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PAPERS

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Report urges Australia to embrace privatisation

A report from the Global Access Partners Urban Water Forum think tank has recommended that Australia should adopt water privatisation, trading and cost transparency to ensure that household supplies remain secure into the future.

The report envisages a wide range of suppliers for customers to choose from, with the government in a regulatory role and providing consumer protection. It says: 'The absence of a competitive market for urban water, together with a variety of institutional constraints, has impeded some potentially attractive solutions. In some cases the absence of market signals and legal restrictions prevent urban water utilities seeking the most cost effective ways to meet their customers' needs.'

The 'staged and contingent' road map for reform, launched last week, says that the interim structure would allow for some competition at the wholesale level but would stop short of full competition until the benefits and design requirements become clear. 'The final decision to move to a fully competitive market is best made once the results of the move to an interim structure are known and understood,' it notes.

The Forum calls for 'market competition and carefully-designed regulation'. It envisages an initial period of market, regulatory and institutional design and planning, necessary to enable the reforms, which could possibly take one to two years to implement, followed by an interim market featuring a competitive wholesale market, to be put in place in two to four years, and – subject to further analysis – a competitive retail market within five to ten years. ●

EC, World Bank and partners meet to discuss coordinating key initiatives

The European Commission (EC), the World Bank and many of their development partners have taken part in meetings to increase their coordination of, and support to, critical infrastructure initiatives in developing countries hard hit by the global economic crisis.

Representatives from multilateral development banks, the European Investment Bank (EIB), bilateral development agencies and development financing organisations met to draw attention to the financing gaps that face many developing countries as they seek to protect existing infrastructure and plan new projects or programmes to create jobs and boost their economies.

The meetings took place under the umbrella of INFRA, the World Bank's Infrastructure Recovery and Assets platform, which now includes many other development partners.

Katherine Sierra, World Bank vice president for sustainable development, told the meeting: 'We are seeing declining investments in national infrastructure plans as a result of the global economic crisis.

'Past experience, such as during the Asian crisis of the late 1990s, clearly tells us that this is not the time to cut back, but rather the time to ramp up infrastructure investments. In the past year, we have raised our infrastructure financing by almost 20% to $20 billion, yet we know that more is needed to help countries emerge from the downturn more quickly and move more quickly into sustained economic growth and poverty reduction.'

Stefano Manservisi, the EC's director general for development and relations with African, Caribbean and Pacific states urged: 'As we did in Europe, we should invest in infrastructure as a means to create growth and jobs in developing countries. If development policy is going to help tackle poverty, aid needs to become much better at leveraging other sources of finance.'

The World Bank notes that global financial crisis has depressed investments in infrastructure projects, particularly in developing countries. The economic crisis may also mean countries compromise on their environmental and climate commitments due to the need to reallocate budget resources to more urgent actions.

Public and private sector investments for new infrastructure, as well as funds for maintaining existing infrastructure in developing countries, are at risk due to the crisis, the Bank notes, adding that infrastructure projects are widely recognised as a key to job creation and laying the ground work for future productivity and growth.

Because it is labour intensive, infrastructure is an important element in most government stimulus packages around the globe. The MDGs (Millennium Development Goals) also recognise access to water and sanitation as a catalyst for poverty reduction.

Delegates to the meetings in Brussels shared information about how best to continue supporting infrastructure projects or programmes in developing countries and how to coordinate support for future projects, and also discussed the creation of a new project preparation facility. ●

water asset management INTERNATIONAL

EDITORIAL

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IIED report warns that Malawi is failing to meet its watsan MDG

Malawi is failing to meet the Millennium Development Goal (MDG) for water and sanitation in its urban areas and misleading official statistics are hiding the scale of the problem, according to research published recently by the International Institute for Environment and Development (IIED) and the Scottish government.

The new IIED study shows that water and sanitation remain 'woefully inadequate' in the informal settlements that are home to around 60% of the country's urban population, despite government claims that nearly all urban citizens have access to safe water and sanitation.

Mtafu Manda, director of the Alma Consultancy in Lilongwe, Malawi, undertook the research in nine of the country's low-income informal urban settlements. Mtafu Manda also teaches at Mzuzu University in Malawi.

The research reports on interviews with 1178 households living in nine low-income settlements in each of Malawi's three largest cities: Blantyre, Lilongwe and Mzuzu. The study included interviews with staff from central and local governments, civil society organisations and water sellers operating water kiosks, where people can buy water by the bucket.

In the nine settlements studied, only 25% of households had their own individual water connections. Half relied on water bought from water kiosks while 13% bought water from another house plot. Kiosks do not provide a 24-hour service; most are open for three hours in the morning and three hours in the afternoon, and remain closed overnight.

Less than 10% of Malawi's urban population have homes connected to sewers. 90% of Blantyre's inhabitants and 92% of Lilongwe's (both with populations of over 600,000) lack a sewer connection.

In Mzuzu, a city with over 100,000 people, there are no sewers. Most people in these three cities rely on pit latrines, and in the informal settlements most households share latrines. Most households in the informal settlements are not served by any household waste collection.

However, official statistics for 2006 suggested that 96% per cent of Malawi's urban population had access to potable water, and 97% had access to safe sanitation. The study reveals that these figures are inaccurate. ●

UNEP report claims green investments 'are a legal responsibility'

Green investments are no longer just a luxury, but are now a legal responsibility, according to a new report by theUnited Nations Environment Programme (UNEP) and a powerful group of asset managers who control some $2 trillion in assets.

The 120-page publication argues that if investment consultants and others do not incorporate environmental, social and governance (ESG) considerations into their services, they face 'a very real risk that they will be sued for negligence'.

It also stressed the central role that the world's largest institutional investors – including pensions funds, insurance companies, sovereign wealth funds and mutual funds – have in easing the transition to a low-carbon and resource-efficient green economy.

UNEP Executive Director Achim Steiner said: 'ESG issues are not peripheral but should be part of mainstream investment decisions-making processes across the industry.'

He also noted that creative market mechanisms and other incentives can help to ensure that as investors return to markets after the current financial turmoil ends, they will put their funds into a greener economy and not the 'brown economy of yesterday'.

The new report, titled 'Fiduciary responsibility: legal and practical aspects of integrating environmental, social and governance issues into institutional investment', was produced by the Asset Management Working Group of the UNEP Finance Initiative (UNEP FI), a partnership between the agency and nearly 200 financial institutions around the world. ●

CIRIA welcomes critical infrastructure reports

CIRIA (construction industry research and information association) has welcomed two reports into the state of critical infrastructure in the UK, written by the Institution of Civil Engineers (ICE) and the Council for Science and Technology (CST).

The reports recommend the appointment of a lead body to oversee the protection and resilience of national infrastructure, one that would work closely with the newly-formed Natural Hazards Team to deliver a clear and consistent vision for future requirements in particular for building with increased resilience to natural hazards such as flooding.

Following the Pitt Review in 2008 and building on previous work, CIRIA, working with consultant Arup as research contractor, is leading a collaborative project – flood resilience and resistance for critical infrastructure – along with the Environment Agency, Network Rail, Highways Agency and other leading infrastructure asset owners and stakeholders. The aim of the project is to increase the resilience of the UK's critical infrastructure assets to flood risk.

The CIRIA and Arup project team undertook extensive consultation, involving a workshop and online questionnaire survey with input from the UK's leading infrastructure asset owners and operators.

The findings are currently being reviewed and incorporated with a wide-ranging literature review of both national and international practice to formulate a final project report, which is due for publication in Autumn 2009.

Interim findings from the CIRIA project were shared with key representatives for the ICE State of the Nation enquiry, which in turn has fed into the CST report. ●

Condition assessment and its role as a component of asset management

Asset management of urban water infrastructure varies in its level of sophistication and generally progresses from condition-based, through performance-based to service-based, to the higher level of risk-based asset management and finally to the newly defined sustainability-based asset management. This paper discusses the role of condition assessment at the different levels of asset management and especially its implementation into a risk-based asset management approach where its application to both proactive and reactive assets is explored. In this context, the approach outlined is aligned with the best practice concept that condition assessment should ideally be undertaken only when required to fill a specific gap in asset-related information to improve decision-making. To allow the selection of the correct procedure an exclusion process is explored in which tools are excluded on the basis of criteria relating to technical feasibility, technical suitability and utility technical capacity. To allow the maximum value of usable options to be obtained a cost-benefit application for the scheduling of future interventions using condition inspection is addressed to allow the optimal timing of intervention. By Stewart Burn and David Marlow.

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Recent infrastructure report cards and studies undertaken in the United Kingdom, Australia and the United States have shown a common theme – that the state of existing infrastructure is deteriorating and there is a significant backlog of renewal/replacement investment required to ensure that water and wastewater utilities can continue to deliver sustainable services to their communities. The long-term cost implications of continuing to have a poorly structured replacement or renewal programme could be significant. For example, the United States-based Water Infrastructure Network estimated that the gap between spending levels and the investment required to meet the United States' national environmental and public health priorities embodied in its Clean Water and Safe Drinking Water Act will reach US$23 billion a year over the next 20 years (Water Infrastructure Network, 2000), while the American Water Works Association estimated that US$250 billion over 30 years might be required nationwide for the replacement of just reticulation water pipes and their associated valves and fittings (AWWA, 2001).

This situation is common to the water sectors of many countries, and has largely come about through pipes reaching the end of their life expectancy in combination with a low rate of replacing these pipes. In many cases this can be related to the adoption of management practices with a short-term focus, which has lead to deferral of the investment required for asset renewals. For example, in the United States, there has been a tendency to focus on 12 to 18 month funding cycles and project delivery due to the nature of annual government budgets. This funding trend, combined with two to four year election cycles, has created an atmosphere that encourages short-term decision making on infrastructure matters, rather than a long-term view (Rast, 2003).

The challenge for many water utilities today is to determine how best to manage their assets with limited replacement funds, while maintaining a satisfactory level of service in the long term.

One of the key issues to maintaining service levels is to understand the condition of the asset stock. Whilst there are many papers in the literature discussing condition assessment techniques (Burn et al 2001, Davis et al 2004, DeSilva et al 2002, Dingus et al 2002, Eiswirth et al 2001, Sadler et al 2003), up until recently there have been no standardized guidelines for conducting condition assessment nor have there been protocols to help utilities better understand asset condition, performance and the required methodologies associated with different levels of sophistication in asset management.

In this context, the question arises as to how utilities should undertake condition assessment within an appropriate asset management framework to address the following issues:

- Meet customer service expectations as well as legislative requirements.
- Determine the risk of failure (probability versus consequence) associated with different assets, and therefore, prioritize spending within limited budgets.
- Understand asset condition and remaining life, allowing for proactive budgeting for renewal/replacement.
- Quantify the benefits of different management/operational strategies.
- Determine asset value and comply with accounting standards such as GASB 34.

A recent report by Marlow et al (2007) discusses these issues in detail and this paper builds upon that report to demonstrate the important link between accepted and emerging principles of asset management. It

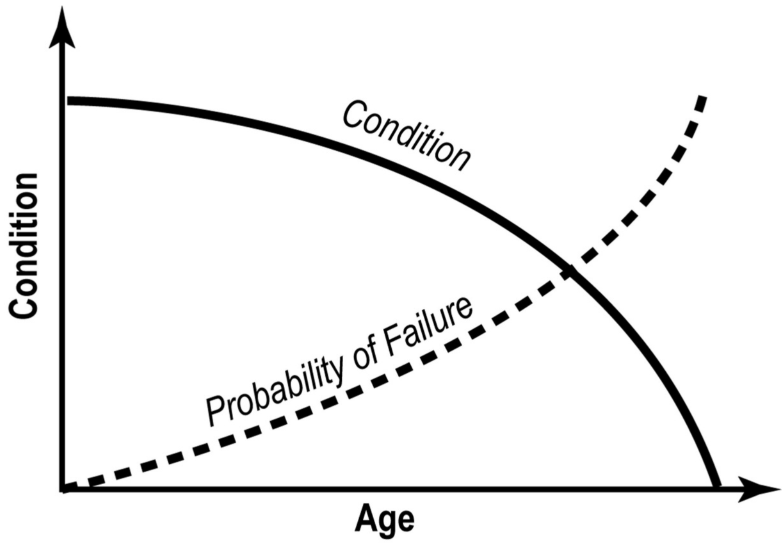


Figure 1
The relationship between asset condition, age and failure probability

discusses approaches to condition assessment, and provides a road map for the effective use of condition assessment tools and techniques within the framework of various asset management approaches, thereby allowing cost effective application of condition inspection and hence optimal timing of interventions.

Asset management approaches

The adoption of formal asset management by utilities has generally lagged behind the development of the asset stock. As such, asset management has commonly evolved and developed around existing utility systems and in light of existing assets. The role of condition assessment as part of this strategy has generally been ignored and condition assessment has been applied in an unstructured manner.

If we examine the development of asset management approaches as discussed by Marlow et al (2007) and Marlow (2009), they can be characterized in terms of a succession of dominant philosophies. In reality, each successive approach builds on the previous one(s), so any explicit division is somewhat artificial. Nevertheless, for the purposes of this discussion, it is useful to consider the approaches as a distinct staged development of increasing asset management sophistication:

- Condition-based asset management
- Performance-based asset management
- Service-based (service level driven) asset management
- Risk-based asset management
- Sustainability-based asset management

In *condition-based asset management*, expenditure is focused on maintaining 'what assets are' (the condition they are in). This is a natural approach for engineers to adopt; if the condition is poor, the asset needs maintenance/ investment to rectify defects.

In a similar vein, *performance-based asset management* focuses on 'what assets do' in a local sense; that is, the question is posed, 'is the asset doing the job that it was intended to?' (This is a question that can often be related to the asset's condition, but may not be.) If not, maintenance and/or capital investment are required. Again, this is a natural way for engineers to consider management of assets.

A more customer-focused approach is taken in *service-based asset management*. Performance is not viewed in terms of local considerations (the design intent of individual assets), but instead is considered in more inclusive terms and at a higher level. The question is posed, 'is the asset contributing appropriately to the delivery of service?' This consideration is made independently of asset condition or its performance relative to design intent.

Service-based asset management thus seeks to maintain the service provided by the asset stock at both the local and regional level, with due consideration given to equitability issues (usually couched in terms of minimum levels of service). This approach is less intuitive for engineers, since it can mean that maintenance/ investment is not always justified for poor condition assets or even poor performing assets where the impact on service is acceptable.

Asset management approach adopted	Proportion
Condition-based	28%
Performance-based	19%
Service-based	10%
Risk-based	14%
No defined strategy	29%

Table 1
Approaches to asset management adopted

Risk-based asset management seeks to achieve optimum life cycle management of assets through consideration of risk to service provision, with risk generally being defined as the product of 'probability of failure' and 'consequence of failure'. The condition and performance of an asset are simply factors in the assessment of risk. Other factors taken into account include business risk factors such as those associated with safety and the environment, customer expectations, reliability, efficiency and effectiveness, finance, reputation and regulatory relationships.

Sustainability-based asset management builds upon risk-based asset management to incorporate the environmental and social concepts via a triple bottom line analysis, thus allowing the principles of sustainability to be considered.

It is interesting to note that in a web-based industry survey (Marlow et al, 2007), utilities were asked to specify which of these categories best described their approach to asset management. The results are shown in Table 1 for a sample of 30 respondents, 21 of which were from the United States. The table shows that there are a wide range of philosophies still being adopted within the sector, and that nearly one-third of the respondents indicated that there was no defined strategy being used.

The role of condition assessment in each of these approaches has been poorly defined and thus a condition assessment protocol needs to be developed to allow utilities to determine the appropriate timing for condition assessment in their decision making process.

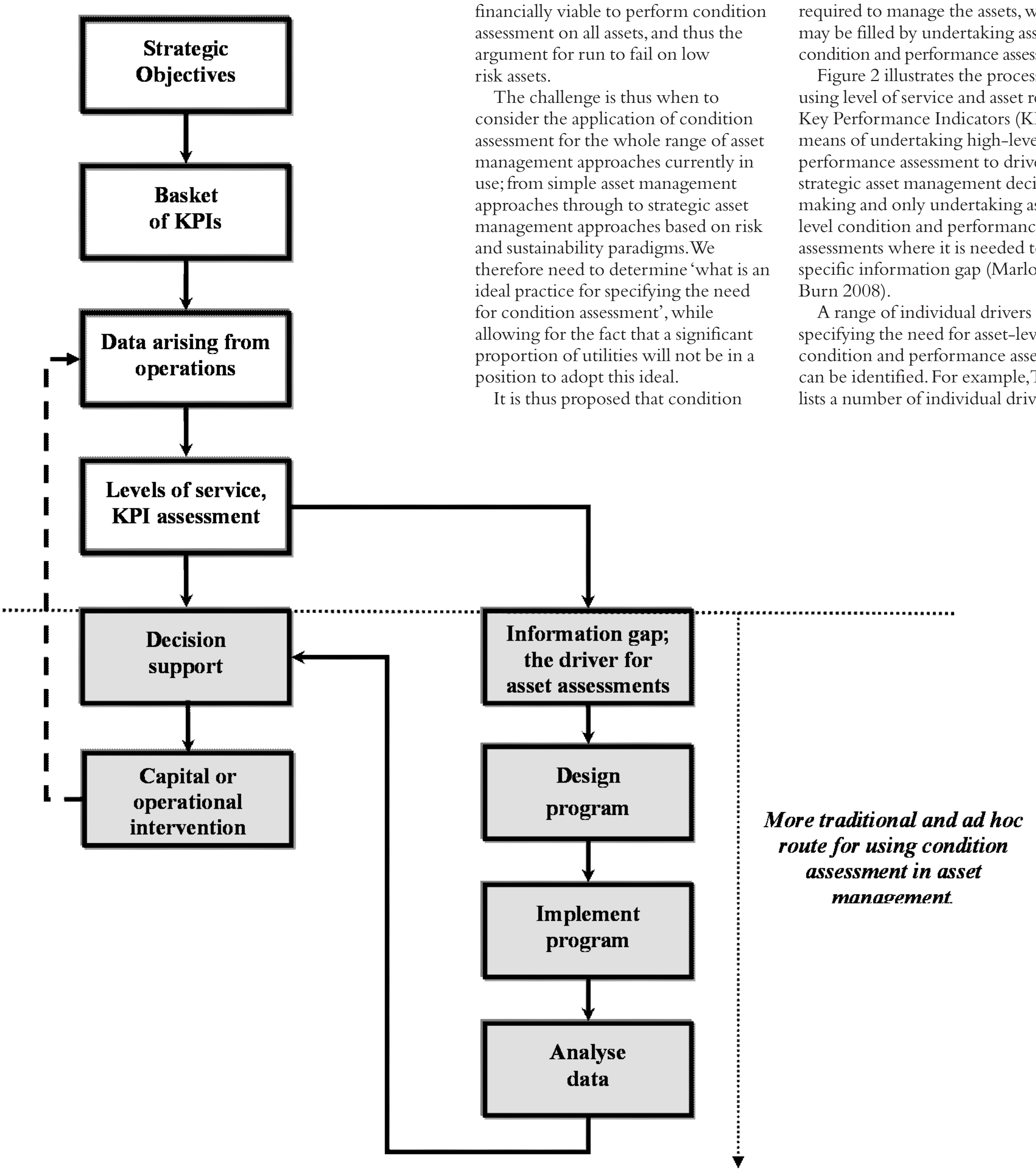
Condition assessment as a component of asset management

As discussed above, there has been a successive development of asset management philosophies (from a focus on asset condition and performance to a focus on service provision, business risk and sustainability) and an associated increase in asset management sophistication in the water utility sectors of a number of countries. Since the more developed asset management philosophies do not focus on asset condition, it can be concluded that strategic asset management does not seek to manage asset condition or performance. Nevertheless, there remains a general relationship between the condition of an asset and its propensity to fail, as illustrated in Figure 1.

To maintain service into the future in an affordable way, the utility must therefore understand the change in structural condition, or the probability of failure of all its assets, both in space and in time (Burn et al, 2009). Condition assessment could thus be used to develop or enhance this understanding in conjunction with assessments of performance undertaken at both asset-specific and system levels. In fact, the US EPA (2002) noted that:

- The best way to determine the remaining useful life of a system is to conduct periodic condition assessments, and
- That it is essential for utilities to complete periodic condition assessments in order to make the best life-cycle decisions regarding maintenance and replacement.

Figure 2
The role of condition assessment in utility decision making



This is in direct contrast to the approach discussed by Burn et al (2007), where condition assessment is only utilized for proactive assets with reactive assets left to operate to failure, using probabilities of failure determined from lifetime modelling to feed into the asset management approach. The approach discussed by Burn et al (2007) is proposed because analysis using Net Present Value (NPV) assessment indicates it is generally not financially viable to perform condition assessment on all assets, and thus the argument for run to fail on low risk assets.

The challenge is thus when to consider the application of condition assessment for the whole range of asset management approaches currently in use; from simple asset management approaches through to strategic asset management approaches based on risk and sustainability paradigms. We therefore need to determine 'what is an ideal practice for specifying the need for condition assessment', while allowing for the fact that a significant proportion of utilities will not be in a position to adopt this ideal.

It is thus proposed that condition assessment should only be used where it is the most cost effective way to fill the required data gaps. High level monitoring of utility performance is a corner stone of asset management, and routine activities do not generate all the data that is needed to manage the asset stock and support decision-making. This is especially true for below ground assets that are hidden from view and can operate for many years before deterioration is sufficient to cause operational issues. As such, even when strategic performance management is undertaken effectively, there is still a gap in the information required to manage the assets, which may be filled by undertaking asset-level condition and performance assessments.

Figure 2 illustrates the process of using level of service and asset related Key Performance Indicators (KPIs) as a means of undertaking high-level performance assessment to drive strategic asset management decision making and only undertaking asset-level condition and performance assessments where it is needed to fill a specific information gap (Marlow and Burn 2008).

A range of individual drivers for specifying the need for asset-level condition and performance assessments can be identified. For example, Table 2 lists a number of individual drivers

Focus	Driver	Asset type
Assess capital maintenance budgets and timing of spend	Condition and performance assessment to provide data for use in budget setting and/or justification of capital deferment.	All assets
Prioritize capital programmes	Condition and performance assessment to target priorities for renewal spend.	All assets
Determine appropriate intervention	Condition assessment to determine the level of renovation required and specify rehabilitation approach; selection of least whole life costing approach (partial replacement, lining, etc.).	All assets, but more likely to be pipes
Demonstrating asset stewardship	Condition and performance assessment to demonstrate the overall condition and/or value of the asset stock (condition/performance profiles by asset value).	All assets
Comply with CMOM regulations		Sewerage only
Financial reporting (GASB 34 modified approach)		All assets
Due diligence	Assessment of condition to understand the value of the asset stock and financial risk exposure.	All assets
Forensic investigations	Condition assessment to understand failure and support litigation.	All assets

Table 2
Focus and drivers for undertaking condition and performance assessment

for undertaking condition and performance assessments. In essence, each driver still relates to a gap in information that has to be filled, but the driver does not arise out of the management of KPIs.

A clear case where the need for assessment and investigation is not driven by high level performance measures is where there is an unexpected and serious failure of an asset. It should be emphasized that, except where the driver is imposed by an external body (e.g., a regulator), this disjointed approach to specifying the need for a condition and performance assessment programme is not deemed ideal practice, although it may be appropriate practice for a given utility taking into account its drivers and particular circumstances

A condition assessment protocol

As noted by Rahman & Vanier (2004), one of the functions of condition assessment is to establish the current condition of assets as a means of prioritizing maintenance and rehabilitation effort. Some assets are more important than others and asset condition is only one of the metrics used when prioritizing interventions.

A standard way to characterize the importance of an asset is to evaluate the risk of failure. Risk is determined by taking into account both the probability and consequence of asset failure. However, since consequences are related to the asset's operational context and system configuration, the potential consequences of asset failure generally remain relatively constant over time. As such, consequence of failure is often used on its own to determine whether a proactive or reactive maintenance strategy should be adopted, as shown in Figure 3.

In contrast, the probability of failure does not stay constant, but increases over the life of the asset as it deteriorates. Condition assessment can be used to understand the level of asset deterioration and the impact this has on the probability of failure. The utility can then attempt to reduce that probability of failure through some operational or capital intervention or accept the level of risk associated with the asset's condition.

When undertaken as part of a risk management strategy, condition assessment is only warranted when it has the potential for facilitating improved management of service delivery or has the potential for reducing risk sufficiently to justify the cost of the assessments. Where no action is taken as a result of an assessment, the benefit is then implicit in the improved knowledge of the asset and asset base.

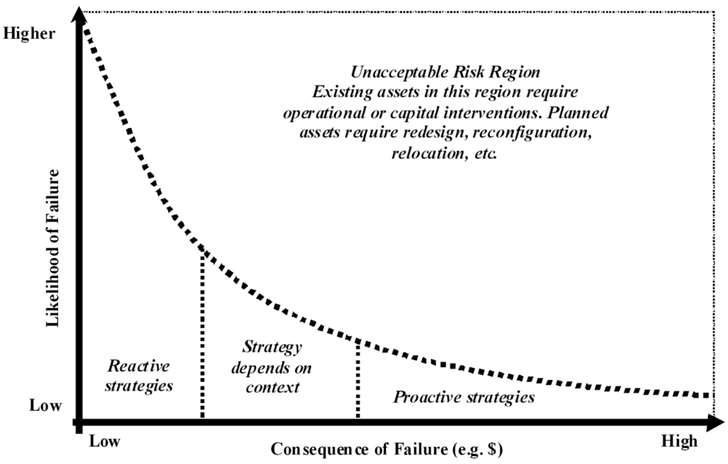
As discussed by Buckland (2000) and Burn et al (2007) and shown in Figure 3, an asset with low consequence of failure is generally managed reactively; i.e. such assets are left to operate until failures start to occur and condition assessment does not play a role in this assessment unless it is economically viable. This approach can be taken because the expected cost of failure does not justify the cost of preventing that failure, though this does not imply that low cost inspection techniques such as operator inspection should not be used where possible (Marlow et al, 2007).

Once an asset has failed, a decision is then made to repair and maintain or replace the asset. This decision can be expanded to consider the replacement of similar assets. The decision to retain or replace the asset(s) would include consideration of budget constraints, the economics of continuing to operate the existing asset, the levels of customer service needed, and operational strategies that can be economically implemented to reduce the impact of retaining a failing asset (Burn et al., 2007).

As shown in Figure 3, proactive strategies are generally applied to assets when the consequences associated with failure are large, and there is the potential for authorities, municipalities and other segments of society to incur high costs (tangible and/or intangible). For such assets, the economics of preventing failure are advantageous and in these cases the application of condition assessment is generally warranted. While proactive strategies tend to be more justifiable at the high consequence end of the spectrum, they may also apply to lower consequence assets if the economics of this are favourable, for example, if low-cost condition assessment is available or if uninterrupted water supply is critical, i.e. dialysis patients.

It is interesting to note that the criterion used to assess end of life are different for reactively and proactively managed assets. In particular, a reactive management strategy is characterized by the use of failure events or failure history in decision making; individual assets may be run to failure or replaced because of the failure history of similar assets. In contrast, for proactively managed assets, end of life criteria are judged in terms of level of deterioration and predictions of failure, rather than through asset failures.

Figure 3
Asset management strategies for assets with different probability and consequence combinations



Selection of condition assessment tools

As discussed by Marlow et al (2007) there are a significant number of assessment techniques and inspection tools available for condition assessment. The selection of the appropriate inspection tool or condition assessment approach is highly dependent upon what outcomes are required from the assessment, the capacity of the tool/technique to provide the necessary information, the availability of appropriate data to contextualize the results, the capacity of the utility to utilize the selected tool/technique and economic factors.

The selection of a suitable tool requires consideration and evaluation of four factors:

- *Technical feasibility*: The utility identifies what inspection/assessment options are feasible for the asset(s) in question.
- *Technical suitability*: The utility evaluates whether the potential options will meet its specific needs, for example, by providing suitable data and/or level of decision support required.
- *Technical capacity*: The utility then evaluates if it possesses the required technical capacity to allow the potential options to be used and, if not, what the gaps in capacity are, including an initial assessment of whether these gaps can be filled.
- *Economic assessment*: The utility evaluates whether the remaining options add value based on the goals of the assessment, considering costs (including capacity building and/or out-sourcing of work) and benefits, and whether one approach clearly gives the best value compared to other available options.

Final selection is made in terms of available resources, the cost-benefits accrued and affordability issues.

The assessment of technical feasibility is based on asset-related criteria and exclusion of tools on that basis provides a list of all feasible options for the asset type in question. The subsequent assessment of technical suitability and technical capacity allow the list of feasible options to be reduced to a list of options that could be used by the utility to select the appropriate technique using economic assessment. The reader is directed to Marlow et al (2007) for more details on the exclusion process for selecting appropriate techniques.

Cost benefit application – case study for optimal intervention

As discussed above, condition assessment should be considered as a valid option only when the cost of intervention warrants it. When an intervention is carried out, the benefit derived is proportional to both the reduction in probability of failure and the expected consequence of that failure. This potential benefit must be balanced against the cost of undertaking the assessment and subsequent interventions. Thus, by having an understanding of the predicted future pipeline failures, the costs associated with each failure and the costs associated with each condition assessment technique, the optimal time for intervention can be determined using NPV assessment.

In the case of large water mains, by knowing the operating and loading conditions of the pipeline, prediction of individual failures along the pipeline is possible using methods described in Davis et al (2008) for asbestos cement (AC) pipes and Davis and Marlow (2008) for cast iron (CI) pipes. A detailed NPV analysis of the risk costs associated from failures before intervention versus the benefits from failures that are avoided following intervention, allows the optimal time for asset replacement to be determined. In practice, because of the significant cost of replacing these assets, the optimal replacement time is often the time for the next proposed condition assessment; i.e. capital works will always be preceded by a condition assessment to confirm the need for the asset replacement.

By way of illustration, Figure 4 shows the failure probability density function for a 600mm CI pipe, as well as the optimal time to undertake the next condition assessment, which in this case is scheduled to occur at 139 years post installation. This effectively puts the pipe replacement outside of short to medium term planning cycles. As such, the utility could, in theory, operate the pipe up to a further 17 years, and then undertake a similar condition assessment study to confirm that the pipe needs to be replaced.

There are, of course, uncertainties inherent in the modelling and assessment process. As such, new information gained through the subsequent condition assessment might indicate that the replacement could again be deferred into the future. In contrast, it should also be recognized that the risk aversion of the utility must be considered, and the decision may be made to replace the pipe earlier than the 17 years. For pipe types other than AC and CI the predicted failures and probability density functions can be determined using the models detailed in Burn et al (2009). This methodology is the basis for the third component (PARMS-RISK) in CSIRO's PARMS asset management strategy

Conclusions

Asset management is increasingly becoming a major component of corporate programmes applied by water utilities worldwide. As part of an asset management strategy, condition assessment is often considered as a key component in determining the residual lifetimes of assets, thus allowing the planning and rehabilitation costs associated with pipe repair or renewal to be determined.

In this paper, a range of asset management approaches are discussed, along with the role of condition assessment as part of these approaches. It is proposed that condition assessment should only be used where it is the most cost effective way to fill data gaps in the asset management methodology chosen. When undertaken as part of a risk based management strategy, condition assessment can only be justified when it has the potential for facilitating improved management or

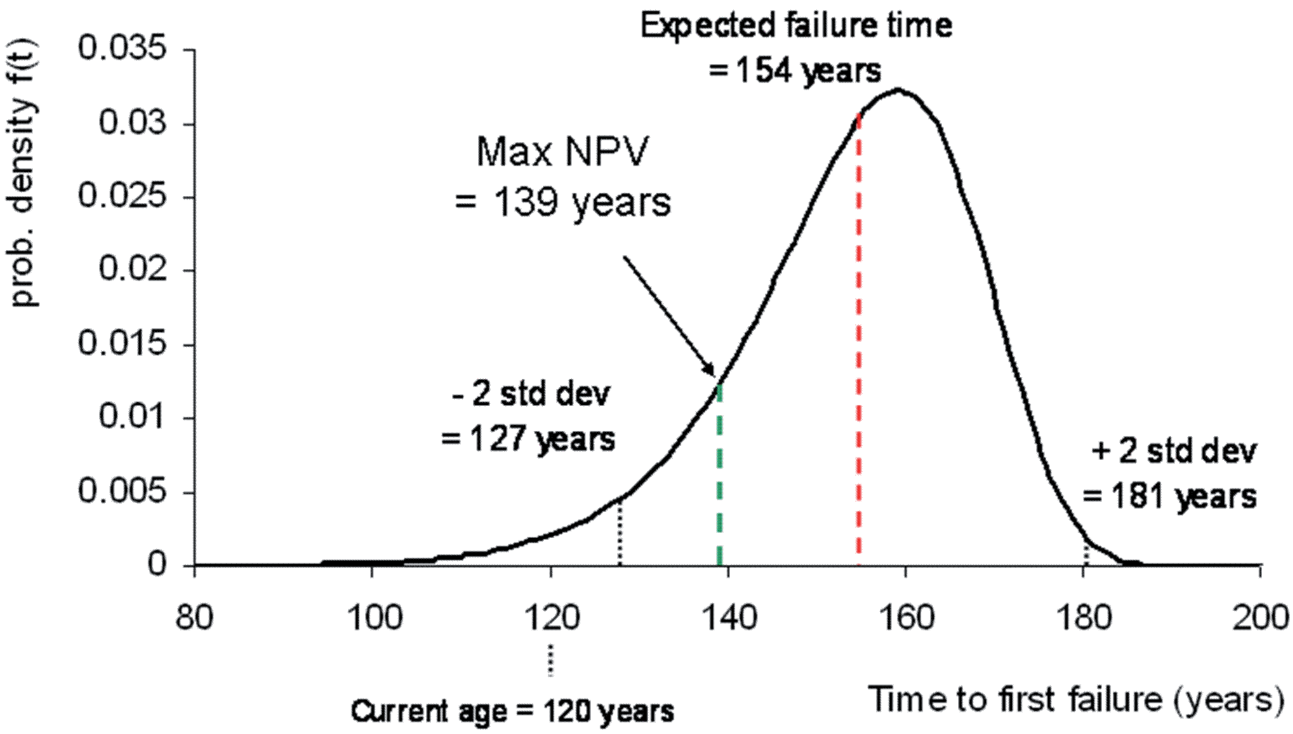


Figure 4 Identification of the optimal times for undertaking condition assessment

service delivery. For assets with a low consequence of failure, condition assessment cannot normally be justified and these assets should be operated to failure. For higher consequence assets condition assessment can be justified and a methodology is briefly discussed for selecting the appropriate condition assessment tool. Finally a methodology is presented that allows the optimal timing of condition assessment in an asset management approach. ●

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Factors influencing midterm rehabilitation of water supply systems

The rehabilitation of a network is usually based upon the age of the asset and its likelihood of failure, but externalities can also have an impact. Gerald Gangl, Daniela Fuchs-Hanusch and Franz Friedl discuss the importance of factoring in the influence of externalities when planning the repair or replacement of assets.

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Several decision making systems for the rehabilitative planning of water supply networks use the failure rate as the main indicator and compare costs for repair and rehabilitation when choosing the pipelines to replace. The failure rate is doubtless one main explanatory factor for the aging process, but several other factors influence the financial decision of whether a pipeline should be renewed or not. A financially optimised and foresighted rehabilitation of the network should also be a main issue for water supply utilities. Externalities in the water sector are significant because fresh water has historically been undervalued, and is still viewed by many as a common good. A transition to full cost recovery for urban water use including externalities (COAG, 1995) will upgrade the decision process for repair or renewal of pipelines and make it more transparent.

Failure rate

When dealing with influencing factors of the midterm rehabilitation of water supply systems it is doubtless necessary to give the attention first to the failure rate. Normally the focus of rehabilitation is not on pipelines without a failure. But when the first failure is occurred it is important to know if the failure rate of the pipe section will rise in a given period. At that point externalities will influence the ongoing decision process.

Failure records reaching at least five to ten years in the past are necessary when defining a limit value of an internal failure rate. According to the recorded data, different models for the prognoses of possible further failures (Cox, 1972; Shamir and Howard, 1979; Herz, 1996) are published in literature. Several factors have to be taken into consideration when predicting the time at which a pipeline will fail.

By using a proportional hazard model (Cox, 1972), a hazard rate can also be calculated for right censored data like those from the pipelines of drinking water systems. When predicting the first failure of a pipeline, the uncertainty of the deterioration process which influences the failure probability is higher than for further failures where information about the condition of the pipe material from former failures is available. Therefore, a separate analysis for the first failure and for following failures is necessary. By using a proportional hazard model with available statistical significant explanatory factors, a rate of possible first failures can be calculated (Gangl, 2008a).

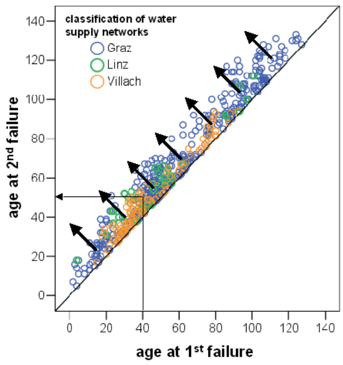

Figure 1
Scatter dot of the time period between first and second failure (Gangl et al. 2007a)

Following failure

Gangl et al. (2007a) have described a model for the mid-term budget planning of pipe-section based analyses of following failures. Provided that further failures occur regarding an aging process, the increase in the failure rate and the time between ongoing failures on a pipe section can be described statistically.

Figure 1 shows an example of calculating the time period between ongoing failures. On a given pipe section, the first failure occurred at an age of 40 years, the second failure occurred at an age of 53 years, the time period between these two failures being 13 years. In a scatter plot (Figure 1), the age of the pipe at the first failure is compared to the age at the second failure. The diagonal of the diagram represents the status when the second failure occurred in the same year as the first failure.

In Figure 2, the distribution of the difference between the age of the pipe at the first failure to its age at the second failure is displayed in a histogram, based on the data from the Austrian cities of Graz, Linz and Villach. The histogram shows that in 50% of all recorded cases the second failure occurred in a period of six years, in 80% of the recorded cases, the second failure occurred in a period of 13 years. In Gangl (2008a), the methodology of fitting several parametric functions (Gamma, Exponential, Logistic, Weibull) to the data for describing the probability of occurrence is explained.

Figure 3 shows the trend of following failures for two material groups based on data from the Austrian

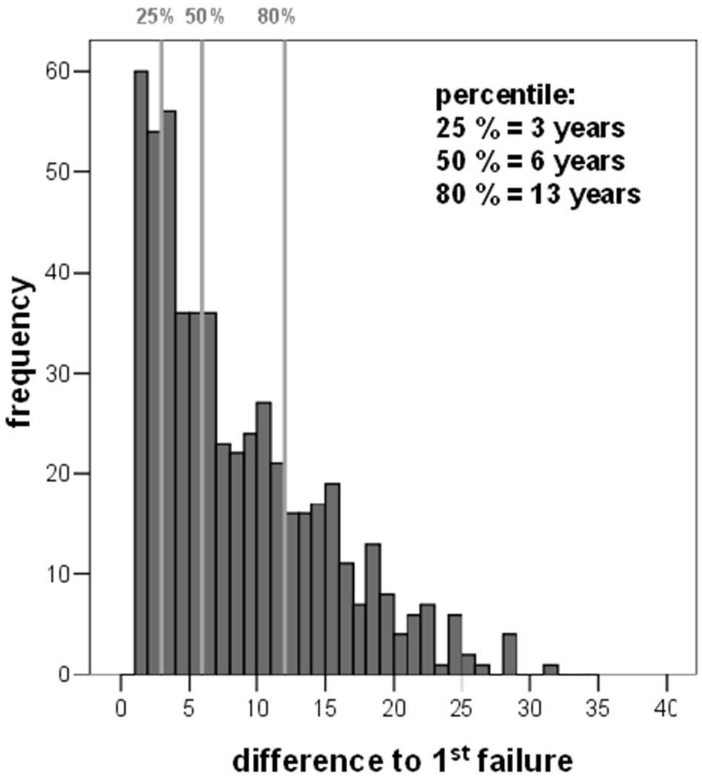

Figure 2
Frequency distribution of the time period between first and second failure (Gangl et al. 2007a)

cities of Graz, Linz and Villach. Fitting a trend function to the time period between ongoing failures using regression analyses provides the possibility of calculating failures in the future.

External factors

An externality is a cost borne or benefit received by a third party not involved directly in a commercial transaction. For existing networks, consideration of externalities involves an ongoing evaluation of the level of risk associated with individual assets. Externalities in the water sector are significant because fresh water has historically been undervalued, and is still viewed by many as a common good. The Council of Australian Government's Water Reform Framework (COAG, 1995) however proposed a transition to full cost recovery for urban water use, which includes consideration of externalities (Marlow & Burn, 2007).

Several financial aspects have to be taken into consideration when making the decision whether to make an ongoing repair or renew a pipeline. In Austria, the standard ÖNORM B 2533 (2004) defines areas in public roadway where drinking water pipelines should be buried. A repair or a renewal of a drinking water pipeline will have an influence on public traffic, even if a no-dig technique is used. According to Gangl et al. (2007b), the social costs for a one day closing of a single lane can be as high as the costs for the repair, the latter costs being the only costs considered in current calculations (Figure 4).

Cities can have a seasonal dependency on traffic regarding vacation times. In cities like Graz (Figure 5), the traffic intensity is significant lower during vacation periods. Studies in the US (Memmott and Young, 2008), New Zealand (Tate et al, 2004) or Germany (Schmidt and Thomas, 1996) show a similar result as there is less travel during holidays and holiday periods than during non-holidays. Hence a planned construction site for rehabilitation has less influence on traffic and congestion costs than an unplanned repair caused by a failure in peak seasons such as April or October.

Drinking water pipelines failures have a seasonal dependency with respect to the material used (Kleiner and Rajani, 2000; Kober, 2007). When seasonal failure peaks are similar to traffic peaks, the influence of a construction site is in evidence. Analyses for the seasonal dependency of traffic and pipe breaks were made for the Austrian city of Graz. A failure in May or June has a high probability of being from a cast iron pipe (Figure 8) and will have a strong influence on public traffic (Figure 7).

One main influencing factor of the probability of a break is the construction of a street above a buried pipeline. Calculations from Friedl (2007) have shown, for example, that the traffic load itself has no influence on pipelines of asbestos cement material (Figure 7). Additional calculations show that for asbestos cement, polyethylene and polyvinylchloride a dynamic lorry-load during the renewal of a street and a remaining covering of 40 cm above the pipeline becomes critical. If the remaining cover is reduced to 40 cm, the dynamic loads from a road roller also cause critical stress to steel. A renewal can therefore lead to a break when the compacting load is too heavy.

Table 1
Cost allocation in the case of a coordinated construction site (Burger and Hochedlinger, 2008)

Utility	Excavation			asphalt cover		
	[single]	[combined]	[savings]	[single]	[combined]	[savings]
Water supply	55,0 €	44,0 €	20%	45,0 €	31,5 €	30%
Gas	37,0 €	29,6 €	20%	37,0 €	25,9 €	30%
Electricity	8,0 €	6,4 €	20%	18,0 €	12,6 €	30%

When this influence is considered, breaks caused by a construction site can be minimised. Therefore, possible breaks based on critical external stress are not taken into consideration when fitting aging functions to the recorded data. The occurrence of these failures can be directly influenced and minimised with an adequate site inspection and should therefore be excluded from financial considerations.

In several cities in Austria, the public authority defines requirements for construction sites. These requirements vary greatly within Austria (Gangl 2008b). The savings based on possible coordination of a construction site are listed as follows:

- Within a multi utility a coordination

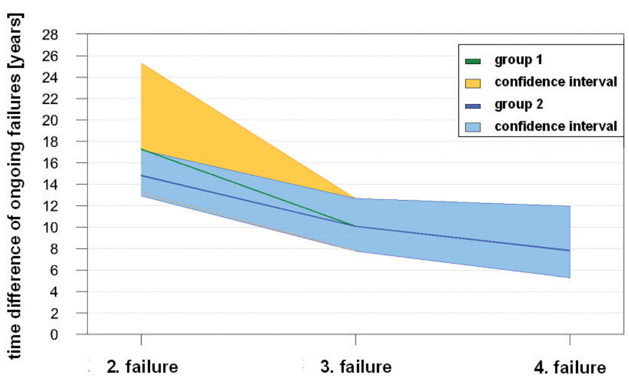

Figure 3
Time difference for ongoing failures (Gangl et al., 2007a)

of sectors like drinking water and gas caused by the similar construction method or drinking water and sewer caused by the depth of the pipe trench is possible. An apportioning of expenses for excavation and asphalt cover should be the result.
- Another saving potential is a coordinated construction site between the water supply utility and the road department (normally under public authority) an apportioning of expanses for renewing the asphalt cover is possible, depending on the different requirements.
- A third saving potential is also coordination between the road department and the water supply utility in case of a combined construction site. Here, all costs for excavation and filling have to be paid by the water supply utility. Thus the cost of a temporary renewal of the asphalt cover until the road is completely renewed by the road department can be saved.

In some cities in Austria no saving potential is possible because of the requirements of the public authority, where all expanses have to be paid by the water supply utility. Coordination with others including the road department should be realised but savings are only possible in the case of a reduced price for excavation per metre through a combined tender.

Burger and Hochedlinger (2008) listed savings for a combined construction site for the utilities drinking water supply, gas and electricity for the Austrian city of Krems (Table 1).

Normally the planned annual construction site coordination of the different infrastructure departments (water, gas, sewer, etc.) is done by the road departement. These expenses are paid by the municipality. A survey by the authors showed that in the seven largest cities of Austria, the meetings for coordinating the planned construction sites are at least quarterly and up to nine times a year. The costs of one meeting can be calculated to be €1680 ($2463) (Table 2). For six meetings a year the coordination costs are about €10,000 ($14,661). The number of planned construction sites depends on the condition of the network and the rehabilitation strategy. A benchmark of three planned construction sites per 100 km can be calculated for the three Austrian cities of Graz, Linz and Villach. For a network of 500 km, the costs for coordination allocated per construction site are therefore €670 ($982).

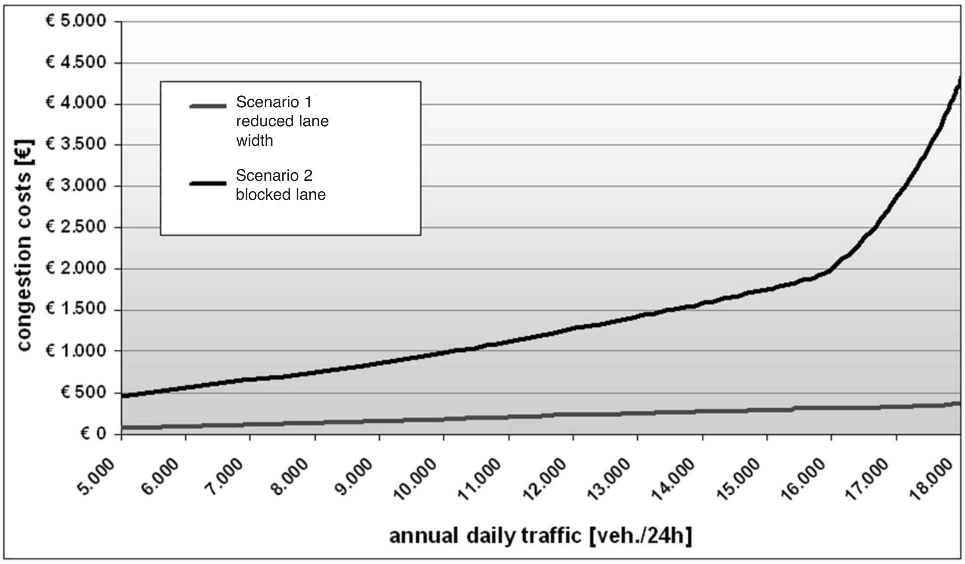

Figure 4
Social costs for a construction site regarding traffic intensity (Gangl et al. 2007b)

Example

A practical example will show the influence of the factors listed in the previous chapters. A pipeline (cast iron, DN 100, built in 1933) is buried under a street with an average daily traffic of 16,500 vehicles/day. Three failures have been recorded in the past with average repair costs of €4900 ($7184). Provided that a single line is closed for two days for repair, a reduced lane width lasts four days and a planned rehabilitation causes a blockade of a single line for six days, congestion costs can be calculated at €6120 ($8974) for a repair and €14,400 ($21,115) for a rehabilitation. When the planned rehabilitation is during summer time with reduced traffic (20% less traffic) social costs will be €8640 ($12,670).

Rehabilitation costs per metre are calculated at €187/m ($274/m). If coordination is possible costs can be reduced up to 20% to €150/m ($220).

To answer the question of whether an ongoing repair strategy or rehabilitation is more efficient, the cash method can be used where costs for an ongoing repair of the old pipe, caused by failures in the future and rehabilitation cost are compared within a given period (Fuchs.-H. et al., 2007). The step-function in Figure 8 represents the costs for repair when a failure occurs in the future. The light grey and the dark grey areas show different occurrence probabilities. The horizontal continuous line represents the costs for rehabilitation with reduced costs (construction site and social costs) in 2008, and the horizontal dotted line represents the costs for rehabilitation without savings in 2008. The continuous line has an intersection within the period of calculation; hence rehabilitation becomes more efficient if social costs and savings are taken into consideration.

Table 2
Costs for coordination of a combined construction site

preparation	meeting	person	costs	costs per meeting	meetings	annual costs
1 day (8h)	0,5 day (4h)	2	70 [€/h]	1 680 €	6	10 080 €

Conclusion

Several technical and economical factors influence the rehabilitation of a drinking water pipeline. Only the

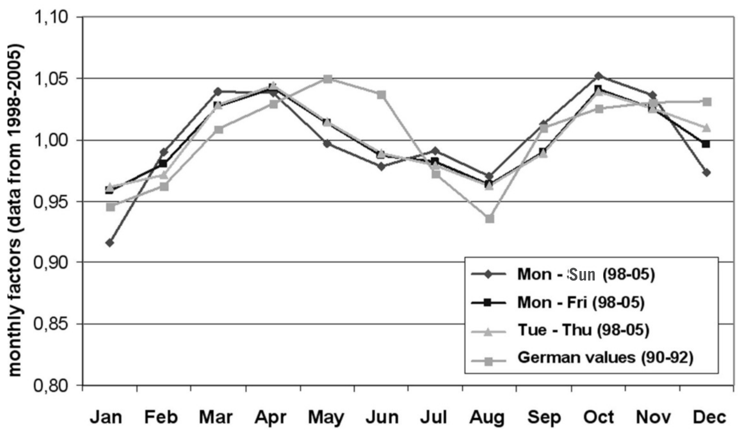

Figure 5
Seasonal dependency of urban traffic intensity (Gangl, 2008a)

consideration of as many factors as possible will lead to foresighted optimal rehabilitation planning. By connecting these factors to each pipeline, a technical and economic based decision for rehabilitation is possible.

When the decision process for repair or rehabilitation is constructed only on the failure rate linked with the costs for the construction site, a repair usually costs less and seems to be more economic. When taking several external factors into consideration which influence the decision process, rehabilitation becomes more efficient than a repair in some cases as shown before.

By using the cash method, the cost-based influence on the time of rehabilitation can be turned into graph form to support the decision whether an ongoing repair strategy or rehabilitation of a pipe section is more efficient. Investments for asset management of a water supply network are nowadays limited and in some countries of the world these investments are verified by a regulator. Therefore the decision process will become more transparent and comprehensible if more technical and economical factors are considered and possible savings identified. ●

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Table 6
Seasonal failure occurrence for cast iron and asbestos cement drinking water pipes (Gangl et al. 2007b)

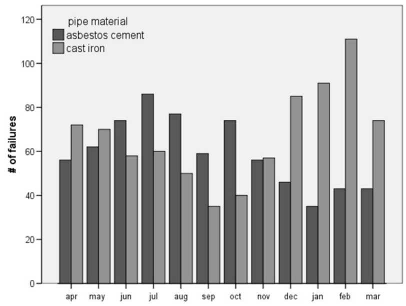


Figure 7
Vertical stress graph of based on surface load compared to limit stress values for asbestos cement (Friedl, 2007)

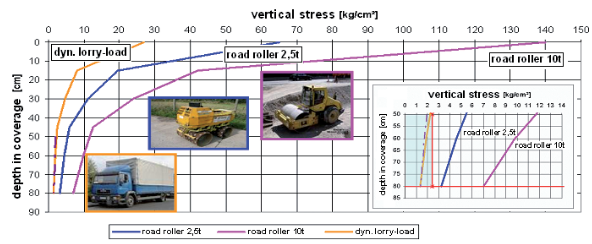
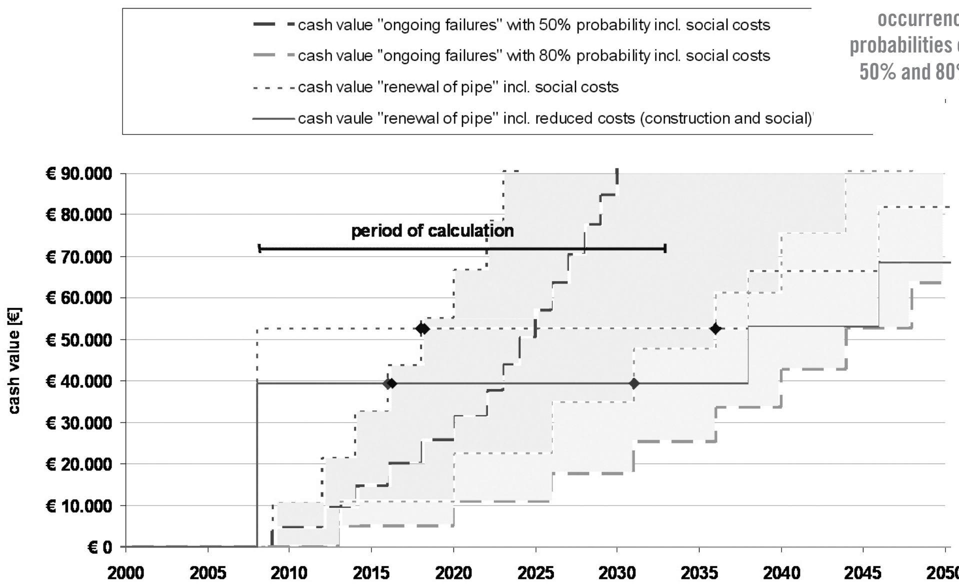


Figure 8
Comparison of the development of cash values for repair and rehabilitation for occurrence probabilities of 50% and 80%



The 2008 international asset management process benchmarking project

The Water Services Association of Australia's Aquamark Framework was originally formed as a tool for assessing asset management processes, then as part of a 2008 project co-sponsored by IWA it was extended in order to develop a global benchmarking model. Peter Gee and Don Vincent discuss the main outcomes of the industry research undertaken.

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The international water industry is undergoing a period of unprecedented change. New challenges such as climate change, increased regulation, competition for funds, skills shortages, technological development, environmental constraints, increasing customer expectations and ageing infrastructure mean that water businesses need to be more efficient and effective than ever before. This is a time when the industry needs to understand how it can best manage the various (and at time conflicting) expectations required of it.

Recognizing the challenges facing the industry and with an appreciation of how modern asset management may assist these businesses meet their various commercial, environmental, social and regulatory obligations, the Water Services Association of Australia (WSAA) developed a means of benchmarking best practice asset management processes within the industry. The objective of this tool is to identify how well a particular participant currently manages its strategy as well as identifying those participants that represent best practice in a range of key process areas.

The tool for assessing asset management processes (Aquamark software) was originally developed for the Australian and New Zealand market. The tool was subjected to external third party audit by an international (UK) expert and the practices, terminology, framework and analysis have been refined to ensure that the tool is equally applicable to utilities globally.

42 water sector utilities participated in this project from Australia, Canada, Hong Kong, New Zealand, Sultanate of Oman, United Arab Emirates and the United States of America, providing a unique and unprecedented opportunity for international asset management process comparison and learning.

The project

WSAA initiated this 2008 project as part of its ongoing benchmarking programme in the water sector. This rolling programme commenced in 2000 with the intention to demonstrate to stakeholders that WSAA members are seeking to achieve international best practice in the delivery of services to their customers. The programme has since encompassed benchmarking of civil maintenance, mechanical-electrical maintenance, customer services, shared services and asset management.

The 2008 project was co-sponsored by the International Water Association (IWA), and delivered through a consultant consortium led by GHD Pty Ltd and including Marchment Hill Consulting and CH2MHill.

The project purpose was to raise the level of asset management practice in the global water industry through identifying process improvements and leading practices that can be shared across the industry.

The process assessment used the Aquamark Asset Management Framework and software tool, developed by WSAA in 2003, specifically to provide a consistent and repeatable web-based asset management process benchmarking model.

The Aquamark Asset Management Framework is based around seven core functions covering the asset lifecycle from its conception (planning) to ultimate replacement, fitted within an organisational context of corporate goals/policy and business support systems, as depicted in Figure 1. The core functions are further subdivided into process, sub-processes and measures to enable detailed assessment.

Consultants from the consortium prepared all project reports, at an overall industry level and for each utility, following the independent review of all utility benchmarking self-assessments, analysis and onsite interviews.

Leading practices were identified across the whole participant group, that were showcased at a three-day Best Practices Conference in Sydney, Australia in October 2008, attended by around 150 representatives of the participating utilities.

The participants

The 42 participants shown in Table 1 were a diverse group of water utilities, ranging in size from the smallest serving some 4000 people and industry, to the largest serving some 6.9 million people. The total asset replacement costs managed by the utilities in the participant group amount to some $48 billion.

The participant group included water-only, wastewater-only and combined service utilities; wholesale, retail and vertically integrated utilities; utilities owned by National, State and local government; corporatised and non-corporatised utilities; and utilities under various levels of external regulatory and legislative control. This diversity enabled some interesting comparison of process development.

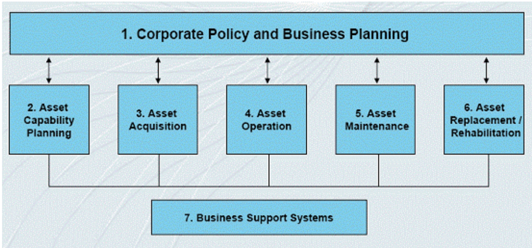


Figure 1
The Aquamark Asset Management Framework

Environmental forces facing the water sector

The water sector faces one of the most – if not the most – challenging strategic outlooks in its history. Numerous global trends are placing pressures on the water sector, and in turn asset management and other business processes. These inter-related trends include:

- Responses to global warming/ climate change
- Significant asset development and growth
- Skills shortages arising from a variety of different factors
- Changes and competing demands from other industries
- New technologies enabling data collection and analysis on a previous unprecedented scale
- Increasing levels of stakeholder involvement and engagement in decision making
- Increasing complexity in customer needs and relationships
- Regulatory scrutiny and control
- Access to capital for investment

These aspects of the strategic context for water utilities are driving changes to the way water utilities are being managed.

Participant group business drivers

To identify those environmental forces relevant to the participant group, an analysis of utility 'business drivers for change over the next four years' was undertaken as part of this project. Each participant selected their highest priority business drivers from a set of pre-defined business drivers.

Participants were grouped into four regions. Table 2 shows a summary of priority business drivers by region. These business drivers show strong alignment with the global environmental forces summarised above.

The business drivers for change occurring most commonly across regions are shown in separate colours. Of the 23 business drivers analysed across all participants, two were common to all four regions:

- Asset acquisition and capital delivery
- Staff skills – experience and retention

These business drivers are closely aligned. The availability of skilled resources, both professional and technical, is a global issue arising through demographic changes and competing demands for resources. The water industry as a whole, including the consulting and contracting sectors, is short of skilled resources. Water utility capital programmes are increasing due to urbanisation, water resource limitations and increased service expectations. The resource shortage impacts significantly on planning and delivery of capital programmes by utilities.

Asset replacement, demand growth and knowledge of assets also rate highly in more than one region. These are due to common factors of urbanisation and the aging of asset bases that were substantially established post-World War II. In addition, the priority of sustainability is a clear driver in Australia as a result of a combination of a prolonged dry period, Government policy, and a desire for better corporate citizenship amongst water utilities.

North America is experiencing a parallel driver of regulation of operational compliance, with utilities being increasingly under scrutiny at both Federal and State level. This commonality of business driver points to the potential for the industry to work cooperatively on an international scale, addressing issues of collective importance.

High level benchmarking results

There are a range of high level observations that are apparent. Some of these are open to individual interpretation, and the interactions between analyses of findings are complex and sometimes difficult to detect. Even with 42 participating utilities, the peer group sizes can be small and apparent trends may not be reliable. The overall results are provided in Figure 2 at a function level.

Some of the key interpretations included:

- The median result at the 'function' level across all participants were similar, with a range of only some 7% in Aquamark scores (from ~ 55% to 62%). On one hand, this was not surprising as one might expect reduced differentiation from the diverse population of participating utilities (diverse in terms of region, size, form of regulation, business function, etc). On the other hand, the consistent medians showed an unexpectedly close balance in development of processes across all functions, including the corporate policy and business planning function where lower scores were historically expected from the participant base.
- The higher median results were in the functions of asset capability forward planning, asset acquisition, asset operations and asset maintenance. At a process level, these included asset financial management, demand planning, asset acquisition and operational monitoring and control. These are functions and processes that are typical of engineering and operationally-based utilities which have a focus on customer service and providing safe and reliable services. The water industry generally has a long and mature history in these functions.
- The lower median scores were in the more strategic and analytical functions of corporate policy and business planning and asset replacement and rehabilitation. At a process level, these included review and improvement processes, quality management and configuration management systems, and the more 'strategic' asset management processes of business based maintenance strategy, operational strategy development, triple bottom line management, end of economic life identification and level of service and stakeholder interface management. This pointed to a need to develop strategic and analytical processes in many water utilities.
- The wide spread of results in all functions indicated divergent levels

Table 1
Benchmarking participants by region

Australia	New Zealand	North America	Middle East / Hong Kong
Barwon Water	Christchurch City Council	**USA**	**HONG KONG**
Brisbane City Council-Water Distribution	Dunedin City Council	Anchorage Water and Wastewater Utility	Hong Kong Water Supplies Department
Central Highlands Water	Manukau Water	Metropolitan Sewer District of Greater Cincinnati	**UNITED ARAB EMIRATES**
City West Water	Metrowater Ltd	City of Portland Environmental Services Bureau	Abu Dhabi Distribution Utility
Coliban Water	North Shore City Council	City of Portland Water Bureau	Abu Dhabi Sewerage Services Utility
Wannon Water	Watercare Services Limited	City of Tacoma Environmental Services	**SULTANATE OF OMAN**
Water Corporation of Western Australia		City of Tacoma Water Services	Oman Waste Water Services Utility
Gladstone Area Water Board		Los Angeles Department of Water and Power - Water	
Gold Coast Water		Philadelphia Water Department	
Goulburn Valley Water		Seattle Public Utilities – Water and Wastewater	
Hobart Water		Tohopekaliga Water Authority	
Hunter Water Corporation		**CANADA**	
Melbourne Water Corporation		City of Toronto	
SEQ Water		The Regional Municipality of Peel	
South Australia Water Corporation		The Regional Municipality of York	
South East Water			
Sydney Catchment Authority			
Sydney Water Corporation			

Region	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
Australia	Sustainability	Staff Skills - Experience	Asset Replacement	Asset Acquisition	Knowledge of Assets
New Zealand	Staff Skills - Experience	Demand Growth	Asset Acquisition	Continuous Improvement	Knowledge of Assets
North America	Regulation Operational Compliance	Asset Replacement	Asset Acquisition	Funding Limitations / Willingness to Pay	Staff Skills - Experience
Middle East / Hong Kong	Asset Acquisition	Demand Growth	Staff Skills - Experience	Asset Replacement	Operational Efficiency

Table 2
Priority business drivers by region

of maturity in asset management processes across the participant group. The analysis revealed five general categories of utility with respect to their stage of asset management process development or maturity – formative (at the lower end), developing, established, mature and advanced (at the upper end).

There is a clear evolution in asset management processes, from formative utilities with less developed strategic and corporate planning processes, to advanced utilities with balanced process scores across all functions.

Regional comparisons

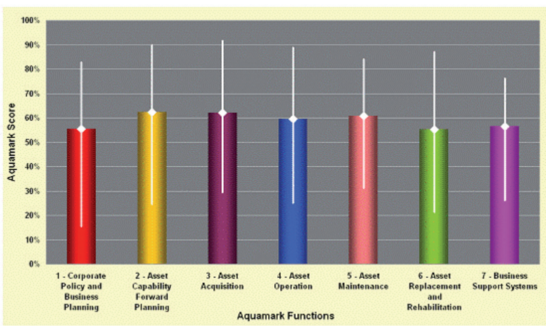
The median aggregate scores for each region are shown comparatively in Figure 3.

Australia and New Zealand scored at a 'mature' level of asset management practice, with Middle East/ Hong Kong and North America characterised by 'developing' and 'established' levels of practice.

Analysis at a regional level drew the following insights:

- Australia and New Zealand regions generally scored similarly and at a 'mature' level of asset management, reflecting development of asset management practice over the past 20 years. Australia had a more consistent profile across all functions, while for New Zealand, asset operations and asset maintenance functions were noticeably higher.
- By comparison, the Middle East/ Hong Kong and North America scored generally lower, with both regions characterised by 'developing' to 'established' asset management practices. Higher scores were generally achieved in the tactical and operations/ maintenance areas. The relative scores across functions aligned with the priority business drivers of demand growth and operational compliance for Middle East/ Hong Kong and North America respectively.
- Australian utilities established higher scores in key corporate and asset decision support areas (e.g. quality management, triple bottom line management, life cycle 'best value' decision making and risk management). Generally in Australia a more highly economically regulated operating environment, established in some cases over a decade, and the corporatisation of many of the major utilities contributed to a higher level of corporate and strategic planning, and development of advanced decision tools and systems.
- In New Zealand, a long-term national focus on asset management, and consequently legislated requirements for asset management planning and customer involvement, achieved the same ends for predominantly municipal-based water utilities. The leading scores for New Zealand were in the asset financial management, level of service and stakeholder/regulatory interface management, people, asset management strategic plan and configuration management systems. New Zealand utilities had significantly lower scores for quality management than in Australia, due to a lower focus on accredited quality management systems. In the asset operations function, New Zealand scored highest in work practices and work control and execution, and also for work practices in asset maintenance.
- In the Middle East and Hong Kong, State-owned corporations under State-driven operating rules or agreements, had generally mature processes for forward planning, and established processes for asset acquisition, operations and maintenance. This region scored highest in the areas of business objective knowledge, and demand projection for asset capability forward planning. There were lower results in corporate and strategic planning and replacement and rehabilitation. In the Middle East, this was considered to be due to the relatively recent formation of these utilities and hence the recent introduction of strategic asset management concepts and process development and documentation.

Figure 2
Overall benchmarking results by function



In North America, characterised by municipal-based utilities under different levels of National and State-based operational performance regulation, the results were similar to the Middle East/Hong Kong with generally established processes for forward planning, asset acquisition, operations and maintenance. There were lower results in corporate and strategic planning and replacement and rehabilitation.

Note that overall regional results were not a reliable guide to the results for any individual utility.

Comparison by utility characteristics

The participant group was analysed for the influence of a range of characteristics on the level of asset management practice (measured by Aquamark). The analysis found:

- *Comparison by utility size*: Larger utilities generally had higher scores than medium or smaller utilities for asset capability forward planning, asset acquisition and asset replacement and rehabilitation, indicating some economies of scale or larger resource bases in these functions. The differences for other functions were less or insignificant. This may be interpreted as indicating that there are economies of scale and larger resource bases for larger utilities in some processes, and that medium and smaller utilities may be swifter in implementation of strategic planning, maintenance and systems improvements. In summary, there is some positive relationship between utility size and Aquamark outcomes, but whether this link is causal cannot be conclusively established, due to sample size.
- *Comparison by utility function*: Integrated (wholesale and retail) utilities, and wholesalers, had higher scores for corporate policy and business planning and asset capability forward planning, while retailers had higher scores for asset capability forward planning, asset operations and asset maintenance. These results reflected a generally more strategic focus for wholesalers managing large, critical assets, compared to retailers which have a greater focus on customer outcomes through network operations and maintenance.
- *Comparison by utility service*: Combined water and wastewater utilities scored significantly higher than either water-only, or to a greater degree, wastewater-only utilities. However, when disaggregating these results by region and function, regional differences appeared to be more significant than service

scope differences.

- *Comparison by organisation type and ownership*: Comparison by organisation type (internal department vs. corporation), and ownership (State-owned vs. local government-owned) provide similar results. Corporations and State-owned utilities (usually both) had significantly higher (15% to 20%) median scores in all functions compared to their internal department and local government-owned (usually both) counterparts. This result is moderated by the regional results, where Australian utilities are predominantly State-owned corporations (13 out of 18) with generally higher scores than the median.
- *Comparison by level of regulation*: Utilities that were extensively economically regulated (external regulator for both price and performance) had significantly higher median scores (around 20%) than partially regulated (performance-only or legislated) utilities. As with comparison by ownership or organisation, the extensively regulated group is dominated by Australia. It appears then, that both higher levels of regulation, and/or legislative controls, go hand in hand with maturity in asset management process development.

Overall, the most significant finding is that the maturity or length of time involved in developing asset management is a stronger determinant of the level of asset management practice than ownership, level of economic regulation or organisational structure. This is characterised by both Australia and New Zealand being at a similar level of practice despite generally different regulatory regimes and ownership arrangements (Australia being largely State-owned corporations under independent regulators – with some exceptions, and New Zealand predominantly local Government owned utilities under legislative controls).

The level of maturity was initiated through taking a business-like approach to water management (by utilities as well as Government), driving efficiency through funding limitations and increased customer expectations. The opportunity exists for utilities in other regions to draw from the learnings in developing this maturity, and significantly enhance and accelerate the development of asset management practice.

Leading practice themes

Seven leading practice themes were developed through a process of collation and distillation of leading practices from the Aquamark assessments, onsite interviews, and nominations from utilities and consultants. A summary of the themes and the basis for their selection are listed below. The leading attributes of these themes were exhibited by a limited number of utilities: it is clear that all participating utilities could learn from at least some of the attributes listed below, and indeed help provide focus for their improvement initiatives.

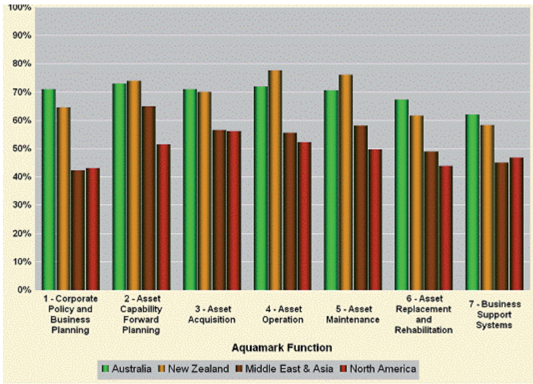


Figure 3
Regional comparison (median aggregate scores)

Culture and the asset management organisation

Those utilities that were leading practitioners of asset management, or showed rapid development of their approach to asset management, demonstrated a combination of factors including leadership, clear and communicated goals, appropriate structures and a commitment to innovation.

Future trends and managing uncertainty

How do we anticipate and respond to the rapidly changing external environment? This theme arose because we are in hugely uncertain times in the water sector globally. The challenges faced by participating regions in the project were quite different, but the approaches to managing uncertainty had some common ground. Three major global challenges for asset management were explored – growth, climate change and structural reform, covering the various planning approaches.

Efficiency, performance and regulation

Customer needs, government regulation, corporate internal drivers and the desire to do better are driving an increased focus on utility efficiency and performance. This theme explored a range of approaches to improving delivery of services and aligning them to customer or regulator requirements.

Growth and capital delivery

Increasing capital works programmes, limited internal resources, demand-driven service provider/contractor markets, and increased expectations are driving more innovative approaches to capital programme delivery. This theme explored industry approaches to selection of the most appropriate delivery mechanism to meet needs while maximising market capability and limited resources.

Asset management planning

Are asset management plans critical to being able to deliver integrated lifecycle asset management? Some participating utilities had comprehensive Asset Management Plans (AMPs) for all assets, while others had very few. AMPs were prepared to varying levels of detail, in many formats and with a wide range of information available and degrees of confidence in their outputs. This theme explored processes and tools for asset management planning.

Sustainability (business risks, people, environment and knowledge)

This theme explored the fundamental elements to be taken into consideration in managing the sustainability of the utility organisation. The key principle here was that sustainability as a concept and practice is viewed and applied not only as an environmental issue, but associated with the life cycle of physical assets, people resources, and the acquisition and retention of knowledge.

Implementation approaches

Sound asset management processes are of limited value unless they are implemented consistently across a utility. However, many organisations encounter difficulties in effectively implementing new processes. What actions can be taken to ensure the effective implementation of changes to asset management practices? This theme explored the key change management principles required to make the implementation of asset management changes successful and enduring.

Major improvement initiatives

A top-down and bottom-up approach was used to identify industry-wide initiatives. Top-down mapped important regional business drivers against overall Aquamark low scores across the participant group. Bottom-up aggregated all individual utility improvement initiatives and selected those topics of greatest frequency as industry-wide initiatives. The analysis clearly revealed improvements of greatest frequency were of a strategic and utility-wide nature, while less frequent initiatives were more tactical and operational.

The following major initiatives were identified to drive improved utility-wide asset management practice.

Key industry-wide improvement initiatives (strategic)

Initiative 1 – people skills and capability
Participants in this study adopted a range of structures and management frameworks which worked to varying degrees to support each utility's commonly cited most important asset – its people. Utilities demonstrating leading practices work to foster an environment where people are encouraged to develop their skills and capability and are rewarded for it. Staff development plans, training and succession planning are key improvements.

Initiative 2 – asset management operating model and organisation
A strong asset management-based operating model can create a step-change in the capability of utilities commencing the process of integrating asset management concepts into their business, and developing strategic asset management capacity. Relatively advanced utilities can also benefit by regenerating focus and direction in asset management.

Initiative 3 – asset management leadership and culture
Asset management leadership and culture initiatives promote employee engagement and acceptance of asset management principles, process improvements, and decision-making capability.

Initiative 4 – asset management continuous improvement
Periodic self assessments of asset management capabilities using the Aquamark framework or similar tools will enable utilities to monitor the progress of their asset management Improvement Initiatives.

Initiative 5 – asset management plans
Formalised AMPs allow capture of asset management intellectual knowledge and can significantly improve asset management decision-making by providing clear guidance. Understanding the proposed uses of Asset Management Plans, internally and externally, helps in establishment of a suitable Plan framework.

Initiative 6 – corporate goals linkage to asset management
Adoption of consistent and clear corporate goals, including policy and business objectives, at an executive, business unit, team and individual level can significantly streamline the delivery of asset management.

Initiative 7 – quality management system
The implementation of a Quality Management System (QMS) improves the formalisation of processes and approaches, leading to sustainability of corporate knowledge, improved efficiency, consistency of approach and outcomes.

Initiative 8 – asset data management strategy
Utilities can expect significantly improved (efficient and accurate) investment decision making through aligning the collection, processing and management of data to meet business decision-making or reporting needs.

Initiative 9 – asset management information systems strategy
Improved integration of business systems with respect to Geographic Information System (GIS), drawing systems, Supervisory Control and Data Acquisition (SCADA), analysis systems such as hydraulic models, the asset register and technical database, financial systems, risk registers, failure and condition registers and works management systems, all support efficiency in data management and decision-making.

Initiative 10 – maintenance strategy
A formalised maintenance strategy (incorporating reactive, preventive, predictive and replacement/rehabilitation strategies) for all assets is a necessary requirement to drive effective maintenance. The strategy should consider high cost or high risk assets first, along with pilot testing to confirm the delivery of maintenance objectives.

Other industry improvement initiatives (tactical)

A range of other improvement initiatives, less important in an overall sense, but deemed 'tactical' improvements, directly related to key business drivers and were applicable to at least some participating utilities. These initiatives included:

- *Initiative 11 – asset based costing system*
- *Initiative 12 – corporate risk assessment*
- *Initiative 13 – demand planning*
- *Initiative 14 – levels of service establishment and forecasting*
- *Initiative 15 – configuration management*
- *Initiative 16 – application of triple bottom line and risk assessment techniques in capital investment evaluation and optimisation*
- *Initiative 17 – procurement best value*
- *Initiative 18 – asset acceptance procedures*
- *Initiative 19 – asset criticality and condition assessment*
- *Initiative 20 – renewals evaluation and forecasting*

Trends in the benchmarking results: from 2004 to 2008

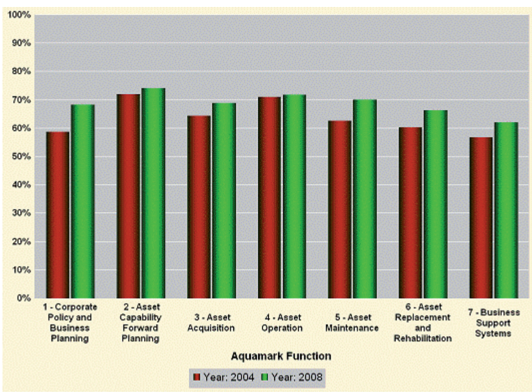
In 2004 a similar study, using an earlier but very similar version of the Aquamark framework, was undertaken by WSAA, involving 21 water utilities. The repeat participants comprised 16 utilities, including 13 Australian small, medium and large sized retail, wholesale and integrated water utilities, two New Zealand and one North American water utility. The results are shown in Figure 4.

The 2008 results for the repeat participant peer group show that Aquamark scores across all functional areas have improved since 2004 to varying degrees. Not surprisingly, there is a relationship between management improvement initiatives and process scores. Interestingly, severe drought conditions in Australia over the last decade have placed pressures on capital delivery, significantly lifting the profile of asset management in several small water utilities.

The greatest increase at a function level was in corporate policy and business planning, with a repeat peer group median increase of 10% since 2004, which is in line with improvement rates observed during previous WSAA civil maintenance and mechanical-electrical maintenance process benchmarking programmes. Of the 11 key improvement recommendations made in 2004, the largest improvements were in the corporate policy and business planning processes of configuration management and quality management, with a smaller increase in triple bottom line management, even though the overall scores in most of these processes are still low and further improvement is recommended.

There was a moderate increase in the score for asset maintenance since 2004, due to increased levels of attention being given to business based maintenance strategy, and maintenance

Figure 4
Aquamark 2004 to 2008 comparative scores



procedures documentation. This is aligned with previous improvement rates in relatively mature utilities. There were nominal increases in asset acquisition due primarily to the need to seek innovation approaches to significantly increased capital programmes; and in asset replacement and rehabilitation from increased efforts in the identification of end of economic life. A similar improvement in business support systems was concentrated on improvements in equipment registers, GIS, SCADA and customer service systems.

There was insignificant or no change in the functions of asset capability forward planning and asset operations. Several water utilities scored lower in some functional areas than they recorded in 2004. The key reasons for this decrease were identified as industry reform changing the scope of services or leaving gaps in processes, intra-utility changes such as leadership or organisational structure changes, or simply a change in asset management maturity leading to a different and firmer view on Aquamark scoring.

Concluding remarks

This project provides a substantial body of knowledge for building improvements in asset management irrespective of the history and context of each utility in terms of region, function, size, ownership, or form of regulation, participants were keen to improve their asset management processes and, by inference, their performance for customers, shareholders, staff and other stakeholders.

The best water utilities take three additional and clear actions:

- They invest in demonstrable leadership of the change initiative. Effective asset management is enabled by the active support of the most senior executives, and is in turn supported by a detailed 'bottom up' commitment to specific, targeted improvement initiatives.
- They regard asset management as an integrated whole, and create initiatives which lead to improvement as part of a cohesive plan (and avoid working in silos).
- They appreciate that building a strong asset management capability takes years – they see it as a journey, and no matter what other issues they confront, they stay focused on the core asset management improvement tasks. As the shift between the 2004 and 2008 results clearly shows, improvement is possible. A conscious decision to improve is at the heart of success. ●

Collecting information to optimise a mains replacement strategy

In order to replace mains in the most effective manner, sufficient data about the network has to be obtained. Jo Parker discusses the best methods of organising information about the network and utilising it as part of a utility's mains replacement strategy.

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Although water mains can have a long life, sometimes well over a 100 years, they do not last forever. Replacing mains is expensive, in the UK it is at least £100 ($163.9)/metre even for very straight-forward schemes, with complicated inner city replacements costing much more. Although some disruption can be reduced with careful application of no-dig techniques, it is always likely to cause some disruption to local people, businesses and traffic. It is therefore essential that mains are replaced at the optimum time to balance cost, customer service and environmental demands.

In order to make informed decisions about the distribution network it is important to have as much information about the network as possible. Most distribution engineers will understand the need for good information. However, the information available often falls short of what is required with a number of shortcomings, even in utilities with sophisticated information systems. These problems include:

- Inability to link different data bases
- Lack of audit to confirm accuracy
- Lack of motivation for field staff to collect accurate information
- Gaps in data
- Too much data being entered with default values
- Trying to capture too much information and ending up with only a partial data base.

With all asset information the GIGO principal applies – if you put Garbage In then you will get Garbage Out. This means that time spent developing initiatives to train field staff about why information is needed and what is needed is well spent as is time developing processes to audit information.

The very minimum which every utility should aim for is a plan of all water pipes placed against a map or aerial photograph background. All valves and other fittings should be identified with a numbering system such that they can be individually identified and the status of the valve recorded. This is particularly important for any valve controlling the boundary to DMAs (district metered areas) and other zoning. Some data about each pipe is essential, particularly the diameter, material and if possible the year laid.

This basic system can be developed and linked into other systems such as customer data bases, providing property numbers and consumption figures, leakage management systems, which record night flows and calculate leakage in each DMA, and network modelling systems, which can help provide answers about how the network is currently performing and will perform in the future.

Ensuring that data can be transferred between systems is important to develop the means to provide the answer as to whether a pipe should be repaired or replaced. Some GIS (Geographic Information Systems) for instance produce data in formats which are not easy to export to other systems.

The European project CARE W developed guidelines for the continuous observation of the performance of the network and the utility, and provides definitions and evaluation of asset of performance indicators (concerning pipe failures, water losses, customer complaints etc.) that can be calculated at the network, zone or even the pipe level (Allegre et al 2005).

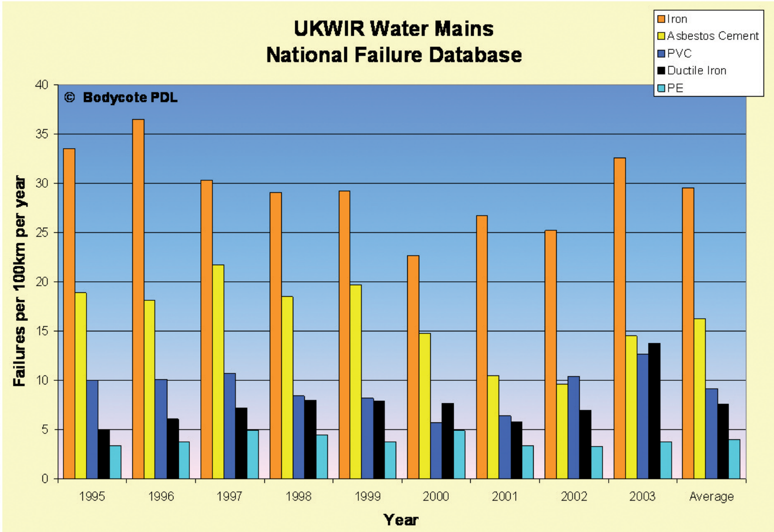
Some water utilities develop a dash board approach with parameters such as burst rates, water quality performance, low pressure incidents and costs measured on a zonal basis. Where DMAs have been established they can provide a useful unit for comparison. Repair levels, leakage levels, rate of rise and, if possible, costs per DMA can provide a simple basis for prioritisation of areas for renovation and replacement. This is particularly valuable for large water utilities where such a system can indicate priority areas for more detailed studies.

A mains failure data base

One of the most important pieces of information is which pipes have failed, when, and if at all possible, how they failed. Whilst this information is often collected, it is not always collected in a format which makes it easy to interrogate. Often the information was originally collected in order to manage the work force or pay a contractor, and it may not be recognised as valuable in itself.

In the UK a national standard has been agreed with three different levels for failure information: basic, preferable and desirable. Basic information includes the date, location and the type of activity, diameter and material of main. Collecting this information has

Figure 1 Early outputs from the UKWIR National Mains Failure Data Base



proved invaluable and all water companies use the information to identify the pipes which have the highest risk of failure in the future. The data base can be further enhanced by extending the information to cover e.g. soil sample results, whether this was a repeat visit, the repair technique used and the jointing technique used for the pipe.

All the UK water utilities also submit data to a national data base, which is now accessed via a website available to members of UK Water Industry Research and set up by WRc. The large mount of data collected means that there is a large volume of failure data which can be investigated to identify the principal factors which affect failure. Combining failure data in this way can be beneficial and a number of other countries are now starting to develop national failure data bases.

Starting from scratch

Not all organisations have a robust asset information system. However, much of the information they will need can be collected and may already be available through, for instance, their leakage or repairs system.

Good records of the mains system in the ground is the first step. The availability of mains data may be dependent on earlier operational policies. If there

Figure 2 Example of geographical output using a GIS system

are gaps in the information it is essential to mobilise all employees and contractors working on the system to collect information at every opportunity. Estimates of age can be made from the age of the surrounding properties. Other utilities may also be able to help, providing details if they have a cause to carry out work. Whenever a water main is exposed there is an opportunity to check the material, age, soil surround and exact location. This will help improve the database.

When repairs are made, it is important to collect as much information about the repair as possible. How the need for a repair was identified should be captured as this may indicate whether the leak developed rapidly or slowly over time. The time of identification may not be the exact time when the failure occurred, but when dealing with pipe lifetimes of decades the inaccuracies are generally not important.

Information about the failure mode should also be collected and simple charts to explain what type of failure, e.g. ring fracture, failure of a ferrule etc. may help field staff. Pipe cut outs should be collected at every opportunity – when connections are made as well as repairs. Soil samples collected at the same time can help provide information about factors affecting the pipe condition. Both pipe and soil sample collection can be encouraged by providing plastic bags with labels ready attached which just need details of the date and location of the work.

Analysing the information

Although some utilities use sophisticated statistical methods to analyse the data, a simple spreadsheet system such as Excel will provide a lot of valuable information. From this it will be possible to identify some trends in failures. Which areas have the highest failure rate? Do failures occur at certain times or after certain weather? Do certain materials or age of pipe fail more frequently?

It helps to be able to analyse data both in groups of different categories such as pipeline material or age and also analyse it geographically. Many GIS systems have excellent data base facilities within the package and thus the information can be analysed and viewed on a geographical basis, which may flag up localised problems, due to for instance, local soil conditions.

Dealing with high burst rates

Whatever method is used to analyse the failure data, some areas or pipes may be identified as having a particularly high failure rate or risk of failure. Just what constitutes high depends on the utility's policy e.g. what level of customer interruptions is acceptable? Whilst it may well be that these pipes need replacing, it is worth checking a number of other issues first.

The relationship between pressure and burst rate has been proven for some time (Thornton and Lambert 2005). Managing the pressure in a zone may reduce burst levels to acceptable levels without any replacement. Even where average pressures are not excessive, pressure variations can lead to higher burst rates and so installing pressure control can still reduce burst rates and prove cost effective (Pearson et al 2005). Work in Sao Paulo, Brazil, Selangor, Malaysia and Ho Chi Minh City, Vietnam showed benefits can be obtained even where starting pressures are low (Thornton et al, 2005). A more recent example in Lucca, Italy showed that substantial improvements in both burst rates and leakage can be obtained by managing pressures and reducing pressure fluctuation, eliminating the need for immediate mains replacement. Conversely, where leakage activity or other operational changes lead to an increase in pressure, it is possible that burst rates may increase as was found in the Bahamas New Providence district (Fanner 2007).

Pressure control will not eliminate the need to replace mains but it will extend the life of pipes and allow major capital schemes to be delayed. However, if pressures are actively controlled and kept within reasonable operating limits and burst rates are still unacceptably high then a mains replacement project will need to be implemented. If working on historic burst rates, schemes will need to be prioritized. This may be done on just unit burst rates e.g. bursts per kilometre per year or on a cost benefit study which takes direct costs or total costs into account, i.e. an estimate of the cost to society due to traffic disruption from unplanned repairs. There is some debate as to how this should be calculated and what construction costs should be included, since it could be argued that the work will be needed sooner or later and bringing it forward requires capital to be made available earlier, but reduces the costs due to repairs and lost water.

In the UK the approach to costing leakage reduction activities has been captured in the report 'The Environmental and Social Value of Leakage Reduction' (Atkinson et al 1999). Further work to assess the cost of street works has been published in a later UKWIR report (Burtwell et al 2005) and the regulator has produced guidelines (OFWAT 2007).

The future

Water utilities are starting to study the implications of current decisions on future performance. Models which predict future failure rates given different investment approaches provide the water utility with a measure of confidence that the condition of the mains network is being maintained. The development of robust information about the networks will support these models and allow utilities to optimize their investment and ensure that mains replacement is carried out in the most economic and efficient way. It can also reassure decision makers that the distribution system will be available for the decades and centuries to come. ●

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