- NASSCO PACP / MACP / LACP
- Ontario Structure Inspection Manual (OSIM)
- Pavement Condition Ratings (e.g., MTO SP-024)
- Drinking Water Quality Management Standard (DWQMS)

Financial reporting
- Generally Accepted Accounting Principles (GAAP)
- Governmental Accounting Standards Board published Statement 34 (GASB 34)
- Public Sector Accounting Board 3150 (PSAB 3150)

Condition reporting
- Asset Condition Reporting System (ACRS)
- ASCE / CSCE State of Infrastructure Report Cards

Complementary standards
- Data Model Structures, such as the Municipal Infrastructure Data Standard (MIDS)
- Project Management Institute Project Management Body of Knowledge (PMBOK)
- Project Management Institute Standards for Program / Portfolio Management

Legislation and regulations
- Municipal Freedom of Information and Protection of Privacy Act (MFIPPA)

Examination of the development of some of the primary guidelines and standards on a historical timeline (Figure 1) offers an interesting perspective of the relationship of individual guidelines and standards to each other. The international approach to asset management appears to have developed primarily from a performance perspective, as is reflected in driving documents such as the IIMM and PAS 55. Contrarily, Canada has had a strong focus on asset condition from the onset.

A wealth of valuable information is available from the collective resources available, both those identified above as well as others omitted for brevity. The difficulty lies in capturing the pertinent concepts and distilling the intended message to retain the value while eschewing obfuscation. The Asset Management Framework was initially developed to address this challenge.

Capacity development or maturity frameworks

A variety of capacity development and maturity assessment frameworks already exist, including within the asset management industry. For instance, a detailed and comprehensive framework has been developed by the Institute of Asset Management (IAM) to assess compliance with PAS 55.

Similarly, processes within the IIMM are evaluated against a maturity continuum that identifies minimum, core, intermediate and advanced maturity. With respect to personnel capacity / competence, the IAM provides a variety of certification and endorsement schemes. Similarly again, the Asset Management Council of Australia has also developed a framework representing their view of asset management and against which to assess asset management practitioners' competence. While the complexity of these frameworks may seem daunting to smaller or less-developed organizations, with some external assistance there is no reason that the benefits and efficiencies of asset management cannot be achieved.

Components of the asset management framework

With frameworks in general, their usefulness is limited by their understandability and applicability. In other words, '[the] challenge is in designing a framework that is comprehensive enough to capture the key issues, but that continues to be manageable' (UNDP, 2009). As a result, one goal of the framework was to present the collective information as simply as possible in order to avoid dissuading its adoption by smaller organizations while still retaining applicability for advanced users. Alongside those goals was the need to retain flexibility for a wide range of potential situations.

The asset management framework was developed to include 11 distinct but interrelated components arranged to follow, as best as they could, the Deming Cycle for continual improvement:

- Strategy and policy
- Inventory
- Condition and performance
- Valuations and financial review
- Knowledge management
- Ownership, responsibility, authority and resources
- Internal process development and review
- Risk assessment, management, and emergency response
- Business management
- Long-term vision and monitoring
- Stakeholder management

To assess organizational capacity maturity, each component was individually rated on a five point scale representing awareness, in development, implemented, integrated, and excellence. As a result of the framework structure, simplicity, and inclusion of the maturity rating scale, a significant feature of this framework is its immediate scalability and flexibility for application in both large and small settings.

Case studies

North West Territories – AE applies the asset management framework to capacity development training

Associated Engineering recently applied an asset management framework to a project for four communities in the North West Territories (NWT). Together with the communities, our objectives were to:

- Assess the current state of each community's asset management maturity and desired level of maturity to develop a roadmap for capacity development
- Complete a survey of all Tangible Capital Assets (TCA) owned and maintained by the communities, and prepare a comprehensive database to capture, retain, and control this information
- Conduct training workshops to advance the community asset management understanding and capacity
- Provide a decision support software application (AssetNav) and training on its use to empower local employees, and improve the communities' asset management decision-making practices and associated activities.

While development of a comprehensive TCA inventory and asset inspection was performed independently for each community, the remaining objectives were delivered collaboratively to all the communities to reduce the overall project costs. In order to permit the delivery of a customized output to each client within a communal environment, it was necessary to integrate the asset management framework into the project from inception.

AE's initial two-day project workshop functioned both as an introduction to general asset management principles, using the Asset Management Framework as the workshop structure. Individual training modules were prepared for each component of the framework, with each module introducing and presenting an overview of the related concepts. The immediate purpose of this training was to bring all project participants to a unified understanding of the project concerns. At the end of each module, workshop attendees were introduced to the framework and levels of maturity associated to that module. Each attendee was then provided the opportunity to rate their current and ideal levels of asset management maturity pertaining to the module. At the end of each module, prior to the self-evaluation, it was again emphasized that a 'higher' level of asset management maturity is not a required or necessary goal; rather, it is important that organizations consider what level of investment and effort is appropriate for their unique situations.

By concluding the modules with a self-assessment session, the training session also provided an opportunity to measure current and desired maturity of local asset management practices. This maturity measurement provided the baseline metrics for providing project road mapping and assessing project success. All four communities were found to be at a basic (awareness) level of maturity upon completion of the training session, with the targeted maturity levels and timelines varying between them. Feedback from the workshop attendees was highly positive. The local, practical perspectives and concerns expressed by the communities in the first workshops were captured and translated into the AssetNav implementation.

Prior to delivery of local servers hosting the decision support software application, AssetNav, a second two-day training workshop was run to present the software application to its final users and solicit any feedback or additional requests. Community employees were trained in applying the software to complete tasks following a training programme structured to match the asset management framework. The purpose behind aligning the software training to the asset management framework was to solidify participants' understanding of the concepts, and illustrate how the software could be used to support various elements of the asset management system. Additional feedback was solicited from the clients to further refine and improve the AssetNav deliverable.

The last major step in the projects was the delivery and installation of the updated software on local host servers. After completing the second two-day workshop session, the software was upgraded to better reflect the requirements the communities had expressed during the workshops. During the installation of the upgraded software on local servers, a final round of training was provided to each community individually to reinforce the previous training, inform them of changes to the software, and answer any subsequent questions or concerns.

AE considers the project a success. The communities are each now equipped with a complete, detailed inventory of all their assets. Further, the workshop participants showed significant increase in their understanding of asset management processes relevant to their situations, and have established champions to direct the local evolution of the practices they have chosen to adopt. Recognizing the importance and potential of a strong asset management culture, one community went so far as to establish a dedicated full-time asset management position. In all cases though, the communities are well positioned to achieve their targeted levels of asset management maturity and understand the next steps needed to take them there.

Perhaps the most important lesson learnt from this case, however, is that an organization is never too small to embrace an asset management culture.

Ontario – AE supports and simplifies condition reporting requirements

The NWT case study illustrated a project where the structured asset management framework from inception to its effective conclusion. A similar decision support system was implemented by AE for an Ontario First Nation community, though, in this case, the project was initiated prior to establishment of the asset management framework. Similar to the previous case study, the project involved preparation of a comprehensive detailed asset inventory and delivery of the decision support software system.

One significant difference between this and the previous case study, however, was that the focus here was less capacity-driven than reporting-driven. As a community operating under Aboriginal Affairs and Northern Development Canada's ACRS reporting regulations, they have long been completing detailed asset condition inspections and maintaining an asset inventory using complicated and effort-intensive manual processes. The primary objective of the project, therefore, was to facilitate and improve the processes used to comply with governing regulations while empowering the community to better utilize the valuable information collected. While the community in this project had existing processes in place to meet their reporting requirements, this project can be considered an effort in capacity development in that its goal was to simplify and streamline these processes. Further, the capture and retention of historic records provides the community with an invaluable source of evidence for future infrastructure decisions.

The asset management framework was applied to this project in two situations:

- To assist in the development of the AssetNav software capabilities
- To provide structure for the final software training session

One of the important components of the project was additional refinement of AssetNav to empower users in evidence-based decision making. The software was closely examined through the individual framework components to consider where it provided, or could provide, support for the associated processes. To this end, the former application was the more significant of the two, as it provided a structure to assess the existing strengths and weaknesses of the software deliverable, and to identify and prioritize areas for improvements.

To achieve the project objectives, advanced reporting functionality was embedded within the decision support software application AssetNav. The reporting functionalities empowered the community to streamline their processes for reporting infrastructure conditions and remaining fully compliant with the regulations. Upon satisfactorily upgrading the software to meet all the reporting needs, AE presented it and its usage to the community. To emphasize how the software's features support evidence-based asset management practices, the software's use was demonstrated from the context of the asset management framework prior to end-user hands-on training.

Again, AE and the project stakeholders both consider this project a success. While the project was expected to be a success prior to the inclusion of the asset management maturity framework, its application clearly strengthened the final product. The application of the framework provided a more direct application of expert knowledge in assessing, and therefore improving, the final deliverable. The framework's inclusion in the final training was less significant, but still resulted in the delivery of a strong, clear message.

Conclusion

The two case studies illustrate separate examples of the successful implementation of the structured framework in asset management capacity development. The first case utilized the framework primarily as a direct training aid, and to provide structure to workshop training modules. The structure resulted in the delivery of a focused, consistent message that was clear and comprehensible. Further, it provided a logical structure for the participants to understand and appreciate the requirements of, and relationship between, different components behind asset management processes.

The outcomes of the first case study illustrate a concept whose importance cannot be overstated: an organization is never too small to embrace an asset management culture.

The second case utilized the framework in a more behind-the-scenes approach as a tool to stimulate and concentrate expert knowledge. In this use the framework proved an equally effective tool for developing the capacity of the system that would ultimately support the community in their asset management efforts, and can therefore also be considered to have been an effective tool for supporting asset management capacity development.

As the culmination of an international effort in distilling and aggregating asset management perspectives and practices, the ISO 55000 standards can be expected to provide a relatively comprehensive view on asset management systems. Despite this, there is still a need to incorporate local, regional, and national requirements for asset management as well as other applicable or desired guidelines, regulations or standards into organizations' practices. The authors believe that such structured frameworks will offer a platform to deliver a uniform perspective of the key puzzle pieces to assist in such capacity development activities well into the future. ●

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Development of an asset management framework: the case study of NWSC, Uganda

Uganda's National Water and Sewerage Corporation (NWSC) has had to meet the needs of a rapidly growing customer base, but infrastructure investments have not been implemented in line with asset management best practices. This has resulted in assets being increasingly stressed from overuse, misuse, underfunding and aging. Gilbert Akol Echelai discusses NWSC's efforts to now implement best practices in asset management in order to attain the core objectives of maximising returns from the use of these assets, while minimising the total cost involved in their acquisition, operation, maintenance and disposal at the end of their life-cycles.

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National Water and Sewerage Corporation (NWSC) is a fully owned government parastatal that was established by the Government of Uganda in 1972 with help from the World Bank, United Nations Development Programme (UNDP) and the World Health Organisation (WHO). The mandate of the corporation is defined in the National Water & Sewerage Corporation Statute of 1995, Section 5 (1), which is to operate and provide water and sewerage services in areas entrusted to it, on a sound, commercial and viable basis. NWSC's operations were initially in three towns of Kampala, Jinja, and Entebbe. Currently, NWSC operates in 23 urban centres spread across the country (see Figure 1).

Like many African countries, Uganda is experiencing rapid urbanisation estimated at an average annual rate of 5.5%. The 2012 Uganda Statistical Abstract puts Uganda's total population at 34.1 million people, with 14.7% (approximately 5.1 million) living in urban centres. Kampala, which is the largest urban centre in Uganda, has an estimated population of 1.7 million people. The GDP growth rate as of 2002 market prices was registered at 5.9% (the last time it was measured). This has translated into the development of the service and industrial sectors, hence compounding the need for water and sewerage services across the country.

In order to meet the increased need for water and sanitation services in the urban centres where it is mandated to operate, NWSC has made significant infrastructural investments. These investments have been in expansion of its water and sewerage network (Network Extensions and intensifications), increase in the number of new connections (customer base), increase in the water storage capacity by establishment and expansion of water storage reservoirs and increase in the water production and sewerage treatment capacity through rehabilitation of existing plants and construction of additional treatment plants.

Given the wide coverage and large investments and the great potential for further expansion, NWSC now realises the need to implement best practices in asset management if it is to attain the core objectives of maximising returns from the use of these assets, while minimising the total cost involved in their acquisition, operation, maintenance and disposal at the end of their lifecycles.

It is against this background that the corporation identified asset management and efficiency as one of its core perspectives in the 2012-2015 Strategic Plan, in line with the theme of the

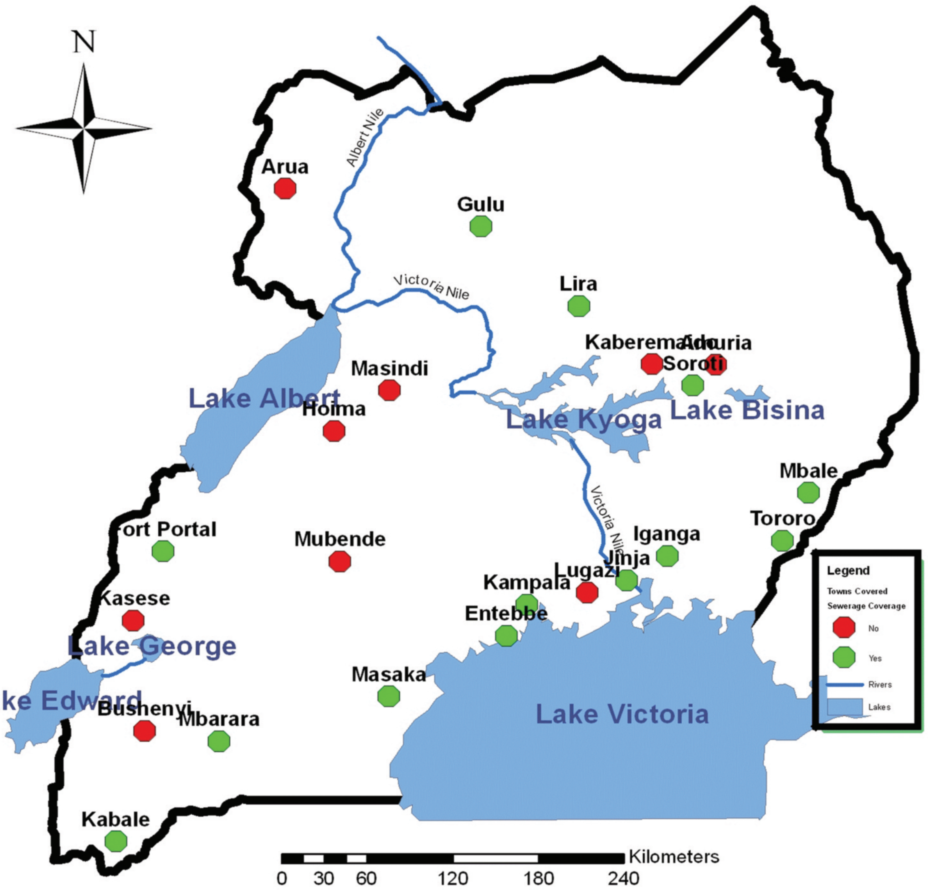

Figure 1 A map of Uganda showing towns covered by NWSC, identifying those with established sewer networks and those without

corporate plan 'Enhancing Financial Sustainability and Infrastructure Growth' of the Corporation. NWSC is now in the process of establishment a comprehensive asset management framework.

Literature review

A number of definitions have been used in order to capture the scope of asset management. These definitions have kept evolving over time as the asset owners, operators, and stakeholders grapple with what exactly constitutes asset management. The complexity in asset management was expressed by Warren Causey (2005). He stated: 'Everyone knows what asset management is, they are just not sure what to call it.' He went ahead to explain that definitions have overtime kept changing partly being driven on one side by the software vendors and on the other side, the users or players in asset management. He goes ahead to pose a few questions: Is it enterprise resource planning (ERP)? Is it enterprise asset management (EAM)? Is it a system that produces process improvement from generation to the field? Is it inventory, financials, warehousing, wires and pipes, or people? What exactly constitutes an asset? Increasingly, utilities are determining that virtually everything they possess is an asset – from the information stored in automated systems, recorded on paper, or even communicated by word of mouth.

According to the United States Federal Highways Administration (1999), asset management is a strategic approach to the optimal allocation of resources for the management, operation, maintenance, and preservation of transportation infrastructure. It further explains that the concept of asset management combines engineering and economic principles with sound business practices to support decision-making at the strategic, network, and project levels. Although by specifying transportation infrastructure, this definition becomes specific to transportation sector, it nonetheless identifies and explains what asset management is as it can be applied in the context of any asset in any sector and industry.

Cambridge Systems Inc. (2004) defines asset management as a set of business principles and best practice methods for improving resource allocation and utilization decisions. It reflects a comprehensive view of system management and performance with the core principles being that it must be: quality driven, involve analysis of options, have decision making based on quality information, and finally, have monitoring to provide clear accountability and feedback. This definition rightly identifies resource allocation (planning) and resource utilisation (operation and maintenance), but rather does not address the exit of an asset from the system and this is important in asset management.

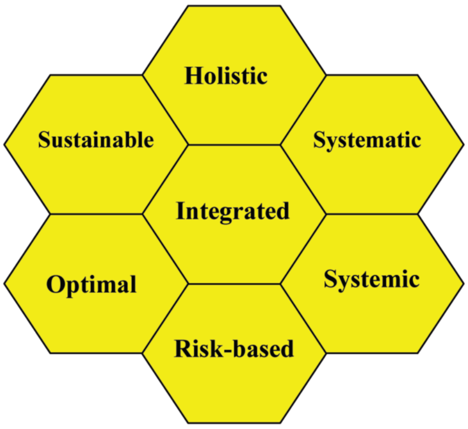

Figure 2
The seven key principles and attributes that underpin the implementation of asset management. Source: adapted from PAS 55 – 1.

AMSA (2002) defines asset management as an integrated optimisation process of managing infrastructure assets to minimise the total cost of owning and operating them, while continuously delivering service levels customers desire, at an acceptable level of risk.

The standard BSI (2008) defines asset management as systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life-cycle for the purpose of achieving its organisational strategic plan. The standard further defines an organisational strategic plan as 'overall long-term plan for the organisation that is derived from and embodies its vision, mission, values, business policies, stakeholder requirements, objectives and the management of its risks.'

Although varying in extent and scope, the above definitions serve to illustrate the different ways in which asset management can be understood and implemented by different organisations. What is common in all these definitions is that asset management takes into consideration capital investment and operations costs, maintenance of adequate service levels, and minimisation of risks to acceptable levels throughout the life-cycle of the assets.

Kaganova (2011) defines capital investment in the context of the public sector, and of local governments (LGs) in particular, as investment in the acquisition or building of new assets or major repair and replacement of existing assets that have an economic life longer than one year and a value above a specified threshold. Capital investment planning (CIP) by LGs includes (or should include) capital investment by the government itself and by its entities, including enterprises established and owned by the government for the provision of municipal services (utility companies). CIP also may include investment by the private sector through public-private partnerships (PPPs). This definition adequately covers the planning of and acquisition of assets by NWSC in executing its mandate of providing potable piped water to the urban centres across Uganda.

Gilbert (2006) asserts that the human species' greatest and most unique ability is to imagine and anticipate objects and episodes that do not currently exist, that is, to plan for the future. That is our individual and collective strength. Gilbert (2011) further asserts that in this context therefore, it is important that utilities utilise planning as a means of ensuring that the future needs of the populations that they serve are provided for in current interventions aimed at providing services.

Todd (2011) defines planning as the process of deciding what to do and how to do it. Planning occurs at many levels, from day-to-day decisions made by individuals and families, to complex decisions made by businesses and governments. He adds that one of the principles of good planning is that individual, short-term decisions should support strategic, long-term goals. In acknowledging this, it is important that comprehensive evaluation and negotiation is undertaken in order to help people accept solutions that may seem difficult and costly in the short-term.

The acronym GIS stands for Geographical Information Systems. Wade (2006) defines GIS as being an integrated collection of computer software and data used to view and manage information connected with specific locations, analyze spatial relationships, and model spatial processes. It can therefore be inferred that GIS is a computer-based system used to store and manipulate geographic information with the following four sets of capabilities to handle geo-referenced data: data input; data management (storage and retrieval); data manipulation and analysis; and finally information output. To constitute a GIS there must be skilled personnel, hardware and software that provide for the capture, management, manipulation and information output.

In this paper, the efforts to develop and implement an asset management framework by NWSC have been documented. A number of case studies and reference materials have been consulted in order to arrive at a framework that meets the overall objective of the corporation of ensuring that the productivity of its assets is maximised while lowering the cost of acquiring and managing them throughout their life.

Background

Uganda's rapid urbanisation, which has been driven by rural-urban migration due to the search for jobs and better services, has led to increased demand for water and sewerage services.

The following are some of the major capital projects undertaken by NWSC from 2009-2012: Gaba Offshore Intake Project (€7 million ($9 million)); Jinja Walukuba Intake Project (€2.5 million ($3 million)) completed in 2011; Kampala Sanitation Programme Phase I and Phase II (€15.3 million and €84 million ($20.4 million and $112 million) respectively) ongoing; Kampala Water Lake Victoria WAT-SAN Project (€212 million ($283 million); Uganda Water Development and Management Project targeting Gulu, Arua, Bushenyi and Mbale supply areas ($55 million); and the rehabilitation and expansion of Gulu water supply and sewerage system ($17 million), among others.

The implementation of the above projects has led to the growth of new connections and thus increases in service delivery for both water and sewerage connections. Between 2009 and 2012 there was a total of 945 new sewerage connections and 71,187 new water connections (an annual average of 23,729). This paper focuses on the efforts by NWSC to implement and institutionalise asset management at the corporate level.

Asset management in NWSC

The term asset management is not new to NWSC. It is, however, the context within which it is defined that has changed and triggered interest and the need for its institutionalisation. It has always been about the general housekeeping that every organisation does. However, with the growth in its asset portfolio, NWSC realised the need for an integrated asset management framework.

The definition and understanding of asset management by NWSC is borrowed from the Publicly Available Specification (PAS) – 55-1. This standard has been developed by the British Standards Institute (BSI) in collaboration with The Institute of Asset Management (IAM). This standard defines asset management as 'systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life-cycle for the purpose of achieving its organisational strategic plan'. It further defines an organisational strategic plan as 'overall long-term plan for the organisation that is derived from and embodies its vision, mission, values, business policies, stakeholder requirements, objectives and the management of its risks'. While borrowing from this definition, NWSC has further defined the extent of its asset management framework as being property, plant and equipment. In implementing an asset management framework, NWSC seeks to minimise the total costs associated with the acquisition, operation, maintenance and renewal of its property, plant and equipment within an environment of limited resources while continuously delivering service levels desired by customers within the legal requirements at an acceptable level of business risk to the stakeholders.

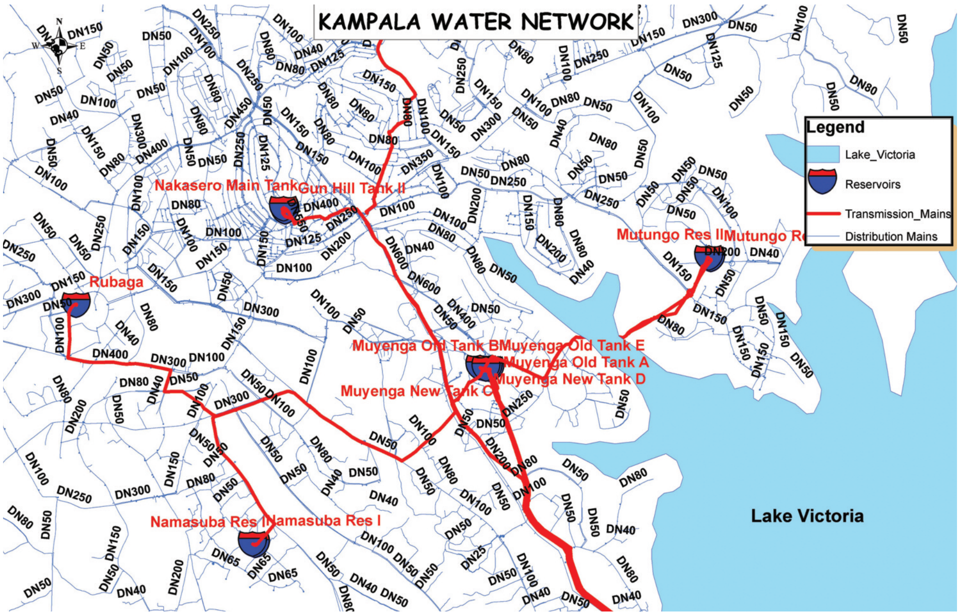

Figure 3 An extract of the water network for the Kampala supply area

The NWSC definition of asset management is premised on five core components:

- Definition of its asset inventory: within the context of physical property, plant and equipment, NWSC seeks to answer the following questions: What does it own as a utility? Where is it? What condition is it in? What is its remaining useful life? And finally, what is its worth?
- What is the optimal level of service? For each asset identified, it is the definition of how the utility wants it to perform in order to ensure that service delivery by the utility is not compromised. This level of service will need to be communicated, be a means of assessing overall system performance, provide a link between costs and service, identify critical assets, service as a guide for internal control and generally reduce costs.
- Which assets are critical to its operations? It is important to understand that not all assets have the same level of criticality in any business. Criticality is determined by how likely an asset is to fail, and what its failure may mean to the utility. This is where aspects of age, condition, failure rate, experience with the asset and the asset history all help to shade light on how likely an asset is to fail. The consequences of failure on the other hand, can be determined by the cost of repair, social costs, legal costs, environmental costs, and reduction in service, among other costs. It is the overall assessment of these factors that will lead to the development of a ranking system for each and every asset under consideration.
- How shall life cycle costing be conducted? The Environmental Finance Center (2006) explains lifecycle costing as 'focus on management options and strategies considering all relevant economic and physical consequences, from initial planning through to disposal'. It therefore includes planning, acquisition or creation or design of an asset, financial management, asset operation and maintenance, condition and performance monitoring and evaluation of an asset, rehabilitation or renewal of assets, disposal and asset audit and review.
- What is NWSC's long-term funding strategy? This is the determination of the best strategy to realise funds for

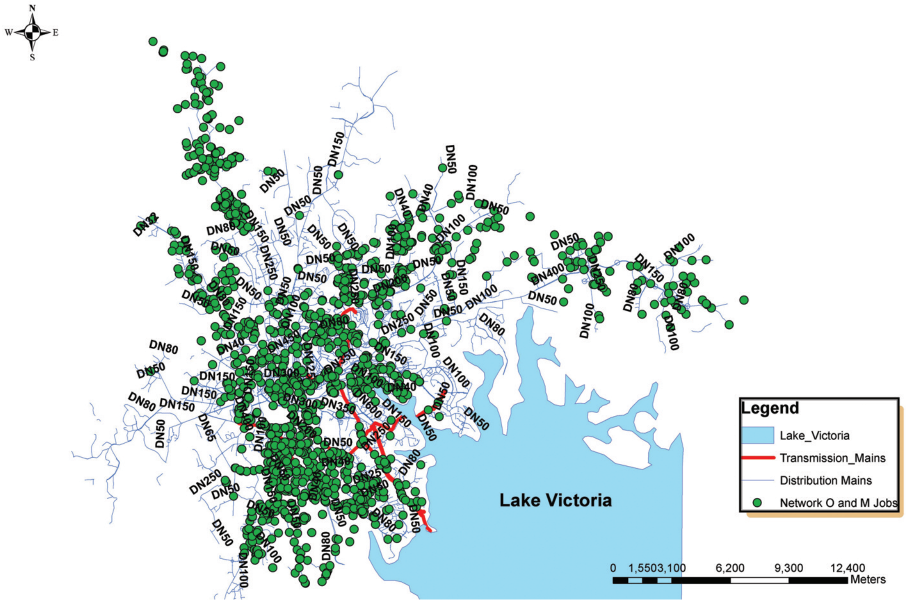

Figure 4
Map of Kampala showing locations of network failures

the acquisition, maintenance, repair / renewal and replacement of the asset. One therefore needs to look at the available options which include the revenues to the utility, utility reserves and funds (bonds, taxes, etc.), and loans / grants.

This signifies that NWSC will be taking a fundamental turn in moving from historical reactive (run-to-failure) models to embracing whole life planning, life cycle costing, planned and proactive maintenance. The Corporation realises the organization-wide impact and interdependencies that exist in its operations, design, asset performance, personnel productivity and lifecycle costs. The assets will be managed across departments, locations, facilities and, in some cases, business units. This is to ensure that by managing assets across the facility, the Corporation will improve utilization and performance, reduce capital costs, reduce asset-related operating costs, extend asset life and subsequently improve return on assets. This shift in focus exemplifies the intended progression from maintenance management to enterprise asset management.

How does it envisage implementation?

NWSC realises that adopting an asset management system will generate a need to create enabling business processes and information systems that will support management of the Corporation's assets. PAS 55 identifies seven key principles and attributes that underpin the implementation of asset management. These are diagrammatically illustrated in Figure 2.

In line with the seven principles above, the following has been done by NWSC:

- Holistic. This principle looks at the whole picture of the asset portfolio by emphasising the combined implications of managing all aspects of an asset, including the different types of assets and their interdependencies. This principle promotes a methodical approach, promoting consistent repeatable and auditable decisions and actions. NWSC has identified its scope as being the life-cycle of the assets.
- Systematic. In line with this principle, NWSC will follow a methodical approach. It has therefore documented the procedure for asset management in line with the requirements of ISO 9001:2008, which is being implemented by the organisation.
- Systemic. NWSC recognises that asset management must be looked at in the context of their systems. The understanding of which assets form which system shall be critical in this implementation.
- Risk-based. NWSC commits to incorporate risk element into the entire decision-making chain of an asset. Resource allocation should reflect the risk identified and the associated costs and benefits.
- Optimal. Seeking the best win-win situation when faced with making a choice between conflicting objectives, such as costs versus performance versus risks. It recognises that interdependencies and combined effects are vital to success.
- Sustainable. Asset management plans must be sustainable in implementation as opposed to being one-offs. Sustainability should cover asset life cycles, systems performance, environmental considerations and any other long term consequences.
- Integrated. The NWSC framework should be interlinked or joined-up. This is where GIS is critical in ensuring that the operations, repair, maintenance, risk analysis, location, depreciation, etc. can be integrated.

The core elements and the seven principles will form the backbone of the asset management elements in NWSC.

What has been done?

The implementation documents identified by the PAS 55 standard include the organisational strategic plan, asset management policy; asset management strategy; asset management objectives and finally, the asset management plans. The completion of the development of the above documents will signal the readiness of NWSC to institutionalise asset management. To date, the following has been done:

Organisational strategic plan

NWSC's organisational strategic plan is the corporate plan which is developed to cover the planning period spanning three years. The current corporate plan (June 2012-July 2015) is themed 'Enhancing financial sustainability and infrastructure growth' (NWSC, 2012). It identifies asset management and efficiency as one of its strategic goals for the three years in line with the expectations of the stakeholders. This is in line with its vision, mission and values. It can therefore be seen that asset management is embedded within the corporate plan of NWSC.

Asset management policy

The role of the policy is to outline the management objectives, and plans relating to asset management. It creates the basis for service delivery against which the asset management strategy and plans can be developed. The policy will outline in detail the five core components of asset management: asset inventory; criticality of the assets; definition of optimal level of service for each asset or asset categories; the asset ranking based on their criticality; life-cycle costing; and the long-term funding strategies. In addressing asset inventory, NWSC has defined seven categories (civil structures, electro-mechanical equipment, IT & office equipment, pipe works, transport equipment, land, and technical process structures). All these shall be looked at within the overall objective of ensuring optimal and sustainable acquisition, use, maintenance, renewal and disposal of assets for the purpose of achieving the strategic goals of NWSC. NWSC is now at this stage and has started the documentation of the policy. The policy is still in its initial stages with only the first core component of inventory making considerable headway due to a number of challenges.

Asset management strategy

The development of the policy will form a platform for the preparation of the asset management strategy. The strategy will define how asset management policy will be implemented as well as ensuring that asset management is established as part of NWSC's plan for the future. The strategy will define what we want to be as a result of implementation of asset management and how we will get there. This calls for identification of the resources and timeframes, ensuring accounting and regulatory compliance, improvements in processes and skills that need to be undertaken, data and other system requirements that may be desired for successful asset management implementation, as well as defining performance levels and ensuring accountability and transparency. We have not yet reached this stage in developing our system. However, successful completion of the policy and the commitment of both management and staff will be critical.

Asset management plans

These are the more detailed definitions of processes that will be used to operationalize the strategies. Plans will define levels of service for each asset category with reference to the inventory / asset register which identifies the assets, strategies to manage funding gaps, schedules of asset management plan reviews, asset management improvement programmes, considerations of alternative service delivery options in the event of failure or constrain on the current available, and demand forecasting and its effects among other things.

Challenges and the way forward

In attempting to implement asset management, NWSC is already experiencing a number of challenges. These challenges present opportunities for NWSC to address its internal institutional bottlenecks in order to position itself for better service delivery. These challenges have been identified as NWSC tries to answer the critical questions in asset management.

It is difficult to distinguish between one part of an asset from another.

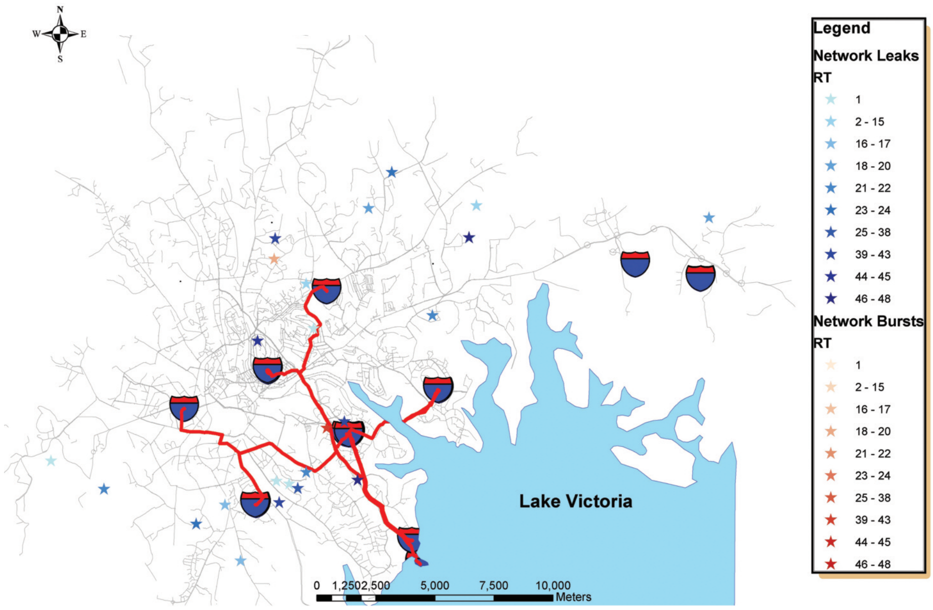

Figure 5
GIS attribute table displaying records linked to the call centre database

This is particularly so for the sewer and water pipe networks. This calls for the identification of different sections and then linking these sections to each other. This is a very tedious exercise, which will require a lot of resources if it is to done properly. The nature of water and sewerage infrastructure is such that there are many nodes formed by joining one section of a pipe to another (Figure 3).

The ability to accurately document the condition of any asset is largely determined by the degree of interaction between the investigator and the asset. This requires that one can see, touch, feel, perform a test, etc. on the asset to determine its condition and functionality. However, for most utilities, the assets are underground. Therefore, in conducting a condition survey of the water and sewerage network and the attendant fixtures, this is a big challenge that requires exposure of these assets or acquisition of special equipment in order to be able to determine these conditions. The way forward is to institutionalise periodic asset condition surveys aimed at ascertaining the status of such buried assets.

The lack of an appropriate asset management policy, strategy and plan is also an issue. The asset management policy is still in development. The completion of the review of the policy will lead to the development of the strategy and finally the plans that can be implemented. In the absence of these, there is still no clear defined way of handling asset management at the moment.

There is also a culture of poor documentation. The staff are used to 'business as usual' practices where maintenance staff perform maintenance works and are not inclined to provide the records relating to the diagnosis and what has been undertaken to address the failure. This generates a situation where data critical to asset management is either incomplete or non-existent. In addressing this challenge, NWSC has institutionalized a call centre database based on the official mailing application Lotus Notes. Currently, every job is registered once reported, assigned through the official mail and the respective supervisor notified. Diagnosis is registered by the officer and forms the basis for requisitioning of the materials to be used. Once the field work is done, a job card containing the diagnosis and what has been undertaken is then printed and signed by the officer in-charge and his supervisor endorses. These job cards are then entered into the GIS database to register the spatial locations of where the jobs were done. The point locations generated are then linked to the call centre database to enable spatial querying of the call center database and its analysis (Figure 4).

The link between the GIS spatial locations and the call centre database is through a unique attribute generated from the call centre database, each time a new job is registered. This unique attribute is captured in the GIS during the creation of the spatial locations (Figure 5).

Although data regarding the assets and their location exists, details of the conditions of these assets are either incomplete or not existing at all. A number of assets currently owned by NWSC were taken over from previous private operators who did not maintain such information. Additionally, the culture of documenting asset conditions is still inadequate in the institution. The water and sewerage infrastructure network is the most affected by pipes that were laid in the early 1960s as no information exists about them. NWSC therefore proposes a systematic asset condition assessment for the asset portfolio where such relevant information does not exist or is incomplete.

Finally, like any initiative, dedicated staffing is critical to the success of the asset management implementation. This is currently not the case in NWSC as the teams spearheading asset management have varied commitments. Clear implementation of the asset management in NWSC will require the creating of a unit / department charged with spearheading the process. This will mean the recruitment / capacity development of staff in order to meet the needs of asset management. It is against this background that NWSC is participating in workshops and has the willingness to develop the capacity of its staff and as well implement the PAS 55 standard in asset management. Like any organisation, recruitment is always a challenge as it is looked at in terms of the additional costs that come along with it. ●

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A multi-criteria model to determine the sustainability level of water services

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Sustainability is frequently associated with the triple bottom line (TBL) approach, but this is not sufficient to describe the sustainability of urban water cycle services (UWCS) since technical and governance aspects are also relevant. Nuno Ferreira da Cruz and Rui Cunha Marques suggest several dimensions, objectives and criteria that represent the sustainability level of UWCS and use a multi-criteria decision analysis model to aggregate these numerous aspects.

There is no unique pathway for the adoption of sustainable practices for utilities, cities, or any other organization involved in urban water cycle services (UWCS). Therefore, there is currently no consensus on how to assess the sustainability of UWCS, although some recent proposals have been made (e.g. van der Steen, 2011, and van Leeuwen et al., 2011). It is obvious, nevertheless, that the complexity of the sustainable urban water cycle is high and the challenges towards achieving it are huge.

This study proposes a framework to measure UWCS sustainability. It was carried out within the TRansitions to the Urban Water Services of Tomorrow (TRUST) research project and follows the major literature in this scope (Marques, 2012). First, both the dimensions and objectives of UWCS sustainability and their corresponding assessment criteria were defined. Second, a set of performance indicators or other metrics were identified for each criterion of the 'economic' dimension. Third, a multi-criteria decision analysis (MCDA) model was developed.

The MCDA technique is particularly useful to assess UWCS sustainability. It allows for taking into account the priorities and preferences of a specific set of actors (that should represent the local, regional and / or national characteristics). For example, in a given jurisdiction some environment criteria can damage economic sustainability (e.g. demanding a high level of wastewater treatment) and the priorities of UWCS in water-scarce regions are naturally different from the areas where these resources are abundant. In addition, sustainability (of UWCS) is a highly contested concept and highly prone to different interpretations.

Water services sustainability

Regarding UWCS the sustainability concept was first defined as 'being those water resource systems designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity' (ASCE and UNESCO, 1998). The emphasis of this definition is mostly on the environmental dimension of UWCS, although the 'objectives of society' also embrace the economic and social dimensions. Urban water services have evolved significantly over time. Not long ago, water quantity, drinking quality and adequate pressure were, per se, conditions of an appropriate drinking water service. Today, they are not enough. Customers and society demand more. Water utilities should be efficient, effective and customer-responsive. The multiple actors and stakeholders with multiple objectives and interests make governance issues (e.g. participation and transparency) very important as well.

Furthermore, due to the increasing cost of water (and wastewater) services and the high investments required and the need to reflect them in polluter and user-pays principles, economic and social dimensions are more and more becoming fundamental issues. Urban water services are important for the social and economic cohesion of society. The population wishes to have a sound drinking water service at an affordable price. Indeed, customers need to feel the value of money spent.

The sustainability concept is frequently associated with the triple bottom line (TBL) approach, comprised of social, environmental and economic dimensions or principles. These dimensions can be regarded as a set of objectives relative to a particular sector that should be pursued. Some authors list criteria for these dimensions, which correspond to the 'set of factors that may be used to assess which of a range of options offers the greatest contribution to achieving sustainability objectives' (Ashley et al., 2004).

Nomenclature issues aside, the question is whether the TBL approach is the most appropriate to deal with UWCS sustainability. We, like others, disagree (at least partially). The social dimension of UWCS sustainability should include aspects related to the access to urban water services, the satisfaction of the users' needs and expectations, the public acceptance and the relevant role in the community of these services. The UWCS environmental dimension concerns the impact of UWCS on living and non-living natural systems and encompasses the optimization of the use of water, energy and materials and the minimization of negative impacts downstream. Other issues, such as biodiversity, could also be included. Finally, the UWCS sustainability economic dimension would include all the objectives related to economic and financial issues, such as the full cost recovery.

However, it seems that the TBL approach is not enough to characterize UWCS sustainability since technical (assets or infrastructure issues) and governance aspects are also quite relevant. Even if they are not ends in themselves, they are instrumental and essential for the social, environmental and economic dimensions and the objectives of sustainability (see the definition of sustainability of the TRUST project, Brattebø et al., 2012). The 'assets' dimension is associated with asset management and the system of physical infrastructure and might encompass aspects concerning the system performance, its durability, reliability, flexibility and adaptability. Governance is related to: the 'rules of the game'; the respect for those rules by the stakeholders; transparency; stakeholder participation in the decision making process, particularly customers; the effectiveness and efficiency of the measures taken; and the quality of the accountability and adjustment mechanisms. The existence and alignment of city planning with the UWCS is also a relevant governance issue.

Methodological framework

The suitability of the five dimensions (TBL plus governance and assets) was discussed in the previous section. Associated with these dimensions or principles of UWCS sustainability

Table 1: Dimensions, objectives and criteria of UWCS sustainability (adapted from Brattebø et al., 2012)

Dimension	Objectives	Criteria	Metrics (illustrative examples)
Social	a) Access to urban water services	a1) Physical service accessibility a2) Economic service accessibility	Water coverage; wastewater coverage Price of the average household consumption (e.g. 12m^3); average bill
	b) Effectively satisfy the current users' needs and expectations	b1) Quality of service b2) Drinking water quality	Interruptions; flooding of properties; billing Drinking water quality
	c) Acceptance and awareness of UWCS	c1) Willingness to pay c2) Complaining c3) Acceptance of new sources of water	Inquiry on willingness to pay Complaints; suggestions Acceptance of reclaimed water
	d) Relevant role in community	d1) Social responsibility d2) Work conditions	Investment on community Training; absenteeism; work accidents, employee satisfaction
Environment	e) Optimize the use of water, energy and materials	e1) Efficient use of water e2) Energy use e3) Material use e4) Final uses of efficiency	Leakage (real losses); leakage best practices; reclaimed water; use of grey water; rainwater harvesting; checklist of best practices Energy efficiency; energy generation; checklist of best practices Checklist of best practices (materials, chemicals and construction) Checklist of best practices (water, wastewater, rain water)
	f) Minimize downstream negative impacts	f1) Pollution prevention f2) Pollution control	Wastewater treatment coverage; quality issues (wastewater, sludge, nutrients, treatment failures, …); overflow discharges; greenhouse gas emissions
Economic	g) Ensure economic sustainability of the UWCS	g1) Investment g2) Efficiency g3) Leverage g4) Liquidity	Innovation; maintenance and replacement of assets Coverage of total costs; staff productivity Debt equity ratio Current ratio
Governance	h) Public participation i) Transparency	h1) Participation initiatives i1) Availability of information and documents i2) Accessible information and written documents i3) Public disclosure	Check list of best practices Check list of best practices Check list of best practices Check list of best practices Check list of best practices Check list of best practices
	j) Accountability	j1) Individual mechanisms of accountability j2) Collective mechanisms of accountability	
	k) Clearness, steadiness and measurability of the UWCS policies	k1) Clearness of policies defined ex-ante k2) Change of policies k3) Implementation of policies	Check list of best practices Check list of best practices Check list of best practices
	l) Existence and alignment of city planning	l1) Corporate planning l2) City planning l3) Water resources planning	Existence of plans (strategic, tactical, …) Check list of best practices Investment on community
Assets	m) Performance n) Robustness	m1) Failures n1) Flexibility n2) Adaptability n3) Reliability	Main failures; sewer blockages Checklist of best practices Checklist of best practices Replacement / rehabilitation; treatment utilization; storage capacity

Table 2. Investment indicators

Indicator	Good performance	Acceptable performance
R&D (% of turnover)	1%	0.2%
Maintenance and replacement of assets (% of network)	3%	1.5%

some specific objectives have been defined. The objectives, in opposition to the dimensions that have a more transversal scope, depend on the field where sustainability is being assessed. Therefore, we set out specific and elaborated objectives for the UWCS, which can change in intensity according to water utilities' situations and their stakeholders. Most of them are not found in other sectors but all of them embrace the TBL approach together with the assets and governance dimensions. Based on the relevant literature and on the discussions of a panel of experts, 14 objectives were defined for sustainable UWCS (Brattebø et al., 2012).

Certain criteria are associated with each objective of UWCS sustainability. Those objectives are achieved if the corresponding criteria are fulfilled (Marques and Leeuwen, 2012). For instance, to achieve the objective of ensuring 'access to urban water services' the satisfaction of the criteria a1) physical service accessibility and a2) economic service accessibility is required. Table 1 presents the criteria for the objectives defined for UWCS sustainability (Brattebø et al., 2012).

Each criterion will require the proper performance descriptors (not only indicators but other metrics, such as best practices check lists or other qualitative scoring systems), which will allow for its operationalization and measurement. A performance descriptor is an indicator or an ordered set of plausible impact levels for a criterion that allows us to measure the degree to which the objectives are being accomplished (Bana e Costa et al., 2003). The metrics displayed in Table 1 are rough indications for each criterion (relative to each objective of UWCS sustainability); they were proposed by the authors and discussed by a group of experts from the TRUST project (Brattebø et al., 2012).

The following section provides detailed metrics for the economic dimension.

Using a multicriteria methodology for the evaluation of UWCS sustainability entails several advantages. For instance, such a framework: allows for the inclusion of all types of criteria (either qualitative or quantitative); the objectives, criteria, scores and weights are explicit and transparent, allowing for open discussion; the decision-making process is participatory and can be documented, facilitating communication, auditing and reviewing; the measurement of each particular aspect (criterion) can be carried out by external experts; it is possible to compute partial and global scores which can be very informative for policy-making; methodologies for assigning scores and weights conforms to sound theoretical principles; and the whole process can be supported by computer-based tools, which speeds up the decision-making. The agenda for the MCDA framework can be easily described:

Given a set 'U' of 'm' UWCS, U = u1, u2, …, um, and a set 'C' of 'n' criteria reflecting the strategic objectives, C = c1, c2, …, cn, evaluate the UWCS considering all criteria.

However, determining and calibrating each one of these parameters is not straightforward. For instance, who will validate the set of criteria (and their respective descriptors) and provide input for weight elicitation? Moreover, to perform a global evaluation with an additive aggregation model one has to accept the 'compensatory' assumption (it must be admissible that a 'good' score in one criterion may compensate a 'bad' score in another criterion). Taking these issues into account and after the designation of the legitimate decision-maker (or group or decision-makers), a simple additive aggregation model can be used to compute the global sustainability score of each UWCS (see equation 1).

$$S(u_i) = \sum_{j=1}^{n} c_j \times S_j(u_i) \quad \text{with} \quad \sum_j c_j = 1 \qquad (1)$$

Where,
$S(u_i)$ is the global sustainability score of UWCS u_i;
c_j is the weighting coefficient of criterion c;
$S_j(u_i)$ is the local score of UWCS u_i considering criterion j.

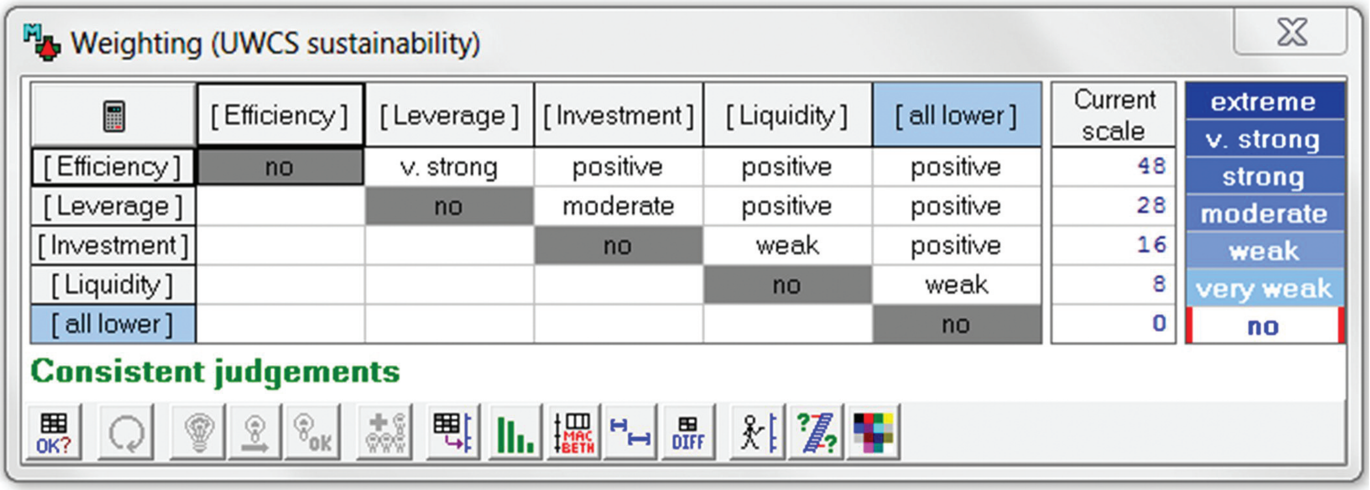
In MCDA frameworks there are two main evaluation stages: the partial (or local) evaluation of UWCS sustainability according to each criterion; and the global evaluation of UWCS sustainability (the aggregation of the partial evaluations). During the partial evaluation stage a scoring function for each criterion will have to be assumed or determined. Scoring functions associate a score (value in a predefined scale) to each level of performance or impact. Descriptors allow for the measurement of 'real-world' impacts and these impacts need to be converted into scores respecting a scale that should remain the same for every criterion. In the current study we assume a linear relationship between performance impacts and scores.

Weighting coefficient are 'scaling constants' that convert partial scores (in each criterion) into global scores. Note that the weight of a given criterion does not represent the 'importance' of that criterion; it represents the increase in the global score associated with a swing in that criterion between a 'lower bound' performance level (for instance with a local score equal to zero) and an 'upper bound' performance level (for instance with a local score equal to 100). These reference levels are useful to operationalize the notion of 'trade-off' and should be established by the decision-maker.

There are several methods available to determine scoring functions and perform weight elicitation (Cruz and Marques, 2013). For instance, to build scoring functions one can use the 'direct-rating', the 'bisection method', the MACBETH approach, among others. To determine weights one can use the 'swing weights method', the 'trade-off' method, the MACBETH approach, the AHP, etc. Here we use the MACBETH approach to construct the model. Weight elicitation using the MACBETH approach involves a process of pairwise comparisons; specifically, the decision-maker evaluates the swings between the reference levels of two criteria using seven qualitative categories for his / her judgments, namely: 'no difference', 'very weak', 'weak', 'moderate', 'strong', 'very strong' or 'extreme' difference in preference. By solving a linear programming problem it is possible to suggest weights that are consistent with the qualitative judgments of the decision-maker (e.g. the M-MACBETH software provides this automatically, see Figure 1). The next section explains in more detail the procedure to compute weights through this approach (for more on this technique see, for example,

Table 3. Efficiency indicators.

Indicator	Good performance	Acceptable performance
Total cost coverage ratio (%)	100%	90%
Staff productivity (No./1000 connections)	2 to 5 employees per 1000 connections	1.5 to 2 or 5 to 5.5 employees per 1000 connections


Weighting (UWCS sustainability)

	[Efficiency]	[Leverage]	[Investment]	[Liquidity]	[all lower]	Current scale
[Efficiency]	no	v. strong	positive	positive	positive	48
[Leverage]		no	moderate	positive	positive	28
[Investment]			no	weak	positive	16
[Liquidity]				no	weak	8
[all lower]					no	0

Figure 1
Judgments of the decision-maker (M-MACBETH software)

Bana e Costa et al., 2003).

In real-world applications, modelling should be developed with the input of the legitimate decision-maker. For instance, for the example presented in the next section, an experienced decision-maker validated the objectives and the structure of the value tree (criteria set of the economic dimension), approved the performance descriptors (metrics), and provided judgments regarding the relative importance of swings between two reference levels in each criterion.

Case-study: the economic dimension

After identifying the fundamental criteria, which is the cornerstone of a global additive evaluation model, the definition of the scales of attractiveness or scoring functions for each criterion is required. Scoring functions convert impacts (performance levels) into scores. Here we have a model that uses quantitative and qualitative criteria.

To illustrate the application of the MCDA model, we discussed the criteria and the descriptors of the economic dimension with a real decision-maker with extensive experience in UWCS management. After this, we asked him to define the upper ('good') and lower ('neutral') references in terms of performance for each criterion. This operationalizes the idea of a good performance and a neutral performance (that is, neither attractive nor repulsive). The following descriptors and reference levels were set in a decision conference with the decision maker:

Investment

Level I. Both indicators in Table 2 are at (or above) the 'good performance' level.

Level II. One of the indicators is at (or above) the 'good performance' level. The other indicator is not below the 'acceptable performance' level. – **Good level**

Level III. Both indicators are at (or above) the 'acceptable performance' level. None is at the (or above the) 'good performance' level. – **Neutral level**

Level IV. One of the indicators is below the 'acceptable performance' level.

Level V. Both indicators are below the 'acceptable performance' level.

Efficiency

Level I. Both indicators in Table 3 are at (or above) the 'Good performance' level.

Level II. One of the indicators is at (or above) the 'Good performance' level. The other indicator is not below the 'Acceptable performance' level. – **Good level**.

Level III. Both indicators are at (or above) the 'Acceptable performance' level. None is at the (or above the) 'Good performance' level. – **Neutral level**

Level IV. One of the indicators is below the 'Acceptable performance' level.

Level V. Both indicators are below the 'Acceptable performance' level.

Leverage

Debt equity ratio (-) –**Neutral level** is 4.0 and **Good level** is 2.5.

Liquidity

Current ratio (-) – **Neutral level** is 0.5 and **Good level** is 1.0.

An explicit statement regarding good and neutral levels of reference makes it possible to represent the notion of intrinsic 'value of sustainability' of each UWCS, assigning it to one of the following categories:

- Highly sustainable UWCS, when it is at least as good as a fictitious good UWCS (a UWCS that has a performance equal to the upper reference level in all criteria)
- Sustainable UWCS, if it is at least as good as a fictitious neutral UWCS, but less attractive than a fictitious good UWCS
- Unsustainable UWCS, if it is not as good as a fictitious neutral UWCS (a UWCS that has a performance equal to the lower reference level in all criteria)

As mentioned above, weights reflect the relevance that the decision-maker gives to the swings in each criterion. Hence, as substitution rates, weights must be determined with reference to criteria impact scales. To compute the weights for the economic dimension we adopted the following procedure: ask the decision-maker to consider a 'virtual UWCS' that is neutral 'all over'; ask which criterion would the decision-maker select to swing from the neutral to the good performance level; continue to ask the same question until the 'virtual UWCS' is at the good performance level in all criteria. Considering the order chosen by the decision-maker it is possible to rank the importance of the swings in each criterion (between neutral and good), from the most attractive to the least attractive, according to their preferences.

After this ordinal ranking of the criteria, the decision-maker is asked to provide a judgment regarding the differences of attractiveness of the swings neutral-to-good between the several criteria. It is not necessary to make all possible pairwise comparisons. As shown in Figure 1, it is possible to compare just successive criteria (for instance). The weights corresponding to the matrix of judgments depicted above are also shown in Figure 1 (under 'current scale'). Having the local scores and the weights, one can compute the global score of the UWCS using equation 1.

Conclusion

This paper presents a proposal for measuring UWCS sustainability based on a MCDA model. After discussing the concept of UWCS sustainability and its dimensions we propose a UWCS sustainability scorecard based on the objectives of UWCS sustainability, their criteria and performance metrics. We set out five different dimensions for UWCS sustainability, which are the following: social, governance, environmental, economic and infrastructural. UWCS sustainability encompasses 14 objectives, which are achieved if the criteria for each one are fulfilled. Each criterion has at least one performance metric associated with it. To assess UWCS sustainability, weights are required for the defined scorecard, which depends on the decision makers (who should be the stakeholders in the case of UWCS). Indeed, the assessment of UWCS sustainability should be validated in the real world. Therefore, the MCDA approach should be applied and tested with the decision makers who are the stakeholders of UWCS under assessment and, particularly, water utilities managers.

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Flood Grouting for Infiltration Reduction on Private Side Sewers

INFR5R11

Author: Martha Burke

The sewers in Seattle's Broadview neighbourhood, built in the 1950s, experience significant inflow and infiltration. Intense wet weather events have resulted in sewer overflows into private residences and the environment and previous work indicates that the majority of this excess flow comes from infiltration. As a result, an infiltration reduction project was investigated to reduce overflows. To reduce that infiltration and achieve maximum success, all components of the sewer system – mainlines, maintenance holes, and private side sewers – have to be addressed. Seattle Public Utilities determined through a business case that to reduce infiltration, flood grouting was the most cost-effective, least disruptive methodology.

Flood grouting involves applying two chemicals in separate steps to treat an entire section of the sewer system between two maintenance holes, including the side sewers. The segment is filled completely to the maintenance hole rim and utilizes hydrostatic pressure by the chemical fluid to apply the grout to the system.

To determine the success of the project, flow meters were installed in the system to document before and after conditions for modelling analysis. The effectiveness of this approach at reducing infiltration compared to the cost, the challenges associated with working on private property, and lessons learned are documented in this paper.

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Research Digest: Decision Analysis/Implementation Guidance - Asset Management Tools Development, Phase 3

SAM1R06i

Author: Duncan Rose

WERF's Strategic Asset Management (SAM) project is comprised of four separate but integrated Tracks. Track 3 was developed to provide guidance on implementing SAM and develop analytic tools for SAM implementation – the Decision Support Tools and Implementation Guidance goal. In Track 3, the Decision Support Tools and Implementation Guidance goal was organized around analytic / decision support tools and an implementation tool.

Phase 3 of the project provided for the development of and inclusion in SIMPLE (WERF's on-line Asset Management Knowledge Base) the following five asset management support tools: Asset Hierarchy Tool; Remaining Effective Life Tool; Life Cycle Cost Projection Tool; End of Asset Life Reinvestment Decision Support Tool; Business Case Tool; and Asset Management Plan Template Tool.

These Tools join the Gap Analysis and the Benefit Cost Tools developed in Phase 1 and the Level of Service, Condition Assessment Scoring, Business Risk Exposure and the Capital Investment Validation and Prioritization Tools developed in Phase 2. This Research Digest briefly outlines the Tools developed in Phase 3 of Track 3.

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Sewer Lateral Electro Scan Field Verification Pilot

INFR4R12

Author: Jerome Flogel

This research effort evaluated an innovative sewer lateral condition assessment tool in unique testing conditions, providing an opportunity for comparison to other traditional assessment approaches. This study field tested over 100 sanitary sewer lateral pipes for potential infiltration-generating defects using the Electro Scan ES-38 technology according to ASTM F2550-006. Results of these inspections were compared to the results of other infiltration data produced in rainfall simulation tests of the same laterals and water exfiltration tests of each scanned pipe. The Electro Scan ES-38 measurements were also compared to closed-circuit television (CCTV) inspection of laterals. Statistical comparisons of Electro Scan ES-38 assessments to estimated leakage rates, from a field rainfall simulation test, were performed to determine the best means of correlating the two data sets.

The research effort was used to test the Electro Scan approach against the dye water/rainfall simulation testing techniques that the City of Wauwatosa (Wauwatosa) has already used to derive convincing condition information in general and on specific properties within the proposed testing area.

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