MARCH 2012
ISSUE 1 ■ VOLUME 8

water asset management INTERNATIONAL

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IWA Publishing

water21 magazine of the International Water Association

AWWA finds cost of potable water repairs and expansions will top one trillion dollars

The cost of repairing and expanding potable water infrastructure in the US will top $1 trillion in the next 25 years, according to an American Water Works Association (AWWA) study.

The report, titled 'Buried no longer: confronting America's water infrastructure challenge', analyses a range of factors including timing of water main installation and life expectancy, materials used, replacement costs and changing demographics.

It notes that smaller communities may face greater challenges as they have fewer people across whom to spread the expense.

The report warns: 'Because pipe assets last a long time, water systems that were built in the latter part of the 19th century and throughout much of the 20th century have, for the most part, never experienced the need for pipe replacement on a large scale.

'The dawn of an era in which the assets will need to be replaced puts a growing stress on communities that will continue to increase for decades to come.'

Other findings include that pipe replacement expenses account for more than 84% of the $278 billion requirement in the north east and mid-west regions to 2035.

In the South and West, where populations are increasing rapidly, expansion accounts for some 62% of the projected $277 billion requirement over the same period.

The required national investment will more than double from the current $13 billion a year to almost $30 billion by the 2040s and will need to be sustained for many years if current performance and service levels are to be maintained, it adds.

In some communities, infrastructure costs alone could more than triple the size of a typical water bill. However, the report concludes that this sum does not need to be spent all at once, and that there is still time to implement asset management plans and set rates that more closely reflect the cost of water services. ●

Tunisia water project supplies water to thousands

Tens of thousands of people living in Tunisia's Guerdane and Remada regions have access to clean drinking water following completion of an International Committee of the Red Cross joint project with the national water board.

A flood of refugees and migrants from Libya during 2011 put huge pressures on scarce water resources. The project involved laying a 6.6km transmission line and replacement / extension of 3km of pipe to connect existing wells to Remada's main reservoir, equipped with an automatic disinfection system. The target population is 15,000 and the new network will help meet rising peak demand.

A further 5km pipeline was laid to supply the city of Ben Guerdane and neighbouring villages, 4000 people in the Choucha refugee camp, and a village in Libya's Jebel Nefusa border region. The implementation cost was CHF293,335 ($324,700) and the new connection provides an additional 101l/s of brackish water which is mixed with reservoir water. The German development bank KFW and the Japan International Cooperation Agency are planning on building a desalination plant to treat the brackish water. As many of the migrants have now returned to Libya, the local Tunisian people will benefit from the work says the Red Cross. ●

Veolia Water Japan wins potable water contracts

Veolia Water Japan, a sister company of Veolia Water, has announced that it has won three operations and maintenance contracts for water and wastewater services in Japan.

Two of these are repeat contracts to serve over 1.2 million inhabitants in Hiroshima and Kyoto, where Veolia Water Japan has held the O&M contract for two wastewater treatment works serving these cities since 2006 and 2009 respectively.

In Hiroshima the contract has been extended for four years, for service to over 649,000 people, and in Kyoto the contract extension is for three years, serving 51,000 people in the city.

The third contract is for the town of Matsuyama, on Shikoku island, for operations and maintenance for five years of the potable water network for 515,000 inhabitants. ●

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Water Asset Management International is an international newsletter on asset management in water and wastewater utilities. The focus of the newsletter is on the strategic aspects of this developing field, providing utilities with international perspectives on infrastructure planning and maintenance as they seek to deliver cost-effective services to their customers.

Instructions for authors are available at: www.iwaponline.com/wami/default.htm

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Water Asset Management International is published four times a year (March, June, April, December) by IWA Publishing. Statements made do not represent the views of the International Water Association or its Governing Board.

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Web: www.iwapublishing.com

SUBSCRIPTIONS

Water Asset Management International is available as either a print or an online subscription.

2012 price (4 issues):
£241 / €363 / $480
(IWA members: £197 / €296 / $375)

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Or visit: www.iwaponline.com/wami/subscriptions.htm

Design & print
Original design: John Berbuto
Printed by Hobbs The Printers, UK

ISSN (print): 1814-5434
ISSN (online): 1814-5442

Data shows clear link between lack of watsan and infant deaths

In a paper published in the journal Environmental Health, researchers at Japan's UN University and Canada's McMaster University analysed data on access to safe water and adequate sanitation across 193 countries, concluding, using regression analysis techniques to filter out other variables, that countries ranked in the bottom 25% in terms of safe water had about 4.7 more deaths per 1000 children under five compared to countries in the top 25%.

Likewise, when judged on access to adequate sanitation, countries in the bottom 25% tier had around 6.6 more deaths per 1000 children under five compared to countries in the top 25% tier. Equating safe water provision and maternal death rates (within a year of childbirth), the paper says the odds of dying increase 42% from the top tier of countries to each subsequent lower tier; with the odds relating to inadequate sanitation rising 48% per tier.

Speaking to *WAMI*, June Cheng, lead author of the paper, said: 'The most significant point from this research is that access to water and sanitation on a country level are independent contributors to infant, child, and maternal mortality. Access to water and sanitation are two basic human needs. Until 100% of the world has such access, I would hesitate to say there has been enough emphasis placed on these two areas. Another important point relating to the MDGs (Millennium Development Goals) is that water and sanitation (MDG 7), rather than being separate from child and maternal mortality (MDG 4, 5), should be seen as inter-related goals.' ● **CF**

Seychelles receives funding for water and wastewater improvements

The European Investment Bank (EIB) is providing €27 million ($35 million) for an investment programme to secure potable water and wastewater provision in the Seychelles, which is currently threatened by irregular rainfall and increasingly long dry periods.

There are planned upgrades to the island's water, as well as new sewer facilities and measures to reduce water loss.

The Seychelles water and sanitation programme will help the Seychelles Public Utilities Corporation to alleviate water shortages by renewing and expanding the water supply on the three main islands to reduce water loss, improve energy efficiency and increase resilience to climate change and less predictable rainfall patterns.

Upgrading existing wastewater facilities on Mahé and building new sanitation infrastructure on La Digue will reduce the risk of contaminating groundwater used for drinking water. The scheme will also contribute to improving environmental and natural disaster risk management, and overall water management.

Specific projects to benefit from the programme include an extensive programme to reduce non-revenue water, including both technical and commercial losses, increase the capacity of four existing desalination plants on Mahé, La Digue and Praslin, improve the Hermitage and Cascade water treatment plants, provide a first time sewerage system in La Digue and extend the Mahé sewerage network. The water network will also be rationalised to improve pressure management and reduce leakages. ●

Aqualia jv to manage Abu Dhabi's wastewater

Aqualia jv, the water management subsidiary of global infrastructure, services and energy provider FCC, has been awarded a contract to manage the sewage and water treatment system in eastern Abu Dhabi. The seven-year contract is worth €76.3 million ($102 million).

The contract includes the operation and maintenance of more than 2400km of sewers, 68 wastewater pumping stations and 19 wastewater treatment plants in the city of Al Ain (in eastern Abu Dhabi, on the border with Oman) and the surrounding areas.

Aqualia has been operating for months in the capital of Saudi Arabia, where it is implementing and executing a project to search for and repair leaks in Riyadh's water network, to increase the network's efficiency. ●

SIPOS actuators to control Portuguese water system

Electric actuators from SIPOS Aktorik have been installed at a major water system in Portugal.

Chosen for their ability to prevent water hammer, says the company, the actuators feature variable speed control to prevent the generation of damaging hydraulic forces.

Following successful testing by Empresa Portuguesa das Águas Livres (EPAL), a first batch of 18 SIPOS 5 Flash actuators has been purchased. More actuators will be ordered during 2012 for a number of feeder lines.

The SIPOS' actuation solution provides valve automation technology for the extensive Castelo de Bode reservoir scheme, which extends over 2100km from its source to the city of Lisbon. ●

The 'new normal' of asset management: improved decision making at Seattle Public Utilities

The US utility Seattle Public Utilities (SPU) has built up an asset management programme that focuses on value of money to the customer and capital improvement plan decision making, which is developing into a 'new normal' of providing services in a more constrained economic climate. Terry Martin discusses SPU's strategy for the cost effective management of its assets, and how this is integrated into the utility's overall management.

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Seattle Public Utilities (SPU) is a municipal utility owned by the City of Seattle, Washington, US, and funded entirely by the rates paid for its services. SPU provides drinking water (both wholesale and retail) to a population of approximately 1.4 million people located within the greater Seattle metropolitan area and also provides retail wastewater, drainage, and solid waste services to roughly 650,000 customers within the City of Seattle itself.

SPU began its formal asset management programme in 2002, largely by adopting the 'Australian approach'. Simply put, this method applies principles that would more likely be seen in a private business environment than a traditional US-based water utility. Such principles are centred on value to the customer, effective risk management, and benefit / cost analysis.

Implementation of an asset management programme was meant to serve several purposes. The main initial goal was to create a higher degree of transparency and analytical rigour around capital-based business decisions. Although progress soon began regarding optimizing operations and maintenance (O&M) activities as well as developing strategic asset management plans (SAMPs), a conscious choice was made to begin with capital improvement plan (CIP) decision making because this was the easiest path to some big 'early wins'. Virtually all large capital decisions now require written business cases, including individual economic analysis, and are reviewed by executive management before approval.

Additional goals of asset management at SPU have been to:

- Deliver essential services with the least cost to the ratepayer
- Create accountability to ratepayers, the mayor, the city council, and state and federal regulators
- Achieve effective and efficient resource management
- Make deliberate decisions in a transparent manner, fully informed by financial, environmental, and social (i.e. 'triple bottom line') life-cycle costs and benefits

Results to date

Some of the most compelling results of SPU's asset management programme can be seen by comparing rate projections prior to the implementation of asset management in 2002 with the actual costs and rates that have resulted since then.

Utility rates have been reduced in comparison to earlier planned levels. Early on in 2002, before implementation of asset management, SPU projected 2004, 2007, and 2010 rates in its four lines of business. These rates were then predicted again two years later. The utility experienced a reduction of between $6 and $13 per household for combined rates for each of the predicted years. Impressive results such as this created a mindset that continues to this day. Besides reducing costs, asset management-based decision making has also led to increased value. Below are a several notable business case decisions (out of a catalogue now numbering almost 500) relating directly to the success of SPU's asset management programme:

- Watershed Bridge Replacement Programme – a significantly altered bridge replacement strategy in SPU's Cedar River watershed, saving over $8 million initially and using existing department staff

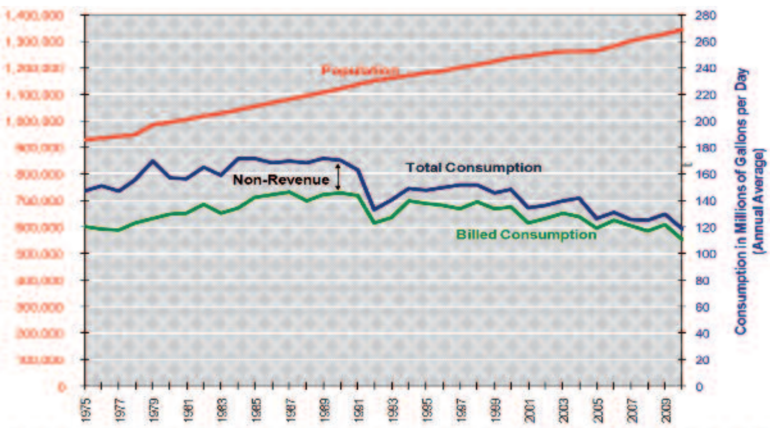

Figure 1
Growth in Seattle's metropolitan population and corresponding water consumption (1975-2010)

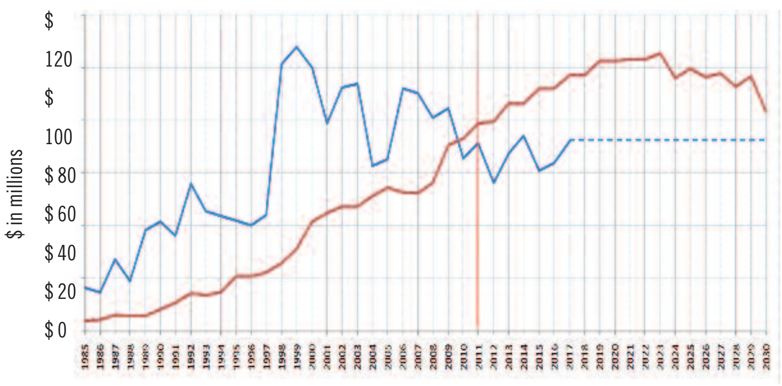

Figure 2
SPU drinking water business CIP (blue) vs. annual debt service (red) (1985-2030).

rather than contractors to build new bridges.

- Morse Lake Pumping Plant – business case analysis served to select an option costing approximately $35 million less than the option that otherwise would have been constructed.
- Reliability-centred maintenance (RCM) – this analysis was used to fundamentally change the methods by which SPU's 68 wastewater pump stations are operated and maintained. RCM has resulted in a significant reduction in sewer overflows while simultaneously reducing maintenance costs.
- Street sweeping for water quality – a business case analysis showed that street sweeping is more cost effective at reducing stormwater pollutants than available capital-based alternatives. SPU's on-going analysis in this field is one of the first of its kind.
- Water main replacement decision model – a data-driven approach to replacing water mains based on economic end of life rather than end of design life. Usage of the model has likely resulted in millions of dollars of savings to SPU's customers by replacing water pipes based on failure-related information rather than theoretical design life.

A history of spending driven largely by external forces… and a future that might look the same

SPU's immediate pre-asset management period can best be described as one of increasing reliance on debt, intensified use of cash reserves, and weakening debt service coverage. Like many US utilities, SPU's spending, and CIP expenditures in particular, had been driven to a large degree by externally-imposed constraints.

Looking back, this particularly affected the drinking water side of business. SPU was required to build two new expensive water treatment plants in the early 2000s (the Tolt water filtration plant was completed in 2000 for $101 million capital cost and the Cedar water treatment facility was finished in 2004 for $80 million capital cost) to meet federal regulatory drinking water requirements. Additionally, in the late 1990s SPU embarked on a long-term programme to cover all open air distribution reservoirs to meet state department of health regulations. This programme has consisted of covering ten such reservoirs at an overall cost of approximately $150 million.

Looking forward, the wastewater side of business now faces many of the same challenges that the drinking water side faced more than a decade ago. SPU is just beginning to embark on a long-term combined sewer overflow (CSO) programme that is estimated to cost approximately $500 million in capital funding to complete. Additionally, ratepayers in the greater Seattle metropolitan area will also be funding a similar and parallel programme, being carried out by the region's wastewater wholesaling agency (King County) that is estimated to cost approximately $700 million during the same time period.

Add to this mix millions of dollars worth of post-9/11 security-related CIP improvements as well as the usual costs of operating and maintaining large networks of aging pipes and pumps, and it is not hard to see how funding requests have quickly added up.

Declining potable water demand

Yet another recent challenge has been the consistent decline of water demand. This reduced water use has had the effect of placing further pressure on raising water (and wastewater) rates. As can be seen from Figure 1, SPU's total potable water demand has steadily declined over the last two decades while the population served has correspondingly increased.

While in recent years reduced per capita water demand has not been uncommon in the North American water sector, SPU's decrease has been particularly pronounced. Primary reasons for this have been an extremely successful water conservation programme combined with plumbing code changes (leading to the installation of more water-miserly fixtures and appliances). Two other reasons, much more minor in proportion than those above but SPU-specific, are permanently altered water usage habits produced by a water curtailment in 1992 (see dip in Figure 1 that never returns to its previous height) and reduced evaporation loss from the covering of SPU's open air distribution reservoirs.

Capital expenditure funding

Due in large part to the aforementioned 'once a generation' capital expenditures borne by the drinking water fund in the 1990s and early 2000s this line of business is facing a heavily debt-laden future (see Figure 2). In fact, annual debt service has increased almost 20-fold since 1985, is currently rising, and will continue to grow well into the 2020s, even with limited further capital expenditure.

It is also worth noting that the current economic downturn has resulted in deteriorating financial conditions such that, in some cases, rate increases may be justified simply to insure that a low interest rate on borrowing can continue.

Fast forward to 2012 and enter the 'new normal'

Given the aforementioned trends, it is absolutely imperative that SPU places even more emphasis than ever on tough decision making that is commensurate with the 'new normal' economic circumstances with which we are now faced. In many ways SPU's situation is not unique in the US water industry at the current time. A recent 'Circle of Blue' article[1] reported that 'in the last year the price of water in 30 US metropolitan areas has increased an average of 9.4% for residential customers with medium consumption levels.'

To this end SPU is further institutionalizing smart decision making and

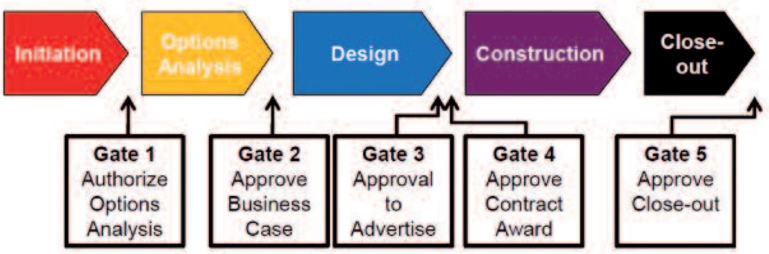

Figure 3
Stage gates and the project development cycle at SPU.

seeking cost effective results. The following are some notable examples of the new mindset facing the utility.

Continued cost effective rehabilitation and replacement of existing and aging infrastructure
SPU continues to utilize data-driven decision models to operate assets with cost effectiveness and economic end of life principles in mind. The organization has chosen to use such models, rather than merely replacing assets when they are 'old' or have reached the end of an arbitrary design life. SPU routinely assesses the condition of its highest value assets, particularly high risk water and sewer pipes. The organization continues to observe relatively low failure rates by industry standards even though existing water and sewer assets are comparatively old relative to SPU's North American peer utilities.

Improved capital and O&M prioritization
SPU will soon be submitting multi-year rate package proposals to the city council for three of its four lines of business. Expectations are that the council will be considerably less accepting than ever of approving rate increase proposals without thorough justification, and even then such requests may not be politically palatable. In anticipation of these circumstances, SPU has taken an approach to prioritization that is markedly different and more rigorous than previous efforts. Making tough, data-based decisions with scarce resources is being emphasized more than ever. Subject matter experts have been systematically brought together to score virtually all projects, programmes, and O&M activities. This in turn has enabled the development of fully explainable ordinal rankings for these items based on agreed upon scoring criteria. Multiple rate path scenarios will soon be applied to these ordinal rankings (across all business areas) to develop fully transparent CIP and O&M packages. This is a notable shift from previous rate proposal efforts where rate packages were often seen as opaque and difficult to explain to inquisitive council members.

Working with regulators to obtain cost effective results
SPU is currently in on-going negotiations with the US Environmental Protection Agency (EPA) in regards to reaching an acceptable number of annual system-wide sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs). While many utilities are faced with high numbers of SSOs (and associated expensive and highly prescribed mandates to reduce these SSOs) the adaptive management-style asset management approach applied by SPU ('The right work, at the right time, at the right cost') could pay huge dividends. Due to this approach SPU appears to already be in the 'high performing band' of wastewater utilities (defined as experiencing less than four SSOs per hundred miles per year) and as such the EPA and the Federal Department of Justice are likely to accept SPU's performance-based and detailed strategy in lieu of a highly prescribed and externally-imposed future capital and O&M plan. This is extremely unusual in the US utility industry and is a testament to SPU's record and programme which has been focused on achieving cost effective results. SPU's SSO strategy to date has included dynamic risk-based scheduling, optimization of sewer pipe cleaning frequency, proactively locating sewer pipes requiring cleaning, increased emphasis on fats, oil, and grease (FOG) removal, and largely refocusing the CCTV inspection programme specifically on SSO reduction.

Defer new water supply sources and seek new customers
SPU is in a somewhat unique situation currently. The utility appears to have near-term excess supplies of potable water (due in large part to the steadily declining demand discussed earlier). However, the department still must operate and maintain an extensive and capital intensive supply, treatment, transmission, and distribution system. One could argue that this is both a fortuitous windfall benefit (plenty of water) but also an evolving major financial challenge (less revenue with which to manage the system). Until recently it was thought that new sources of raw water supply would be needed, and fairly soon. It now appears that this concern can be delayed for at least a decade and perhaps much longer, even though SPU's service area population continues to grow. Conversely, this newly achieved supply 'cushion' will allow, and perhaps even encourage, the utility to proactively seek new and alternative sources of revenue. This is just another example of the 'new normal' need to solve different and novel challenges.

Value analysis and value engineering
SPU began a formal value engineering (VE) programme in 2009. Early results have been effective, and in response the organization has recently instituted a value analysis (VA) programme as well. Any project estimated to have a lifecycle cost in excess of $5 million will now be subjected to both a VA study (a formalized third party options analysis workshop including in-depth risk analysis) and a VE study (a formalized third party workshop at the 30% design stage) to increase value and / or reduce costs. SPU's VE workshops to date have shown remarkable return on investment and are considered a successful new aspect of the organization's asset management philosophy.

Innovative contracting
While perhaps not technically viewed as an asset management-centric activity, it is worth mentioning that SPU, which has historically been an enthusiastic proponent of alternative contracting methodologies, has recently made the conscious decision to use alternative contracting to an even greater extent. This has been partly driven by the success of SPU's two aforementioned water treatment plants, both of which were initiated as long-term design-build-operate projects in the early 2000s and continue to consistently meet water quality targets at low cost. Additionally, SPU is preparing to embark on multiple large wastewater, solid waste, and drinking water CIP projects using the general contractor / construction manager contracting methodology. If past results are any indication it is felt that using these alternative contracting methods, which engage contractors at an early design stage to help achieve improved constructability and lower costs, will provide enhanced value to SPU and its ratepayers.

Development and implementation of a stage gates project management system
Improving project delivery is a key initiative for SPU. In the department's on-going efforts to deliver projects in a timely and effective manner, SPU has recently expanded its asset management decision making model to include governance decision 'stage gates' at key points in the planning, design, construction, and close-out phases of projects. Our research has shown that approximately 85% of Fortune 500 companies use such a project management system, however its use is still uncommon within the public utility sector in the US. Stage gates, another example of an idea that SPU has learned from the Australian utility sector in general and the Hunter Water Corporation in particular, is a system of check points that provide executive leadership with key information to help make fully informed decisions. Figure 3 shows the locations of the gates in the project development lifecycle at SPU.

Implementation of stage gates at SPU has:

- Created greater coordination and efficiency as projects move through the five decision checkpoints

- Improved project delivery and asset management by ensuring that the criteria of each 'gate' are met before moving to the next gate
- Ensured that SPU develops and delivers capital projects using a clear and transparent decision making process
- Continued to ensure that triple bottom line (financial, social and environmental) factors are a part of all decision making

O&M planning and productivity improvements
This is the next frontier of SPU's asset management programme. As discussed earlier a conscious decision was made in the early 2000s to focus on capital decisions first because they could provide solid 'early wins'. Conversely, SPU will soon be placing increased emphasis on outcome-based O&M planning, as well as crew scheduling, deployment, and productivity. Such efforts have been difficult and inconsistent to date, often due to incomplete data, less than perfect communication of common goals, and SPU's highly unionized environment. However, we now feel that the time is right for the more nuanced type of effort that this will require.

Asset management – good business sense for the 'new normal' and beyond

In the end one could argue that successful asset management is simply the ability of an organization to make high quality, data-based business decisions. We have found that the foundation of such a programme involves creating optimal value to the customer, using triple bottom line principles wherever possible, leveraging benefit / cost analysis and risk management in significant business decisions, and creating a 'challenge' work environment where asking hard questions and having difficult conversations is the norm. While implementing a wide array of analytical tools is undoubtedly of great value, our experience has shown that the greatest tool of all is a workplace environment where questioning business as usual is encouraged and commonplace. Since our current 'new normal' situation of relative economic hardship does not appear to be ending any time soon it could be that others, as we have, will find the terms 'asset management' and 'good business sense' synonymous and use them to make the best decisions possible for their ratepayers in the challenging years to come. ●

Note

[1] *Walton, B (2011), The Price of Water 2011: Prices Rise an Average of 9 Percent in Major US Cities. Circle of Blue (www.circleofblue.org).*

Developing a robust water utility vulnerability index

A water utility vulnerability index is used to predict the future performance of a utility, but changing conditions can lead to misspecified data that no longer accurately reflects the future. A promising approach to improving the accuracy of a water utility vulnerability index in the face of such uncertainty can be based on enhancing the robustness of the index to changing conditions. In this article, L Joe Moffitt, Nikolaos Zirogiannis and Alexandar Danilenko leverage info-gap decision theory in pursuit of a robust water utility vulnerability index.

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A water utility vulnerability index (WUVI) is an aggregation of individual variables to provide an easily understood and communicable prediction of a water utility's future. Early detection of future problems can give lead time to avert crises. Unfortunately, conditions and relationships can, and often do change, so that an index describing current and historical data may become misspecified and unable to predict the future with sufficient accuracy to have value. Many regard the misspecification resulting from reliance on historical data in a dynamic environment as the main problem in any predictive activity.

Development of a WUVI that can accommodate an uncertain future is believed to be especially significant in the case of water utilities due to the potential, and largely unknown, impacts of climate change. The latter may yield unprecedented challenges to management and highlights the desirability of a good early warning system based on an index. A promising approach to improving the accuracy of a WUVI in the face of such uncertainty can be based on enhancing the robustness of the index to changing conditions.

Conceptual framework

Vulnerability can be defined generally as the degree to which a system is susceptible to, or unable to cope with, future adverse external stresses; i.e., liable to succumb to future stresses. Using this definition, vulnerability can be interpreted and regarded as the likelihood of a system failing to cope with future stresses. In the context of water utilities, vulnerability is inverse to future performance in the sense that a utility scoring highly on a vulnerability index will be a utility with a probable future performance problem.

Measurement of vulnerability is found across a number of sub-disciplines of economics and a number of different measurement techniques have been used. A common approach to measuring vulnerability is the use of a composite indicator; i.e., an aggregation of individual variables to provide an easily understood and communicable prediction of future performance. For example, in finance, there is a substantial literature on use of indices to measure credit default risk (see e.g., Oral et al. 1992; Easton and Rockerbie, 1999; and earlier literature cited there) and a more recent literature on predicting hedge fund failure (e.g., Liang and Park, 2010 and literature cited there). In macroeconomics, measurement of the vulnerability of an entire economy to future recession has been pursued in several studies (see e.g., Estrella and Mishkin, 1998; Silvia et al. 2008).

In resource economics, measurement of vulnerability to natural resource supply interruptions has become popular, especially in regard to energy resources (see e.g., Gupta 2008; Gnansounou 2008; Cabalu 2010).

More recently, research in the economics of homeland security has pursued indices for use by policy officials in assessing the vulnerability of communities to disaster (see e.g., Cutter et al. 2010 and literature cited there). A critical issue in constructing indices generally is the weighting scheme that is applied to the individual variables that are aggregated. The measurement of vulnerability via an index is, of course, no exception.

Subjective and / or ad hoc weighting schemes have been used but have been criticized for their subjectivity. Indices with a more objective basis have been pursued by using data analysis to assist in constructing an aggregate of the individual variables. With regard to a probabilistic interpretation of vulnerability, the analyses of vulnerability to recession conducted by Estrella and Mishkin (1998) and Silvia et al. (2008) in macroeconomics demonstrate an applicable approach based on probit analysis to estimate an optimal weighting of individual variables for use in index construction.

Our model and estimation method rely on several tenets. Our goal is to make clear our notion of a WUVI, the underlying nature of the vulnerability that we purport to estimate, the target audience that is envisioned to make use of the WUVI, and how our notion of the WUVI will be utilized by the target audience. All of these tenets lay a foundation for the model and estimation method.

First, we conceive of a WUVI as an estimated probability. The estimated probability is that of a water utility experiencing what will be recognized by objective observers at a specified future time as a performance problem. Because many water projects involve a two-year planning horizon, we take the specified future time as two years into the future in the modelling and estimation.

Second, the underlying nature of the vulnerability is broadly defined to encompass a utility's operational, financial, and social performance. Hence, the performance of a utility is not only judged on operational and financial criteria, but also on how well the utility delivers services to the population, including the poor, in its service area. A team at the World Bank devised a set of criteria that is a first attempt to measure how utilities are doing that is not focused entirely on financial and operational performance (van den Berg and Danilenko (2010)).

This team developed an overall measure of a water utility's health known as its APGAR score. The APGAR score is an index that assesses the overall health of a utility. The performance of a utility with an APGAR score less than or equal to 3.7 is classified as critically low. With this perspective, a performance problem can arise from various issues including water supply coverage; sewer coverage; non-revenue water; affordability of water and wastewater services; collection period; and operating cost coverage ratio. The concept of a WUVI that we pursue is the probability of an overall service problem as measured by such a low APGAR score. Hence, our conception of a WUVI is an index that estimates the probability of a performance problem, according to one or more of these criteria, two years into the future. We envision, in standard economics terminology but without explicit specification, a structural model of a water utility including its financial and service components. Our notion of vulnerability is a probability based on, again in an economist's terminology, the reduced form of the structural model.

Third, the reason for estimating a WUVI is to provide utility managers and policy officials with an early indication of a future performance problem. Our approach to estimation places emphasis on accurate prediction within the sample observations as measured by goodness of fit. In this regard, it is recognized throughout our modelling and estimation that any formulation of a WUVI will represent an approximation to a true but perhaps unknowable predictive model. For example, the latter may involve enumerable variables and exotic functional relationships which could never be precisely estimated under any circumstances. Our approach is focused squarely on arriving at a WUVI, which will provide useful information in practical application while recognizing that there will always be approximations involved.

Fourth, our conceptualization of a WUVI is as an early warning device rather than an 'actionable' index. By this, we mean that a high value of the WUVI is a symptom of a possible future problem but does not indicate the specifics of the future problem. Hence, we envision that managers and policy makers would treat a high value of the WUVI as an indication that further diagnostics are desirable to determine the issues faced by a particular utility and to formulate potential remedies. From this perspective, the estimated WUVI is similar in character to many indicators already in use in other fields, most notably, the life sciences. For example, body temperature removed from the norm in humans and animals is not 'actionable' in itself, but rather is an indication that some further testing and evaluation is needed to identify the source of the abnormality and appropriate actions. This type of indication corresponds precisely to our notion of a WUVI. In addition, we envisage the construction of the WUVI as statistical in nature. We seek to detect statistical relationships that have, in the past, foreshadowed future water utility vulnerability regardless of whether or not the underlying complexity can be subjected to a detailed logical analysis. Such detection of patterns purely for forecasting purposes is evident in many fields ranging from security analysis to meteorology and we also adopt this perspective.

Probit analysis with goodness of fit for model selection

An overview of the probit analysis with model selection is as follows. The analysis posits that a latent variable, determining a water utility's ability to cope at a future time, denoted Y^*, can be expressed as a linear function of other variables, X (a vector), at present and past times, with an additive, normally distributed error, U. The variable Y^* is not directly observable but rather an indicator variable, Y, is observed and indicates the sign of Y^*. Statistical inference is applied to observed values of the variables to enable estimation of the unknown parameters in the linear function.

Estimation of the WUVI via the method of maximum likelihood and evaluation of the index can be described in more detail using the following notation:

Let i denote a water utility, t denote a year, and j denote a variable believed to be a potentially relevant predictor of failure of a water utility. Hence:

X_{ijt} = water utility i's jth indicator variable during year t

X = a matrix where each row shows the indicators for water utility i during year t

$Y^{\star}_{it+k}$ = water utility i's ability to cope with stresses during year t + k

$$= \beta_0 + \Sigma_{l=0}^{L} \beta_{1l} X_{i1t-l} + \Sigma_{l=0}^{L} \beta_{2l} X_{i2t-l} + \cdots \Sigma_{l=0}^{L} \beta_{Jl} X_{iJt-l} + U_{it} \text{ where } U_{it} \sim N(0,1)$$

Y_{it} = an indicator of water utility i's (unobserved) ability to cope with stresses during year t ($Y_{it} = 0$ means water utility i coped with all stresses during year t, while $Y_{it} = 1$ means water utility i was unable to cope with at least one stress during year t); hence, $Y_{it} = 1$; if $Y^{\star}_{it} > 0$ and $= 0$, otherwise. Lagged values of the predictive variables up to L years are permitted as shown. In matrix notation:

Y = a vector where each row indicates whether water utility i was able to cope during year t

Given observed values, Y_{it} and X_{ijt}, estimation of $\beta = [\beta_0\ \beta_1 \ldots \beta_J\}'$ can proceed via the method of maximum likelihood where the log-likelihood function, lnL, is given by:

$$1nL(\beta) = \Sigma_{it \ni Yit=1}\ 1n\phi(X_{it}'\beta) + \Sigma_{it \ni Yit=0}\ (1 - 1n\phi(X_{it}'\beta))$$

where ϕ is the cumulative distribution function of the standard normal probability distribution.

Maximizing lnL over the parameters provides maximum likelihood estimates of the optimal weights conditional on the set of variables (the js) included as index components. The maximum likelihood estimator of weights assigned to a set of individual variables is a best weighting for a particular set of variables. The best composition of individual variables in an index needs to be determined. There are $2^{J+1} - 1$ possible sets of index components. A goodness of fit criterion for model selection can be applied to identify the best index composition and associated weights.

Determination of the optimal variables and associated weights for the WUVI can be done via goodness of fit as a model selection criterion. In general, the model selection problem is one of choosing a probability density function, f, to characterize a random variable, Y, when any of the models f^k(Y, β_k) with parameter vector β_k, k = 1, 2, … , $2^{J+1} - 1$ is possible.

Because we estimate the probit model using the method of maximum likelihood, we view the value of the likelihood function as a fundamental criterion for evaluating and comparing models. In this regard, the most popular model selection criterion is that developed by Akaike and subsequent refinements of it (Akaike 1973; Cavanaugh 1999). The Akaike information criterion (AIC) is a widely known and extensively used tool for statistical model selection. The AIC serves as an asymptotically unbiased estimator of a measure of divergence between the true model and a fitted model. The Akaike criterion does not presume that the true model is among the K models under consideration. The criterion is to choose the model which solves:

$$k^{\star} = \underset{k}{\arg\min}\ AIC^{k}\ (\beta_k, n_k)$$

where $AIC^k\ (\beta_k, n_k) = -2\ 1nL^k(X,\hat{\beta}_k) + 2n_k$, $1nL_k(X,\hat{\beta}_k)$ is the maximized log-likelihood function of model k, and n_k is the dimension of β_k. Denote the solution to this problem as $k^{\star}$. Using AIC, only the relative fitness of competing models is used to select a model.

Vulnerability of water utility i is estimated by $\phi(x'\hat{\beta}_{k\star})$ where x is a vector of values of the variables associated with model $k^{\star}$. Hence, given the parameter estimates, $\hat{\beta}_{k\star}$, the value of the WUVI can be easily determined.

Data and baseline estimates

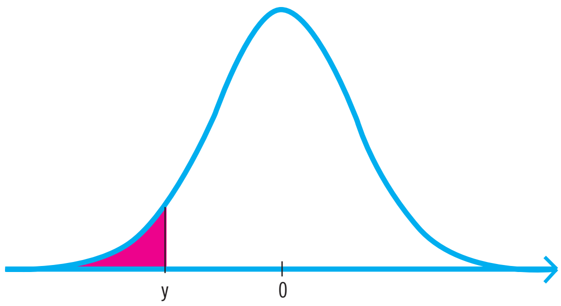
The International Benchmarking Network for Water and Sanitation Utilities (IBNET) is an online database containing annual observations on many indicators for more than 3000 water utilities in 85 countries (IBNET 2010). Many of the indicators reported in IBNET may be used in assessing the current performance as well as the vulnerability of water utilities. For example, using these data, a team at the World Bank (see van den Berg and Danilenko (2010)) devised a set of criteria that constituted a first attempt to measure the current performance of a water utility using financial, operational, and social criteria.

A formula for a WUVI was first estimated using the conventional statistical model presented in the previous section. The econometric analysis is based on IBNET data consisting of 1143 observations from more than 100 water utilities. A number of different variables and lag lengths were evaluated in order to determine the best WUVI for the purpose of forecasting two years into the future. The probit analysis and model selection procedure described in the previous section were implemented with these IBNET data and yielded the 'best fit' estimates shown in the formula in Figure 1.

As shown by the formula in Figure 1, the 'best fit' was achieved by constructing the WUVI with five variables evaluated at time t (i.e., lag-length, L, defined in the previous section set equal to zero). The five variables included in the WUVI formula are: 'water coverage', defined as the percentage of households in the utility's service area receiving water service from the utility; 'sewer coverage', defined as the percentage of households in the utility's service area receiving sewer service from the utility; 'non-revenue water', defined as cubic metres per kilometre per day of water in the utility's service area for which the utility does not receive compensation; 'affordability', defined as the percentage the utility's revenue per capita is of per capita gross national income; and 'collection period' defined as the number of days required for the utility to collect for water and / or sewer services provided.

The value of the WUVI is easily found for a water utility using the formula shown in Figure 1 and a table or computer programme that finds values of the standard normal distribution. Figure 1 shows the WUVI evaluated as the left tail of the standard normal distribution as depicted by the shaded area in the figure. As indicated in the second section, the WUVI estimates the probability that a water utility will experience a performance problem two years ahead conditional on the current values of the five variables. Given the current values of the five variables, the formula in Figure 1 provides the value from which the area in the left tail is evaluated. The size of the area is the WUVI; i.e., the estimated probability

Figure 1
WUVI evaluated as the left tail (shaded area) of the standard normal distribution with maximum likelihood estimates of parameters



where y = 1.22
- 0.028 water coverage$_t$
- 0.016 sewer coverage$_t$
+ 0.004 non-revenue water$_t$
+ 0.273 total revenue / service population / gross national income$_t$
+ 0.001 collection period$_t$

of a future problem.

A critical difficulty that may arise in applying the WUVI formula shown in Figure 1 is that it expresses maximum fidelity to the existing database while the future may involve relationships that are different from those that gave rise to the database. Such future uncertainties may involve urbanization, financial and energy crises, and perhaps most importantly, climate change. The next section turns to making the WUVI more resilient to such future uncertainties.

Robustness analysis

As reviewed earlier, vulnerability indices are generally estimated using current and historical data as a basis for projecting future performance. The same will be true of nearly all conceptualizations of a WUVI. Unfortunately, conditions and relationships can, and often do change, so that an index describing current and historical data quite well may become misspecified and unable to characterize the future with sufficient accuracy to have value. Many regard the misspecification resulting from reliance on historical data in a dynamic environment as the main problem in any predictive activity.

The problem can be described specifically as follows. Given an existing database, a WUVI is usually estimated, as in the previous section, to provide a best fit to the data. In simplified terms, the WUVI is found as WUVI = $f(X,\hat{\beta}_{k\star})$ where $\hat{\beta}_{k\star}$ is a vector of parameter estimates that provides a best fit to the existing data.

Unfortunately, as forecasters often find out, the future can be different than the past. For example, due to urbanization, financial and energy crises, and perhaps most importantly, climate change, the historical database may not provide an accurate reflection of the future relationship between the component variables and vulnerability. If, for example, due to climate change, future vulnerability of a water utility is not characterized by WUVI = $f(X,\hat{\beta}_{k\star})$ as it was during the period of the database but rather has changed to WUVI = $f(X,\hat{\beta}_{k\star\star})$, then using the estimate $\hat{\beta}_{k\star}$ may mislead about the utility's vulnerability. Hence, in the presence of future climate change, estimating the WUVI by seeking a best fit to the existing database may not yield a satisfactory result.

A promising approach to improving the predictive ability of a WUVI in the face of such uncertainty can be based on enhancing the robustness of the index to future conditions / relationships as based on info-gap decision theory (see e.g., Ben-Haim 2006). Info-gap decision theory (Ben-Haim 2006) is primarily a prescriptive theory providing support to decision makers under uncertainty. Distinct from traditional alternatives, the info-gap approach is not a closed computational methodology but rather a flexible perspective on decision analysis whose assessments assist decision makers in evaluating options, developing strategies, and evolving preferences. An info-gap is a disparity between what is known, referred to as the nominal model, and what needs to be known in order to make a comprehensive decision. The theory is based on a model of uncertainty, a model of the system that generates outcomes, and a performance requirement.

Specific formulation of an info-gap model of uncertainty depends on the type of initial information available, which is then invested in determining the structure of a family of nested sets of uncertain events. Nesting imposes the property of 'clustering', which is a characteristic as well as a unifying feature of a wide range of info-gap models of uncertainty; e.g., convex, non-convex, continuous, discrete, bounded, unbounded, hybrid, as well as others employing various measures of deviation.

The uncertainty model, system model, and performance requirement are combined in formulating a robustness function which supports the choice of action. From an info-gap perspective, a decision which achieves an acceptable outcome over a large range of uncertain realizations is preferable to a decision which fails to achieve an acceptable outcome even under small error. Info-gap theory takes the position that the best strategy is the one that satisfies the decision maker with an outcome that is both acceptable and makes the decision maker as immune as possible from an unacceptable outcome. In brief, an info-gap robust optimal decision maximizes the reliability of an adequate outcome. In this way, a robustness function generates preferences on available decisions.

With respect to statistical estimation / forecasting, the implications of the info-gap theory are quite unique in advocating an expression of less than complete fidelity to an existing database. While what are often referred to as robust statistical methods may afford special consideration of so-called outliers in a database, methods based on info-gap are concerned with the possibility that the entire database may, in a sense, be an outlier with respect to future conditions due to the possibility of structural change (e.g., climate change). Hence, info-gap robustness in estimation / forecasting is manifested in a method that does not express complete fidelity to an existing database. Future conditions / relationships may differ from those reflected in the database as characterized with the probit function, $\tilde{f}$, shown in the preceding section.

A verbal description of the info-gap methodology developed analytically next is as follows. We will find the robustness of an estimate of the parameter vector β as the maximum distance of any probability density function from its associated probability density function which still enables a satisfactory fit to the database. Note that every estimate of β has a robustness associated with every level of fit. The robustness curve in the left panel of Figure 2 shows the robustness of the maximum likelihood estimate shown in Figure 1 for each level of fit. We choose the estimate of the parameter vector β as the estimate which is most robust in achieving a satisfactory fit. The advantage of this approach is that the robust estimate of β gives the maximum room for error with respect to future uncertainties while nevertheless providing a satisfactory fit to existing data.

Implementation of the info-gap perspective in a statistics framework is developed analytically as follows.

Letting $\mathbb{P}$ denote the set of probability density functions on the domain of $\tilde{f}$, the possibility of changing relationships in the future is accommodated by the following uncertainty model:

$$\mathcal{U}(\alpha,\tilde{f}(y;\beta)) = \{f(y): f(y) \in \mathbb{P}, |f(y) - \tilde{f}(y;\beta)| \leq a\}, a \geq 0$$

where $f(y)$ is any probability density function; i.e., any function $f(y)$ with the properties $f(y) \geq 0$ for all y and $\int f(y)\,dy = 1$.

Robustness is measured by the largest value of α for which there is an $f(y)$ maintaining acceptable fidelity to the database. The latter is a performance requirement denoted by $L^\star$ as shown in the expression for robustness:

$$\hat{\alpha}(\beta, L^*) = \max\{\alpha: (\min_{(f(y) \in \mathcal{U}(\alpha,\tilde{f}(y;\beta)))} 1nL(f,y)) \geq L^\star\}$$

The robustness function, $\hat{\alpha}(\beta, L^*)$, shows the largest horizon of uncertainty for which the poorest performing probability density function in the uncertainty model, at that horizon, meets the performance requirement. It can be used to evaluate the robustness of the parameter vector, β, for any performance level and, hence, can be used to evaluate the robustness of any WUVI that can be expressed as an linear combination of its component variables.

A graph which features performance

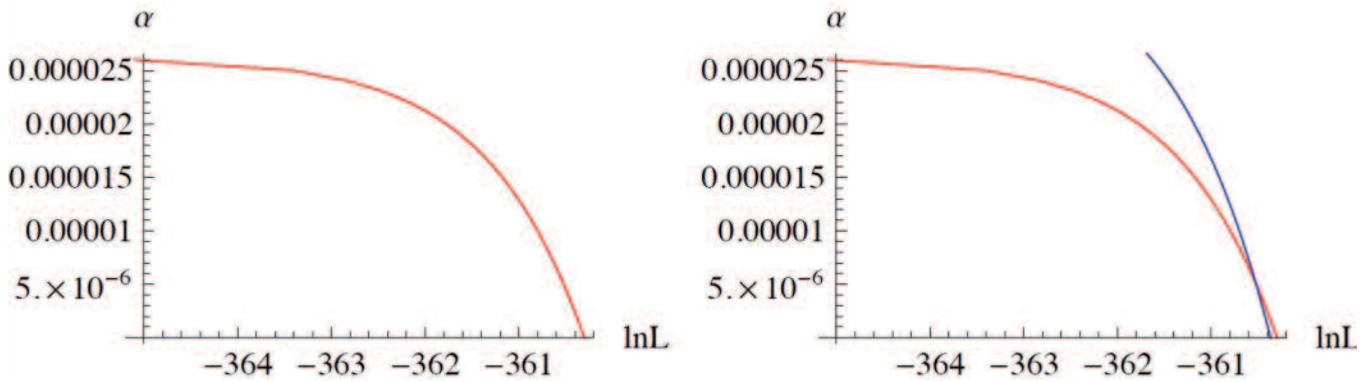


Figure 2
Robustness curve for the maximum likelihood estimate (left panel in red) and with another parameter estimate (right panel in blue)

($L^\star$) on the horizontal axis and robustness,($\hat{\alpha}(\beta, L^*)$), on the vertical axis can be constructed for any values of the parameter vector, β. For example, as already noted, the left panel of Figure 2 shows the robustness curve for the maximum likelihood estimate of β (denoted by $\beta^\star$) reported in the previous section while the right panel shows the robustness curve for both the maximum likelihood estimate and another estimate as well. The interpretation of the robustness curve for the maximum likelihood estimate in the left panel of Figure 2 is as follows: the vertical coordinate shows the maximum deviation (α) from the probability density function associated with $\beta^\star$ that can provide the fit to the database given by the horizontal coordinate. Given this interpretation, it makes sense that the robustness curve associated with $\beta^\star$ intersects the horizontal axis in the figure at the maximum of the likelihood function for the database. No other value of the parameter β can achieve a comparable fit, which implies that the robustness of $\beta^\star$ is zero. Of course, the exact same interpretation can be given to a robustness curve associated with any other value of the parameter β such as the second curve depicted in blue in the right panel of Figure 2. From the right panel, it can be seen that the curve shown in blue is relatively more robust to the left of the intersection with the curve shown in red (based on $\beta^\star$).

The crossing of the robustness curves shown in right panel of Figure 2 is not atypical and reflects the fact that different parameter vectors can be relatively more robust at different performance levels. The underlying reason is that the alternative parameter value alters the shape of the probability density function enabling it to encompass a relatively wide range of probability density functions (relative to $\beta^\star$) in providing a less precise fit to the database. Evaluation of alternative WUVIs in terms of robustness may yield a WUVI with improved forecasting capability.

Davidovitch and Ben-Haim (2011) show that a single robustness curve is maximally robust for a given performance level. In view of their result, Figure 3 shows the maximum robustness possible for a large number of performance requirements. Hence, the curves shown indicate the robust frontier of a family of robustness curves such as the two shown in the right panel of Figure 2.

An algorithm for finding the robustness frontier and associated parameter estimates has yet to be developed. A numerical procedure can be at least used to obtain approximate values of the robust parameter estimates. First, a decision must be made about the degree of fidelity that will be expressed to the database. Recognizing that the future may be different due in no small part to climate change, a performance requirement representing a half percent reduction in the value of the log-likelihood function at the maximum likelihood estimate, i.e., lnL = -362.1, was selected and a numerical procedure was implemented to determine the parameter estimates associated with the point on the robustness frontier at this level of performance. The robust estimates are shown in Figure 4. As can be seen from Figure 3, Figure 4 estimates provide for achievement of the desired fit for deviations of more than .000026 from the fitted the value of the probability density function.

Vulnerability of water utility i is estimated by $\phi(x'\hat{\beta})$. Hence, given the robust parameter estimates, $\hat{\beta}$ from the value of the WUVI can be easily determined. Note that the robust estimates will not provide as good a fit to the existing database as the maximum likelihood estimates shown in Figure 1. However, given the real possibility of changing structural relationships in the future, the robust estimates will forecast well enough with the existing database and may well be better able to provide a satisfactory fit and forecasts of a future database generated under alternative climatic conditions.

Concluding remarks

This paper has derived robust parameter estimates to construct a robust water utility vulnerability index. The estimation method employed is a first link between info-gap decision theory and probit

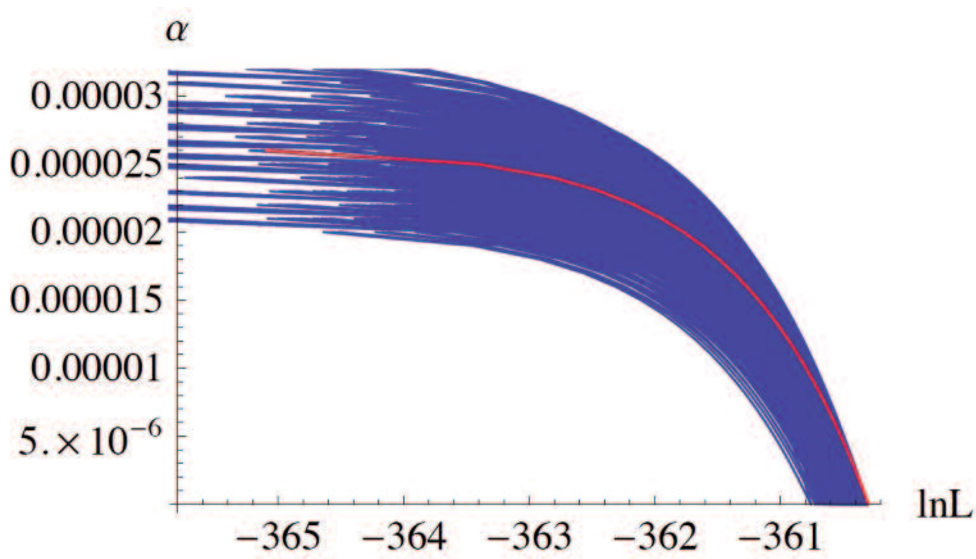
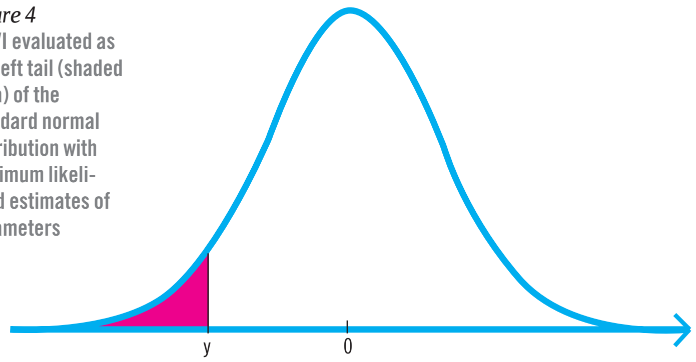


Figure 3
Robustness curve for the maximum likelihood estimate (red) and other parameter estimates (blue)

Figure 4
WUVI evaluated as the left tail (shaded area) of the standard normal distribution with maximum likelihood estimates of parameters



where y = 1.21
- 0.028 water coverage$_t$
- 0.016 sewer coverage$_t$
+ 0.004 non-revenue water$_t$
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+ 0.001 collection period$_t$

analysis and is the first application of its kind in the water utility area. Accommodating future structural change in forecasting is becoming increasingly popular in econometrics (see e.g., Pettenuzzo and Timmermann (2011)). This is due perhaps to the recognition that a changing global and dynamic environment must be accommodated by some means if acceptable performance in forecasting is to be achieved. The robust estimation of a WUVI in this paper is a step in this direction. Future research will focus on development of an algorithm to efficiently derive the robustness frontier and associated parameter estimates and to determine if additional components related to urbanization, financial and energy crises, and climate change can be added to the WUVI. ●

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This paper was presented at Pi2011 – the IWA International Conference on Benchmarking and Performance Assessment of Water Services, 14-16 March 2011, Valencia, Spain.

AM DIARY

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

Water Loss UK
26-27 March 2012, NEC Birmingham, UK
Web: www.waterlossuk.com

The Future of Utilities and the Smart Utility Forum
27-29 March 2012, London, UK
Web: http://marketforce.eu.com

Water Utility Management and Pricing Policy Workshop
3 April 2012, Lemesos, Greece
Contact: Phryne Potamou
Email: contact@wbl.com.cy

Smart Water Systems
16-17 April 2012, London, UK
Web: www.smi-online.co.uk

European Utility Conference
18-20 April 2012, Vienna, Austria
Web: www.euc2012vienna.at/European_Utility_Conference_Vienna_2012.html

Water Loss Europe 2012
23-25 May 2012, Ferrara, Italy
Web: www.waterlosseurope.com

Water Convention 2012: Water Solutions for Livable and Sustainable Cities
1-5 July 2012, Singapore
Web: www.siww.com.sg/water-convention

IWA World Water Congress & Exhibition
16-21 September 2012, Busan, Korea
Email: 2012busan@iwahq.org
Web: www.iwa2012busan.org

9th International Symposium on Water Supply Technology 2012
20-22 November 2012, Yokohama, Japan
Web: www.jwrc-net.or.jp/aswin/en/symposium_archive/index.html

DEWATS in Asia
20-23 November 2012, Nagpur, India
Web: http://iwahq.org/1sl/events/iwa-events/2012/dewats-in-asia.html

Asset Management for Enhancing Energy Efficiency in Water and Wastewater Systems
24-26 April 2013, Marbella, Spain
Email: info@iceam2013.es

A triple bottom line approach to asset management and sustainability

Sustainability and asset management are different frameworks with overlapping core principles that can be integrated and expressed using a triple bottom line approach of economic, social and environmental aspects. Priscilla Bloomfield, Lindsay Ritter and John Fortin discuss how alignment between the principals of sustainability and asset management can be achieved to reduce costs, improve service efficiency and limit a utility's impact on the environment.

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Both public and private agencies are operating in a world that is much different than it was even a few short years ago. The world is unprecedentedly more connected and transparent, driving increased awareness and the need for organizations to respond to a greater set of stakeholders, while also managing an expanding list of resources that are critical and vital for long-term operational success. This change has driven organizations to view themselves as a responsible citizen, consulting with and held accountable to a much wider range of stakeholders than in years past. This new dynamic also requires organizations of all types and sizes to operate in a global economy that is facing increasingly strained resources, both natural and capital. With this new reality, both enterprise and governmental organizations have been reaching for operational and decision methods that help navigate this complex set of circumstances. Both asset management and sustainability frameworks have emerged to effectively serve this purpose.

The term sustainability has been emerging for the past 30 years with the internationally accepted definition described in the Bruntland Commission's 1983 publication of Our Common Future as: 'meeting the needs of the present without compromising the ability of future generations to meet their own needs'. Key concepts that are inclusive to strategies for sustainability include ethics, governance, transparency, business relationships, financial stewardship, economic development, value, employment practices, and environment stewardship. While these considerations are inherent to sustainability, in practice both public and private agencies often focus on environmental stewardship in their sustainability efforts, and consequentially miss their opportunity to implement broader, more integrated solutions.

Asset management has also been an emerging concept for the past 25 years, evolving into a broadly defined system that is to 'provide a desired level of service through the management of assets in the most cost-effective manner for present and future customers' (NAMS, 2006). This definition is equally interpretive as the definition of sustainability, since assets are all uniquely defined based on the organization's views and practices. In its broadest sense, asset management aims to ensure good decision making, minimize lifecycle costs, evaluate, understand and manage risk, improve reliability, enhance knowledge management and decision making, improve communications with internal and external stakeholders and the public, and make effective use of infrastructure's lifecycle. Conversely, a narrow interpretation focused solely on existing physical assets limits broader goals and outcomes that are attainable through the asset management framework.

While asset management and sustainability are both sometimes limited in practice, integrating the two frameworks proves to be a robust and effective use of best management processes, which better meets the intent of both frameworks. This paper will look at the high-level function of sustainability and asset management, demonstrating how integrating the two frameworks guides effective best management practices at all phases in the lifecycle.

Approach objectives

The integration of asset management and sustainability is possible due to the overlap of core concepts inherent in both frameworks. A key element, although there are many, of both approaches is the focus on lifecycle (planning, design, construction, operation, maintenance, repair and replacement, disposal). Figure 1 illustrates the core elements of each framework, demonstrating their overlap. The emphasis on lifecycle serves as a point of intersection from which the sustainability and asset management frameworks can be integrated.

Both asset management and sustainability are intended to be robust frameworks that address multiple objectives, and these overarching themes are shown in Table 1. In outlining several of the core components of the two frameworks, this table also illustrates the two distinct approaches each framework takes in reaching their overlapping goals. For example, a primary objective of sustainability is to minimize the use of natural resources. Efforts are made in planning, design, construction, operations, and maintenance to reduce the use of those resources that are mined, extracted, or produced, such as water, energy, materials, etc. Equally, asset management aims to minimize lifecycle costs by extending the life of an asset, and thus reduce the use of materials and consumables, which results in improved reliability and reduced cost throughout all the lifecycle phases. Both sustainability and asset management drive optimum lifecycle decisions that maximize shareholder wealth by minimizing the long-term use of scarce resources.

Both asset management and sustainability aim to achieve enhanced performance in these core components. However, strict interpretations of sustainability and asset management drive narrow solutions that focus on only half of the issues inherited in these core components. The integration of frameworks allows for a systematic approach to address the comprehensive set of concerns that ensure resource stewardship, effective cost and risk management, outstanding regulatory performance, stakeholder engagement, and customer satisfaction.

Recognizing the inherent relationship between asset management and sustainability allows for a broadened definition of an asset as infrastructure, or even more specifically, a piece of equipment, a structure, or a pipe, to encompass an organization's personnel and natural resources. This pushes asset management into a more holistic framework, driving a greater set of operational goals than capital stewardship alone. By expanding the definition of an asset as discussed, an asset becomes synonymous with a resource. Sustainability, in its strict interpretation, is focused on natural or environmental resources. By expanding the definition of a resource to include people and economics, sustainability becomes more holistic as well. The expansion of the terms asset and resource also serves to provide almost complete alignment with each other and can be expressed simply by the triple bottom line framework, which addresses social, environmental, and economic perspectives, such that both asset management and sustainability are centred around optimizing financial / economic, environmental / natural resources, and social / staff aspects, now and into the future, as shown in Table 2.

By taking an approach that integrates sustainability and asset management, which are viewed as essentially synonymous with definition expansion, through the use of the triple bottom line framework, a project or organization is applying best management practices that provide a better outcome by optimizing economic, social, and environmental factors in a win-win-win fashion.

Figure 1
The core elements of each framework

Planning, design, and construction

In taking a lifecycle perspective to discuss the integration of sustainability and asset management, planning, design, and construction provide key opportunities for the benefits from an integrated approach to be achieved. In addition, by comprehensively addressing opportunities from these benefits in the initial planning, goal setting and decision making, greater synergy between asset management and sustainability can be achieved.

Planning is a vital part of the lifecycle in which to apply an integrated approach, because all subsequent phases of the lifecycle follow from planning. So, by using the integrated approach, asset management and sustainability will be incorporated to an extent throughout the rest of the lifecycle. Design is equally as important as it will dictate operations, maintenance, repair / rehabilitation, and eventual replacement or disposal phases throughout the life of the asset and how those phases of the lifecycle will be tied to fiscal, employee / social, and environmental / natural resource impacts. Construction is the physical manifestation and therefore extension of the design, in addition to having direct impacts to the neighbourhood, local ecosystem, and cost of its infrastructure. The fundamental components of the approach address the triple bottom line framework in planning, design, and construction in how to provide community benefits and reduce risk, protect natural resources, and strengthen the local economy while minimizing lifecycle costs.

There are numerous opportunities to apply this integrated approach in planning, which include: incorporating community or regional partnership opportunities to reduce risk, lower costs, strengthen the local economy, and enhance the community; planning for durability, flexibility, and adaptability with a long-term view in mind, such as addressing climate change impacts by considering siting vulnerabilities and future capacity needs; and incorporating the triple bottom line framework into decision making by performing business case evaluations to determine the solution with the best cost to benefit ratio while reducing risk and engaging stakeholders to create greater support / buy in and meet level of service goals.

The integrated approach can be applied to design through designing for efficient operations, system optimization, and use of resources to meet level of service goals, meet social needs by lowering costs, reduce the use of water, energy, and virgin materials, working towards long asset life and extension to reduce costs, and increasing reliability, and finally meet environmental needs by reducing environmental impacts of material, energy, and fuel use, increasing the use of renewable energy / energy efficient and sustainable equipment and materials to reduce costs, reduce greenhouse gas emissions, and improve the work place environment, and undertaking end of life recycling or alternate use opportunities to reduce costs, reduce the use of natural resources, and benefit the community.

Construction opportunities include: optimizing logistics to minimize community disruption (noise, dust, light, odour, traffic) and reduce costs and impacts to the environment by reducing the use of energy and fuel; using locally sourced materials to strengthen the local economy, increase reliability, reduce costs associated with shorter distances required for transportation, and reduce

	SUSTAINABILITY	ASSET MANAGEMENT
Waste & Replacement Management	• Waste stream management	• Optimal equipment replacement
Utilities & Natural Resource Consumption	• Nature resources management	• Efficiency
Cost & Risk Management	• Reduced unintended consequences • Sustainable return on investment	• Probability of failure related to consequences of failure • Cost management
Environmental Quality & Compliance	• Water quality & ecosystem protection • Pollution mitigation	• Maintain permit requirements • Regulatory impacts on operations
Stakeholders & Customers	• Quality of life (customers, community & workforce)	• Levels of service

Table 1
Objectives of asset management and sustainability

fuel consumption / greenhouse gas emissions that negatively affect the environment; maximizing onsite infiltration of stormwater runoff and conserving water to reduce treatment and infrastructure costs, replenish groundwater supplies, and reduce negative environmental impacts; reducing waste, recycling, reusing, and salvaging materials to reduce disposal costs and offset the need to buy additional materials or equipment and eliminate the need to extract virgin materials; and addressing traffic to reduce congestion, provide multimodal options, and improve local quality of life for the attraction and retention of employees. Many of the same opportunities for applying the integrated approach to the construction phase of the lifecycle also apply to the replacement phase.

Case study of Greenroads rating system

The Greenroads rating system is a decision tool that can be used by roadway owners, transportation planners, designers, contractors, developers, policy makers, and materials suppliers for planning, roadway design and construction projects. Greenroads is a collection of best practices that apply to roadway design and construction, much like the Leadership in Energy and Environmental Design (LEED) rating system for buildings. It can be used in the planning stages to consider a variety of potential elements to include in the project, in the design stages to incorporate specific elements, and in the construction stage for material choices and best management practices.

The tool focuses on five areas that touch all three areas of the triple bottom line approach (economic, environmental, social): environment and water; access and equity; construction activities; materials and resources; and pavement technologies. The intent is to encourage responsible decision-making by bringing various elements into planning, design, and construction, such as a lifecycle cost analysis for pavement section and stormwater elements, having a pavement management system and a roadside maintenance plan, connecting habitat across roadways, performing roadway safety audits, promoting community values, reducing emissions with quantifiable methods, improving pedestrian, bike, and transit accessibility, using alternative fuels in construction equipment, using recycled or reusing materials for new pavement, using regional materials to reduce transportation, improving energy efficiency of operational systems, designing pavements for long-life, reducing the urban heat island effect, and relating construction to performance data.

Using the Greenroads tool for roadway planning, design, and construction yields many documented benefits, including:

- Lower capital costs because recycled materials are less expensive and using resources more effectively results in less waste and therefore lower disposal costs. Better planning and designs eliminate the need for additional infrastructure (i.e. installing a proper drainage system initially prevents future problems)
- Lower operations and maintenance costs because the materials, technologies and systems used are designed to last longer
- Fewer traffic impacts because a longer lasting roadway requires fewer construction projects to repair issues
- Higher property values for commercial and residential properties surrounded by smart and durable infrastructure.
- Fewer environmental impacts due to less stormwater runoff and improvements to sensitive ecosystems
- Better eligibility for grant funding such as the Transportation Investment Generating Economic Recovery grants, United States Department of Transportation Tiger and Tiger 2 grants, and some state Department of Transportation (Oregon, Washington).

Specific projects that have used the Greenroads tool that demonstrate the benefits of an integrated approach include the 14th Street, Market Street to Colfax Avenue project by the City and County of Denver, Colorado, US. This project reused existing pavement, resulting in the extension of the of the road's remaining useful life and the use of less virgin material, employed condition assessments to develop pavement deterioration curves and project remaining useful life to optimize lifecycle costs through better timing and planning for repairs, enriched the community through educational outreach and public art installations, and using permeable pavement to reduce environmental impacts (Weiland, 2010).

The Oregon Department of Transportation US 97: Lava Butte – S. Century Drive Section project used non-potable effluent for water needs resulting in reduced contractor costs and the conservation of potable water and reused onsite vegetation material, such as grinding tree stumps for mulch, to offset the purchase cost and the environmental impacts of transporting mulch. The project also sourced materials locally to increase the reliability of materials, reduce costs, and minimize environmental impacts, such as greenhouse gas emissions due to shorter transportation distances. Other project components included the installation of long life pavement for extended asset life and lower lifecycle costs, the reuse of pavement, which resulted in saving $10-$15 dollars per ton of pavement as well as using less virgin materials, and the use of native, non-invasive vegetation species and undercrossings to help connect wildlife areas and save animal lives, reducing property damage and risk of human injury from fewer animal-vehicle collisions (Scarsella, 2010).

Operations and maintenance

It is well understood that the operations and maintenance phases of the lifecycle represents the longest, often most costly, and most critical in an asset's lifecycle. Therefore, thoughtful consideration of operations and maintenance during the planning, design and construction phases can provide significant opportunities for sustainability and effective asset management during the majority of the life of the asset. Because these phases of the lifecycle are so significant, a continuous improvement approach for managing the triple bottom line aspects are critical, and there are various benchmarking frameworks for continuous improvement. Continual 'practises' improvement is important. These frameworks, along with the adoption and ongoing use of performance management systems and key performance indicators (KPIs), can support efficient and effective operations and maintenance.

From an operational perspective, the use of operation optimization efforts can significantly impact triple bottom line management efforts. A formal programme typically focuses in the areas of water, energy, chemical, and fuel usage in an effort to reduce use of resources and minimize impacts on the environment and annual operating costs. Optimizing system operations has resulted in reduced maintenance issues, which reduces costs, improves reliability, and contributes to the extension of asset life and its associated benefits (less use of virgin material, lower costs, etc). In addition, these optimization efforts can result in significant changes in standard operating procedures, minimizing the time systems are in use which reduces the need for redundant equipment, and therefore the need to use virgin materials to create a new asset, increasing reliability and maintaining levels of service, and prolonging asset life and thus saving both money and natural resources.

Utilizing a proactive maintenance programme provides another significant opportunity to achieve triple bottom line benefits, such as lifecycle savings and improved customer levels of service through improved system reliability, reductions in the use of natural resources, and asset life extension. Increasingly, there is a trend to conduct maintenance management benchmarking studies in an effort to move from reactive to proactive maintenance programmes, with the support of computerized maintenance management systems (CMMS) and activities such as condition assessments. Using KPIs to set goals around the triple bottom line framework and the CMMS for tracking, continual improvement of maintenance activities can lead to the realization of the integrated approach benefits.

The maintenance initiatives employed often include both preventive and predictive maintenance programmes, which are designed to ensure effective equipment health and performance monitoring. Predictive maintenance leverage technologies such as oil analysis to help forecast appropriate maintenance activities. For example, where historically preventative maintenance approaches used a time based schedule for oil changes (every three months), the oil analysis results indicate the need for changing the oil based on the condition of the oil. By understanding the condition of the oil, oil changes are only completed when necessary, resulting in a significant reduction in the number of oil changes needed. The benefits from the predictive maintenance approach are reductions in the use of oil, and therefore lower costs and less impact to the environment, more efficient use of maintenance staff and increased reliability since staff can focus on the assets that actually require maintenance, reduced risk from the avoidance of costly and catastrophic failures, and the extension of asset life. In addition to oil programmes, there are other technologies that monitor performance and condition such as energy usage / efficiency, vibration, heat and flows that are used to help provide early detection of inefficiencies and failure, resulting in lower costs, fewer environmental impacts and improved levels of service. Many of the benefits that can be achieved through the application of the integrated approach for maintenance are also attainable for the repair and replacement phase of the lifecycle.

Using a work management planning and scheduling function for operations and maintenance activities enables efficient scheduling and planning of resource use for staff and materials, as well as increased reliability and decreased risk of failure. Through the use of CMMS and KPIs, the effective use of planning and scheduling can, in effect, increase staff availability and prolong asset life.

Case study Ohio

The use of a maintenance management benchmarking exercise can offer an effective approach in designing and implementing a comprehensive and integrated improvement programme. A large wastewater utility in Ohio embarked on such a journey in the mid-1990s. Their programme has evolved over time through the inclusion of a continuous improvement cycle as a core element. Today, their programme includes best practices such as:

- CMMS optimization
- KPI development
- Establishment of a formal planning and scheduling group
- Preventive maintenance task analysis
- Predictive maintenance programme development
- Lubrication / oil standardization and consolidation
- Operations optimization reviews

By implementing benchmarking recommendations, this organization has been able to realize the following benefits:

- Staffing resource efficiencies and cost savings through the use of a CMMS and formal planning and scheduling functions
- Improved reliability and extended asset life and through proactive preventative and predictive maintenance programmes
- Reduced waste and use of resources as a result of the lubrication / oil and operations optimization efforts

Decommissioning and disposition

Decommissioning and disposition at the end of the lifecycle also marks an important stage in which a combined asset management and sustainability approach produces strong benefits. Disposition itself, more so than other

Table 2
The triple bottom line of economic, environmental and social aspects

TRIPLE BOTTOM LINE	ASSET MANAGEMENT	SUSTAINABILITY
ECONOMIC	Minimize costs	Minimize the use of consumables – materials, chemicals, energy, fuel
ENVIRONMENTAL	Extend asset life reduces waste and use of virgin materials	Reduce use of natural resources and impacts to the environment
SOCIAL	Reduce risk, provide better value to customers, conduct succession planning, and increase reliability	Retain/attract good employees, engage and improve the community, and be a responsible utility

stages in the lifecycle, has a relatively balanced approach in management practiced because environmental remediation and project management costs are both high priorities. Depending on the nature of the site, one priority can easily dominate the other. If a site contains hazardous materials such as a nuclear or weapons facility, environmental remediation becomes the primary objective. Likewise, disposition of a commercial site might be solely driven by costs and schedule, especially if the local ordinances do not require demolition material to be recycled.

Decommissioning typically has strong focus on legacy, seeking to either prepare the site to be redeveloped driving economic growth, or to restore the land to a natural state, persevered for wildlife and recreation, providing both social and environmental benefits.

Decommissioning and disposition goals and results tend to be focused on one or two aspects of the triple bottom line approach. However, they have the opportunity to fully integrate economic, social and environmental objectives. Using an asset management and sustainability framework for disposition allows for resources to be recovered and either sold or reused, enhanced environmental protection of the land and water bodies, as well as an increased focus on safety of workers resulting in fewer injuries, maximized schedules and minimized costs. Asset management and sustainability focused decommissioning can result in the creation of multiuse sites, encouraging redevelopment, driving economic growth, and creating recreational space with restored natural habitats while also creating space for cultural facilities.

Disposition-focused case study

Rocky Flats Nuclear Weapons Plant, a former plutonium and uranium weapons component plant, began it disposition and decommissioning in July of 1995, including the processing, stabilization, and disposition of more than 14 metric tons of fissile and nuclear materials and disposition of more than 800 facilities. With innovating performance based contracting that drove the remarkable results, Rocky Flats closure was a unique project that exemplified the robust benefits that are produced when economic, environmental, and social objectives are equally weighed and considered. Significant savings were achieved, in part, through streamlined site operating and safety procedures and the elimination of unnecessary requirements, as site risks were reduced. Environmental quality was ensured through the stabilization and packaging of 106 metric tons of high-plutonium-content residues for disposal. Safe storage, packaging, and disposition of 21 metric tons of SNM (highly enriched uranium and plutonium) were completed more than a decade ahead of schedule (beating the regulatory milestone by ten years). Resource recovery was achieved through the resale / reuse of uranium to brokers from Rocky Flats, including 2.5 percent enriched uranium for fuel products, highly enriched uranium for use in the Naval Reactor Program, and depleted uranium for use in making armour and weapon projectiles. This experience enabled material that had previously been marked for disposition to be appropriate for commercial sale.

Success at Rocky Flats freed up $600 million per year for the United States government to use on other projects. Previous Department of Energy estimates projected the closure of Rocky Flats by 2065 at a cost of $36 billion. With the innovative approach that was used, the Rocky Flats Closure Project was completed in October 2005, 60 years ahead of original government estimates and $550 million less than the final contract budget. Allen Schubert, Director of Strategic Planning, Rocky Flats Project, commented on the project's approach that yielded many triple bottom line benefits by stating: 'The programme motivated employees to think of creative ways to get the job done… employees began to sit back and think about how can I get this particular work done in a way that I could save money and be safer? A number of significant innovations were born, resulting in many, many hundreds of millions of dollars in savings.'

Triple bottom line benefits for the Rocky Flats Closure Project include the total cost coming in at $30 billion less than the initial contract budget, the completion date 65 years earlier than projected saving $100 million in security per year alone, 283 million square feet of land being decontaminated and the area now being a wildlife refuge, the pollution per gram of soil was decreased by over 95% (44% below target), and the safety rate was improved by over 400% ($300,000 rebate from insurance). In 1995 there were 900 employee grievances and in 2005 there were only a handful, there were over 200 innovations developed in conjunction with the Department of Energy, including glove box decontamination from one per year to three per day, and 20% of profits were paid to all employees, including union.

Decommissioning-focused case study

In downtown Milwaukee, US, on the Menomonee River, 140 acres (56ha) had a long history of being dedicated to the locomotive industry. With such a history, the land was contaminated with heavy metals, petroleum, chlorinated organics, and asbestos. In 2003, this riverfront was an underserved area, lacking commercial or residential use. With a vision for redevelopment and the leadership to drive implementation, the City of Milwaukee received the property via condemnation. Focused on decommissioning with strong triple bottom line legacy components, the City began planning an integrated development plan to create the Menomonee Valley Industrial Center, rich in recreational, economic, and natural assets. The project grew out of a 1998 City-adopted plan that recommended the City acquire and redevelop the 133-acre vacant Milwaukee Road Shops facility, abandoned in 1985.

Much like the Rocky Flats Closure Project, the decommissioning of the Menomenee Valley Industrial Center was focused on innovated approaches to achieve triple bottom line results. Developing a first-of-its-kind onsite management plan with the site's regulatory agencies, $15 million of savings was realized by successfully negotiating through the onsite stabilization and encapsulation of asbestos-containing materials. In addition, more than $25 million was saved through value engineering, new-found revenue streams, and reuse of materials – recycled glass, timber, and brick, which was otherwise destined for a landfill. Green infrastructure (wetlands, open space, and other previous space) was used to manage stormwater, create habitat and return native species to the area landscape. This approach also allowed for a new 'green' recreational spaces for the community – including bike and walking trails, soccer fields, tennis courts, pedestrian bridges, fishing areas, and access to the cleaner river via canoe ramps. What was once unusable land will bring as many as 1500 jobs to Milwaukee and create an increase of more than $120 million in recreational, aesthetic, and ecological value for the people of Milwaukee due to the City's leadership.

Summary

Both asset management and sustainability are holistic, systematic approaches that should be highly integrated to achieve best management practices, and, with expansion of the terms 'asset' and 'resource', these two approaches are essentially identical. The integrated asset management and sustainability framework addresses the triple bottom line approach through significant reduction in the use of natural resources, such as of water, energy, chemicals, materials, and land and waste generation (and thus cost), reduced costs of constructing and operating capital facilities over their full lifecycles through sustainable supply chain management and optimization of fleet, operations, and maintenance processes, systematic and consistent compliance with safety, availability, performance, and environmental requirements, improved accountability, service management, risk management, and financial efficiency, effective information retention and improved regulatory compliance, increased environmental benefits, improved community engagement, level of service delivery, and public safety and reduced disruptions from as noise, air, dust, odour, traffic, crime, and longer service life for facilities and infrastructure. It should be noted that organizational effectiveness and leadership, along with supporting information and management systems, are key ingredients to sustaining an integrated asset management and sustainability approach.

Customers, stakeholders, communities, and the public are asking enterprise and governmental organizations to do more with less in a responsible manner. Both asset management and sustainability, used conjunctively in a robust framework, provide that answer with greater value, demonstrating good decision making and an effective means to plan, document, and communicate the vision, goals, progress, and successes both internally and externally. Regardless of which phase in the lifecycle, this approach can be successfully applied to achieve economic, environmental and social benefits. ●

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Optimizing asset investments across asset types

With water distribution networks aging, requiring significant investment by utilities, a structured, risk-based planning approach is needed for utilities to achieve the greatest benefit from limited budget opportunities. Dilip Kumar Shivalingappa and Paul Chinowsky discuss how asset management is perceived in different industries, and how optimization can be achieved across various asset management scenarios that take into account different asset types.

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The American Society of Civil Engineers (ASCE) issued an infrastructure report card in 2009 giving a bleak cumulative ranking of D[1]. The ranking, which grades the condition of 15 infrastructure entities such as drinking water, roads, bridges, energy and dams, was the same as the previous report, released in 2005, whilst in 2001 the grade was D+, slightly better but still poor. It was stated that there is a risk in reversing the public health, environmental and economic gains of the past three decades if infrastructure is allowed to continue deteriorating. The current problem is that most of the infrastructure is aging and spending has not been adequate to repair, replace, or rehabilitate assets within the systems. The ASCE estimates that the government and the private sector need to invest $2.2 trillion over five years, roughly 15.9% of the gross national product.

The historical approach adopted by cities, utilities and other organizations to identify assets for inspection, repair or replacement has been reactive in nature, prioritizing renewals on a first-come, first-served basis as problems arise. This is particularly true for buried infrastructure and large asset networks such as pipelines and overhead and buried cables, which provide particular challenges in forecasting failure. This approach makes year-to-year budgets difficult to determine or justify and usually results in additional expense because reactive measures are typically more expensive than proactive ones.

In contrast, structured risk-based planning determines budgets based on current versus target risk levels, allowing organizations to save money over the long-term while developing quantifiable capital planning that can be adjusted based on current budget constraint scenarios. Other benefits include improved customer service resulting from fewer interruptions and more coordinated long-term planning across different departments.

Typical challenges to a proactive approach include a lack of reliable local data on the life expectancy of assets and an inability to effectively coordinate plans across multiple departments. While risk planning proves effective for single infrastructure types, the most efficiency is gained by considering multiple asset types – particularly for underground projects that typically require resident disruptions during upgrades.

Industry knowledge

Many directors[2] and analysts think 'asset management' is all about corporate mergers and acquisitions, return on capital employed and 'asset stripping'. Others have grabbed the phrase to mean 'more professional maintenance', 'equipment tagging and tracking', or 'asset information and work management software'. True asset management defines what a joined-up physical asset management system needs to include. It requires a life cycle view and optimal mixture of capital investments, operations, maintenance, resourcing, risks, performance and sustainability. Here are six distinct yet common current uses of the term 'asset management':

- The financial services sector has long used the phrase to describe the management of a stock or investment portfolio – trying to find the best mix of capital security / growth and interest rates / yield.
- The board (usually financial) of directors and some city analysts use the term in relation to mergers and acquisitions – buying and selling companies, reorganizing them, divesting low value elements and trying to raise capital value and / or yields.
- Equipment maintainers have also adopted the term in order to gain greater credibility and visibility for their activities, as 'maintenance' has for so long been treated as a necessary evil, and low on the budgeting priority list.
- In line with the maintainers seeking greater corporate credibility, the large number of software vendors[3] selling asset information management systems (including asset registers, GIS systems, work management, history gathering, materials control & cost reporting, etc.) have often relabelled their products as 'enterprise asset management systems'[4]. This has given rise to a misconception that asset management is a technology initiative to sort out the data and IT infrastructure.
- If we dig deeper into the information systems world, we even find 'asset management' interpreted as simply the bar-code labelling of computers and peripherals, and the tracking of their location / status (i.e. 'asset tracking').
- Finally, a few critical infrastructure or plant owners and operators have adopted the term 'asset management' to describe their core role in life[5] – both caring for, and making best sustained use of, physical plant, infrastructure and its associated facilities.

Optimization

The final definition above constitutes the basis for the significant performance improvement opportunity available to almost every company in every industrial sector. If we broaden the scope to describe not just physical assets, but any core, owned elements of significant value to the company (such as good reputation, licenses, workforce capabilities, experience and knowledge, data, intellectual property, etc.), then optimized, integrated asset management represents the sustained best mix of: asset care (i.e. maintenance and risk management); and asset exploitation (i.e. use of the asset to meet some corporate objective and / or achieve some performance benefit).

Perhaps not surprisingly this is what the financial services sector uses the term to describe – finding the right combination of asset value retention (capital value / security) and exploitation (yield) over the required horizon. Like different bank accounts or investment options, physical infrastructure can also be protected and well cared-for, with high capital security (condition) but lower immediate returns (profit), or it can be 'sweated' for better short-term gains, but at the risk and condition cost of future usefulness / value. Asset management involves trying to juggle the conflicting objectives – milking the cow today but also caring for it so that it can be milked and / or sold well in the future.

'Optimization' is the word for the resolution of such trade-offs and compromise requirements, but few really understand what it means in practice. Balanced scorecards for example are nearly always misnamed – there is no 'balancing' mechanism in sight! In fact, 'balance' is not what we are looking for anyway: balance involves equality of impact, pressure or achievement. Optimization, on the other hand, involves trying to find the most attractive combination (sum) of conflicting elements (which may involve lots of cost and very little risk, or vice versa, or any other combination – just so long as the net total impact is the best that can be achieved).

Of course there are significant challenges in putting numbers to Figure 1. The uncertainties about asset behaviour, future requirements,

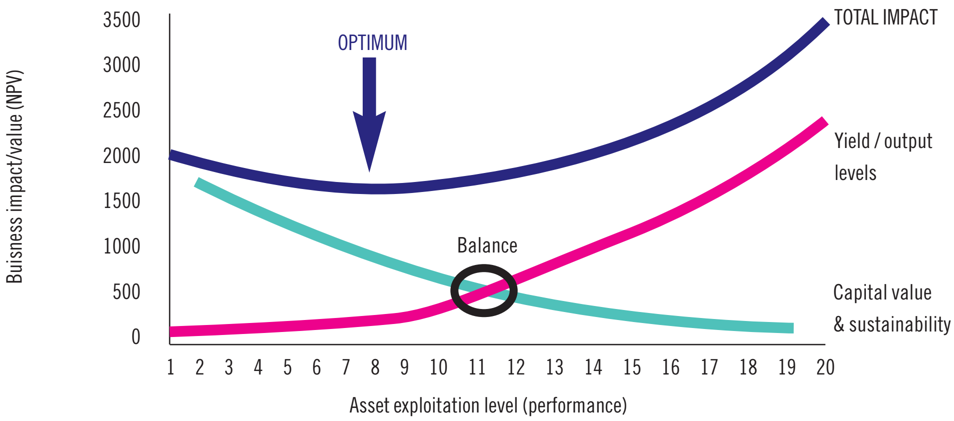


Figure 1
The core elements of each framework

performance values, costs and risks all contribute to make the lines 'fuzzy'. Furthermore, we tend to organize ourselves into groups of functional specialism so that we do not see the whole picture anyway. Departments are set up to design / build the assets (engineering), exploit them (operations or production), or to care for them (maintenance). Often, only the finance director or corporate leadership, or even the customer, has the self-interest in optimizing the combination, unless asset-based management has been adopted properly. Organizing a company by 'activity type' may be administratively convenient, but it loses sight of the whole.

The origins of integrated, optimized asset management

The term 'asset management' would not normally be expected to set many on fire with enthusiastic zeal. It sounds too much like housekeeping and a boring, disciplined 'ticking of all the boxes'. However, the surge in corporate and regulatory interest for better optimized, integrated[6] asset management has gathered considerable momentum over the last few years. There is certainly a big contrast between merely 'managing the assets' (which many companies would feel they have been doing for decades), and the integrated, optimized whole-life management of physical, human, intellectual, reputational, financial and other assets.

The 'asset' definition has differed between interpretations – some set the boundary as the water / wastewater network as the starting point, with all associated infrastructure to extract it, others chose physical infrastructure (platforms) in the first place as the units of business or profit centres. The common and vital feature, however, is the recognition that needs to be much more closely linked (possibly lying in one pair of hands: the 'asset manager'), so the person / team that has to deliver the output also has full relevant budget decision making information: what is worth spending, when, to achieve / improve / sustain the performance. Any shared services or resources have to compete in an open market fashion for the attention and funding of the (asset) budget holders.

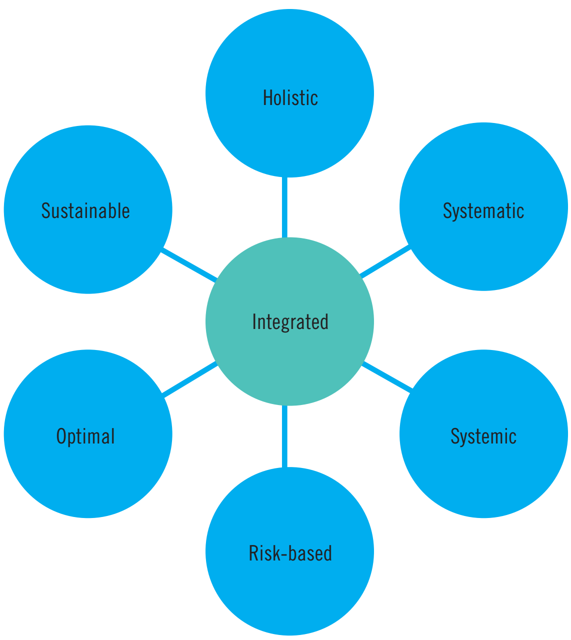
As defined in the specification PAS 55:2008, the optimal management of physical assets is: systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan.[7]

The integrated asset management identifies a number of critical attributes that characterizes a joined-up and sustainable asset management system (Figure 2).

The seven key attributes of good practices in asset management are:

- Holistic: asset management must be cross-disciplinary, total value focused
- Systematic: rigorously applied in a structured management system
- Systemic: looking at assets in their system context, again for net, total value rather than component or localized goals
- Risk-based: incorporating risk appropriately into all decision making
- Optimal: seeking the best compromise between conflicting objectives, such as costs versus performance versus risk, or short-term versus long-term benefits
- Sustainable: plan must deliver optimal whole asset life cycles rather than artificial short-term results at the expense of long-term consequences
- Integrated: at the heart of good asset management lies the need to be joined-up. The total jigsaw puzzle needs to work as a whole – and this is not simply the 'sum of the parts'.

Figure 2
The seven steps of asset management good practice



As infrastructure is built or rehabilitated, life-cycle cost analysis should be performed for all infrastructure systems to account for initial construction, operation, maintenance, environmental, safety and other costs reasonably anticipated during the life of the project, such as recovery after disruption from natural or manmade hazards. Additionally, owners of the infrastructure should be required to perform ongoing evaluations and maintenance to keep the system functioning at a safe and satisfactory level. Life-cycle cost analysis, ongoing maintenance, and planned renewal will result in more sustainable and resilient infrastructure systems and ensure they can meet the needs of future users.

Problem overview

As utilities across the United States have started to make advances towards a more risk-based approach to asset renewal forecasting, two challenges have arisen: the lack of reliable, local data on the expected lives of assets; and the need to effectively coordinate with the plans of other departments (e.g., streets, gas, electric, optic cable) to maximize the cost-effectiveness of asset renewal efforts.

Of course, 'linear' assets are not as simple as discrete location sites, systems or resources. However, the fact that infrastructure is a network of wires, pipes or routes does not fundamentally change the requirement. The unit of performance delivery is still a compound system (of different component asset types working together), and the responsibilities for budget assignment need to be targeted in due proportion to the performance contribution that is possible.

Research approach

As part of this research, a pilot project will be identified and developed to represent the next steps for our industry towards more cost-effective, accurate, risk-based asset renewal planning. Specific benefits of these efforts are expected to include:

- Cross-departmental asset management strategy
- Use of locally-generated deterioration curves rather than industry standard curves
- Renewal forecasts integrated and optimized in consideration of other asset repair plans
- More accurate risk-based asset renewal forecasts and budget planning
- Lower overall costs and reduced construction inconvenience for customers
- Effective tools for communicating collection system risks to decision makers
- Model for more effective data utilization and improved capital improvement programme (CIP) project prioritization

In this pilot project at a municipal utility, over a five square mile (8km^2) area the assets of pavements, the water collection system and the water distribution system are focused on.

Three Optimization Models (ex: Fuzzy, Markovian, Artificial Neural) will be developed and results will be analyzed, compared and documented, whilst a 50-year asset renewal cost forecasting will also be developed. The three scenarios that will be developed are 'do nothing', 'budget constraint' and 'risk constraint'.

A truly asset-centred business model has not yet been widely recognized or adopted in the utilities – most are still thinking in terms of 'the asset' as the entire infrastructure / network and continue to divide responsibilities by asset type (e.g. electrical protection equipment, signaling or wastewater treatment) rather than units of performance-boundaried system (e.g. source-to-tap water catchment area or primary trunk route). At senior management levels, the adoption of an 'asset management' model has been interpreted to mean a new mix of functional responsibilities. This does at least emphasize the need for directional thinking on a more global scale (what is worth doing, where, when and why), not just delivery efficiency (doing the same thing quicker, cheaper). ●

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AWARE-P asset management planning software released

A beta version of the European leading-edge support software project AWARE-P has been released, resulting from collaboration between Portugal's National Civil Engineering Laboratory (LNEC), the Technical University of Lisbon (IST), Portugal's Water and Waste Services Regulator (ERSAR), the ADDITION and YDREAMS software firms and the Norwegian Building and Infrastructure Institute (SINTEF).

The AWARE-P infrastructure asset management (IAM) planning software for drinking water, wastewater and stormwater services is an organized assessment environment where planning solutions or competing projects are measured up and compared through selected performance, risk and cost metrics.

Dr Helena Alegre, the project's initiator and scientific co-ordinator, said to Water Asset Management International that the overall aim of the project is to address unsustainable management of urban water infrastructure and to 'have balance between the performance of the systems, the risk involved for the utility and the customer and the costs involved'.

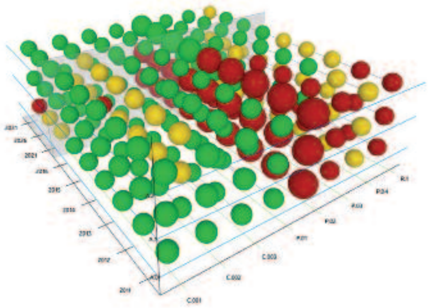
'We [were looking to] develop a [new] approach for infrastructure asset management and to develop products ready to use at the professional level by utilities,' she explained. 'All of the products of the project are available for everyone who wants to use them, free of charge.'

The AWARE-P software comprises a portfolio of metrics and analysis tools that may be used individually for diagnosis and sensitivity gain purposes, or as part of the integrated planning procedure laid out by the AWARE-P IAM programme. The AWARE-P approach allows asset managers to make informed decisions on operation and management of a system through evaluating the dimensions of performance, risk and cost.

'We don't really have a competitor in the market because normally what you find are products that are more directed to maintenance of the assets, investment planning, condition assessment, or hydraulic analysis and risk management,' said Alegre. 'What we are really trying to achieve is an integrated comprehensive approach that takes on board the strategic, technical and operational levels of decision making.

'[The software allows a user to] compare the different intervention alternatives accounting for performance, risk and cost over the long-term. You cannot allocate a specific level of service to one element of the network – a single pipe is useless by itself, so its value depends upon the system's behaviour. This is something that the classical way of asset management doesn't deal with in a proper way. So we developed research in order to address this physical indefinite life and the network behaviour of these systems.

'One of the important things in the AWARE approach and software is that they are fully aligned with IWA performance indicator systems and the benchmarking manual of best practice,' she said. 'So we have incorporated into the AWARE library all of the performance indicators of the IWA PI systems that may be relevant for infrastructure asset management. This is the basis of our comparison between the different alternative [maintenance] strategies.'



There has already been a good response to the beta version of the software, said Alegre, and LNEC is looking towards expanding the AWARE-P approach with further project work. 'We are launching a national project called the national initiative for asset management,' Alegre commented. 'This is a Portuguese project where we are going to work with 16 utilities to assist them with developing their own infrastructure asset management plans based on the AWARE approach. This is a 17 month project, self-funded, that is going to start in April and this will also allow us to develop some new modules of the AWARE software.' ● **CF**

A walkthrough and example case data can be found at www.baseform.org/np4/apps/awareApp.html. More information on the AWARE-P project can be found at: www.aware-p.org

WAMI PUBLICATIONS

Deterioration Rates of Long-life, Low Probability of Failure Assets: Project Report
Author: UKWIR
Several asset groups within the water industry can best be described as long life, low probability, extreme consequence of failure assets. Inclusion of these assets within company investment plans requires consideration of the probability and consequences of asset failure in the future. Where failure probabilities are low, few historical failure data will be available for analysis. Therefore, failure probability must be estimated using alternative methodologies.

With this objective in mind, a toolbox has been developed covering key asset groups and failure modes which also includes worked examples and case studies which demonstrate a range of real life scenarios.

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Leading Practices for Strategic Asset Management
SAM1R06h
Author: Linda Blankenship
In response to the need identified by its utility members, the Water Environment Research Foundation has funded a research programme on Strategic Asset Management (SAM) Implementation and Communication for wastewater and water utilities.

An objective of the research programme has been to improve economic life and realize cost savings in the provision of water and wastewater system services. In particular, the research documented in this report has focused on identifying and documenting leading strategic asset management practices used by utilities. This title belongs to WERF Research Report Series.

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WERF Report SAM1R06e
Author: Duncan Rose
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IWA Publishing June 2012
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