TOOL FOR RISK MANAGEMENT OF WATER UTILITY ASSETS

Report Ref. No. 08/RG/05/25

Global Water Research Coalition

Awwa Research Foundation

Advancing the Science of Water®

Water Environment Research Foundation

WATER SERVICES ASSOCIATION of Australia

Programme Area & Reference	**Regulatory : Assets RG/05**
Report Title	**Tool for Risk Management of Water Utility Assets**
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Report Type	**Final Report**
Period Covered	**2007 / 2008**

Published by UK Water Industry Research Limited
1 Queen Anne's Gate, London SW1H 9BT

First published 2008

ISBN 1 84057 502 6

Printed by Webree.com Ltd.

UKWIR Report Ref No 08/RG/05/25

Global Water Research Coalition:

Global cooperation for the generation of water knowledge

GWRC is a non-profit organisation that serves as the collaborative mechanism for water research. The product the GWRC offers its members is water research information and knowledge. The Coalition will focus in water supply and wastewater issues and renewable water resources: the urban water cycle.

The present members of the GWRC are:

- Awwa Research Foundation (US)
- EAWAG – Swiss Federal Institute for Aquatic Science and Technology (Switzerland)
- Kiwa (Netherlands)
- PUB (Singapore)
- Suez Environmental – CIRSEE (France)
- Stowa – Foundation for Applied Water Research (Netherlands)
- DVGW TZW – Water Technology Center (Germany)
- UK Water Industry Research (UK)
- Veolia Water – Anjou Recherche (France)
- Water Environment Research Foundation (US)
- Water Quality Research Australia (Australia)
- Water Research Commission (South Africa)
- WateReuse Foundation (US)
- Water Services Association of Australia

These organisations are all in charge of a national research program addressing the different parts of the water cycle. They have provided the impetus, credibility, and initial funding for the GWRC. Each brings a unique set of skills and knowledge to the Coalition. In addition, GWRC is affiliated with International Water Association, whose strong international network of scientific professionals and water managers will aid in the development of a solid global research agenda and dissemination of knowledge. Through its member organisations GWRC represents the interests and needs of 500 million consumers and has access to a research program with an annual budget of more than € 125 million.

The GWRC was officially formed in April 2002 with the signing of the partnership agreement at the International Water Association 3rd World Water Congress.The US Environmental Protection Agency is the first partner of the GWRC. A partnership agreement was signed in July 2003

Acknowledgements

It is important to note the invaluable contribution that the project steering group and peer reviewers have made to the development and testing of this tool and guidelines.

We would especially like to thank:

- Ted Thairs – UKWIR project manager
- Chris Royce – Anglian Water and UKWIR representative
- Simon Pollard – Cranfield University
- Andrew Smith – Yorkshire Water
- Adrian Rees – Thames Water
- Maya Irwin – Scottish Water
- Frank Grimshaw – Severn Trent Water
- Maureen Hodgins – AWWARF representative
- Dr. Roy Ramani – WERF representative
- Frans Schulting – GWRC representative
- Peter Buckland – WSAA representative

We would also like to thank all of those who took part in the initial risk definition e-mail debate, those who responded to the survey of water utilities, and everyone who took the time to test the tool and guidelines.

UK WATER INDUSTRY RESEARCH LIMITED

TOOL FOR RISK MANAGEMENT OF WATER UTILITY ASSETS

Executive Summary

Introduction

Mott MacDonald was commissioned by UK Water Industry Research Ltd (UKWIR) on behalf of the Global Water Research Coalition (GWRC), to develop a framework and tool for risk management of water utility assets. The project was co-funded and supported by UKWIR and a number of GWRC members[1]. The objectives of the project were to:

1. develop a framework that will enable water utilities to adopt a common understanding and common principles in risk management of their assets, conforming with relevant international standards and best practice and allowing risks to be compared and prioritised between utilities and other organisations; and

2. elaborate an approach, adaptable to individual circumstances, for water utilities to adopt in the assessment and management of risk of their assets, covering cost, decision models, strategic security, the role of expert judgement and the impact of asset standards on performance (including environmental), risk, customer service and investment requirements.

The approach aims to help users identify risks and potential mitigation options in a consistent manner across all areas of the utility's asset management activity. It enables the cost of investment to be compared with the risk reduction benefit that would be delivered in terms of business impacts and customer service, helping asset managers to decide which investments are most important.

Risk assessment provides users with an understanding of the causal events and the way they can lead to customer service failures. The process becomes risk management when the knowledge is used to decide whether to change the asset base or its operation to reduce risk, and those decisions are implemented. Risk is not reduced by the assessment process or the decision to take action, but rather by the completion of the implementation stage.

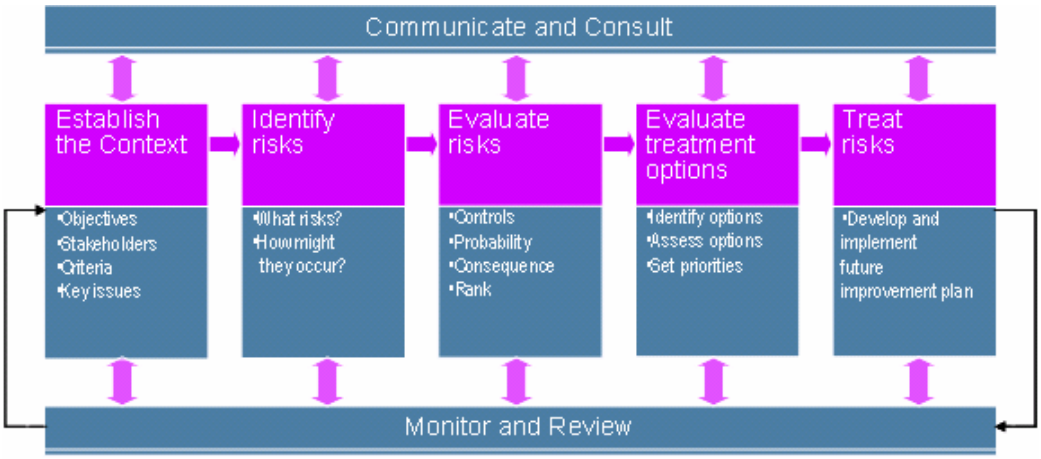
Developing a risk management approach

Risk is considered in the context of negative impacts on areas such as customer service, the environment, health and safety or the utility itself. The term 'risk' was defined in as unambiguous a way as possible, to ensure clarity for users and to identify the function that the risk management tool will fulfil. A literature review covered the main features of processes currently in use together with a survey of water utilities within the GWRC to establish the 'appetite' and requirements for the risk management guidelines and tool. The survey

[1] GWRC co-funders: Awwa Research Foundation (AwwaRF), Water Environment Research Foundation (WERF) and the Water Services Association of Australia (WSAA).

confirmed interest in producing a set of risk management guidelines for the water industry, applicable internationally regardless of the utility's approach to asset management.

The result was a high-level risk management process that could be implemented at various levels of detail, derived from that published in the International Infrastructure Management Manual and the Australia and New Zealand standard AS/NZS 4360, shown below:



A functional specification, detailing the main features of the tool's design, was based on the process above. An iterative approach to development included the international project steering group and peer review. Development of the risk management guidelines followed a similar process, alongside the development of the tool.

Outputs

The risk management process was sub-divided into individual steps and guidelines on the implementation of each step were produced. The guidelines were developed in a tabular format so that for each step the theory, main activities, and appropriate examples are given. The tabular format allows users to follow themes through the steps, without having to read the whole entry for each step.

A spreadsheet tool was produced to exemplify the guidelines. It allows users to enter risks, evaluate them and explore the costs and impacts of different options for treating the risk. Users may define some of the tool settings, so that the context may be unique to their utility, or alternatively use the default settings. The tool shows how risk assessments take account of the root causes and the way they lead, through asset failure, to business and customer service consequences. It takes account of the varying likelihood that individual consequences will occur, as well as that of the risk itself.

Although the tool provides a working demonstration of the guidelines, it is not full-featured software and is intended to demonstrate the way in which the risk assessment process may be applied, rather than to be deployed as full business software. The tool also has the potential

for wider application, outside the water industry, owing to its foundation in standard risk management principles.

Instructions for using the tool were produced as an on-line document, viewable from internet browsers, which relates the guidance to the features of the spreadsheet tool. The instructions are also available as a printable document.

A separate quick-start guide leads users through the main steps of using the tool, but without the detail of the full guidelines. The quick-start guide will be useful for practitioners wanting to explore the tool and forms a useful starting point for familiarisation with the process. The user will then be able to approach the full guidelines with a basic understanding of the process as demonstrated by the tool.

Benefits of risk management

The process of risk management provides organisations with a consistent approach to identifying what could prevent them from achieving their objectives. It allows the costs and benefits of treating risks to be evaluated, enabling practitioners to choose appropriate action to protect objectives.

Recommendations

Water utilities should adopt the risk management guidelines to help develop their risk management processes.

The tool should be used to help train staff in the risk management process and as a starting point for utilities to specify their own databases for recording and managing risks and their treatments.

For further information please contact UK Water Industry Research Limited, 1 Queen Anne's Gate, London SW1H 9BT quoting the report reference number

UKWIR Report Ref No 08/RG/05/25

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Material on Accompanying CD-ROM

Glossary

Asset	**Plant, machinery, property, buildings, vehicles and other items and related systems that have a distinct and quantifiable business function or service. [Ref: PAS 55]**
Asset management	**Systematic and coordinated activities and practices through which an organisation optimally manages its assets, and their associated performance, risks and expenditures over their lifecycle for the purpose of achieving its statutory and/or regulatory obligations and economic levels of service. [Ref: developed from PAS 55]**
Asset inventory	**A standardised data set covering the asset base of an appointed water company. It divides assets into classifications (for example, mains by diameter) and records physical attributes for each (for example, condition and length). [Ref: Ofwat glossary]**
Asset register	**A record of asset information considered worthy of separate identification including inventory, historical, financial, condition, construction, technical and financial information about each. [Ref: IIMM]**
Business consequence	**Category of effects upon business resulting from an initiating event.**
Business objective	**A goal that the company sets itself or is set.**
Capital expenditure (Capex)	**Expenditure used to create new assets or to increase the capacity of existing assets beyond their original design capacity or service potential [Ref: IIMM].** ***See also depreciable Capex and Salvageable Capex.***
Capital maintenance	**Planned work by appointed water companies to replace and repair water and sewerage assets to provide continuing services to customers [Ref: Ofwat glossary].**
Cause	**An entity that produces an effect or event.**
Confidence	**Level of certainty in the accuracy of data and predictions.**
Consequence	**The direct or indirect impact that [an event] has on the provision by the overall system of service to customers and the environment, and/or on [company] costs. [Ref: UKWIR, Capital Maintenance Planning: A Common Framework (CMPCF), 2002]**
Control (measures)	**Activities and processes applied to prevent or lessen risk events or risk consequences that might occur.**

Depreciable (and non-depreciable) Capex	**Assets decline in value for every year owned. This is accounted for by allocation of the capital expenditure (minus the Salvageable Capex) over its useful life. Non-depreciable Capex is the amount that will not depreciate over time, e.g. a car will depreciate over time but property will often appreciate.**
Discounting	**A technique for converting cash flows that occur over time to equivalent amounts at a common point in time. [Ref: IIMM]**
Discount rate	**A rate used in discounting to relate present and future money values; see Discounting.**
Frequency	**The number of occurrences within a given period (in this case, 1 year).**
Gross risk	**Total risk measured by the probability of an event leading to a given outcome.**
GWRC	**Global Water Research Coalition. Non-profit organisation that was established to serve as the collaborative mechanism for 12 world-leading water research organisations. *See GWRC information and disclaimer page.***
Hazard	**Something that has the potential to cause harm.**
Impact	**The measurable result of a defined risk event and its effects.**
Infrastructure (assets)	**Mainly underground assets, such as water mains and sewers and also dams and reservoirs that last for a long time. [Ref: Ofwat Glossary]**
Initiating event	**An event which can cause a risk to materialise.**
Life cycle	**Time interval that commences with the identification of the need for an asset and terminates with the decommissioning of the asset or any liabilities thereafter. [Ref: PAS 55]**
Likelihood	**The frequency or plausibility of the chance that a defined outcome will in fact eventuate. Where this is expressed in quantitative terms, it is a probability. [Note: this usage conflicts with that in the statistical literature] [Ref: Defra]**
Mitigation	**An array of strategies with the purpose of ameliorating the extent or severity of exposure to a hazard and its consequences. [taken from Defra]**
Net Present Value (NPV)	**The value of an asset to the organisation, derived from the continued use and subsequent disposal in present monetary terms**
Non-infrastructure	**Mainly surface assets, such as water and sewerage treatment works, pumping stations, company laboratories, depots and workshops.**

(assets)	**[Ref: Ofwat Glossary]**
Operating expenditure (Opex)	**Expenditure for the day-to-day running of services and assets, for example power costs.**
Primary consequence	**The immediately recognisable consequence of a specific initiating event.**
Qualitative	**Information that can be difficult to measure in numeric terms, often of a subjective nature.**
Quantitative	**Measurement of a quantity or amount based on numerical figures.**
Risk	**Risk is a measure of the degree of exposure to the consequences that might result from an event that might happen.**
Risk assessment	**Qualitative or quantitative evaluation of risk.**
Risk management	**The process of decision making and implementation of measures to reduce or contain the risk(s) identified. [Ref: Defra]**
Root cause	**The underlying reason behind an initiating event occurring.**
Salvageable Capex	**The amount of capital that is retrievable after the assessment period. This will often be zero. E.g. in this case, a large dam would be able to provide service for hundreds of years but the assessment timeframe of 25 years does not take this into account. Therefore, a Salvageable Capex value is entered to represent this.** **NB: the salvageable capex figure is entered as a positive number but is treated as a negative, representing capital returned.**
Service	**Includes service to customers (e.g. clean water), the environment (e.g. pollution control), third parties in the community (e.g. the avoidance of traffic disruption) and [company] employees (e.g. a safe working environment). [Ref: UKWIR CMPCF]**
Serviceability	**The capability of an asset to provide service. [Ref: UKWIR CMPCF]**
Stakeholder	**An organisation or individual that has a direct interest in the utility. Stakeholders for water utilities are likely to include domestic and industrial water and wastewater service users, Government departments and regulators.**
Treatment option	**Option that is implemented to control or mitigate risk. Treatment options may be applied to any identified causes or to the initiating event itself.**

Uncertainty	**A state of knowledge under which the range of possible outcomes has been well characterised, but there exists insufficient information confidently to determine the probabilities associated with these outcomes. [Ref: Defra]**
Whole-life cost	**The net present cost of a project, or the asset provided by the project, to deliver defined outputs that includes the running and maintenance costs over an extended period. The period can include the replacement of the asset, and is not fixed. The period is usually taken as that where the discounted future costs are material to the net present cost. [Ref: Ofwat Glossary]**

Definitions taken from:

Definitions were based on the literature where possible and were agreed with the project steering group. The references referred to in the glossary are listed below:

PAS 55: *Publicly Available Specification 55-1 (Volume 1), Specification for the optimized management of physical infrastructure assets*, The Institute of Asset Management, 2004.

Ofwat Glossary: *Understanding Ofwat: A Glossary of the most commonly-used Ofwat terms,* Ofwat (The Water Services Regulation Authority of England and Wales), 2007.

IIMM: *International Infrastructure Management Manual, International Edition (Version 3.0),* 2006.

UKWIR CMPCF: Capital Maintenance Planning: A Common Framework, UKWIR (United Kingdom Water Industry Research Limited), 2002.

Defra: Review of Defra's (Department for Environment Food and Rural Affairs) ability to compare risks across different policy areas, Final Report and Recommendations Paper, Defra Science Advisory Council (SAC), 2007.

AS/NZS 4360: The Australian/New Zealand Standard for Risk Management (4360), Standards Association of Australia, 1999.

1 Introduction

Mott MacDonald was commissioned by UK Water Industry Research Ltd on behalf of the Global Water Research Coalition (GWRC)[2], to develop a tool for risk management of water utility assets. The project was funded by UKWIR and co-funded and supported by a number of GWRC members; AWWA Research Foundation (AWWARF), Water Environment Research Foundation (WERF) and the Water Services Association of Australia (WSAA). The project reviewed current practice in the water and other industries, proposed an approach to risk management that was suitable for use in the water industry (Figure 5) and developed a simple risk management tool to exemplify the guidance. The items delivered are:

- Tool for risk management of water utility assets, exemplifying the guidance.
- Electronic full guide to using the tool, viewable in internet browsers.
- Project report:
    - Final Project report (this report).
    - Appendix 3: Quick-start guide to using the tool.
    - Appendix 4: Guidelines for risk management.
    - Appendix 5: Printable copy of the electronic full guide to using the tool.

The project was delivered in two phases: firstly a review of the need for such a tool and a summary of the main risk management principles to be embodied in it, concluding in a functional specification, and secondly the delivery of the tool and associated guidelines.

1.1 Phase One

The term 'risk management' is used informally and the context varies between users and situations, but for successful business use it has to have a common meaning to all users. Hence the first task of the project was to define 'risk' in as unambiguous a way as possible, to help to identify the function that the risk management tool will fulfil. The definition and its explanation are given in Chapter 2, together with a glossary of the main terms identified in the literature.

A literature review identified the main features of risk management processes currently in use, covering publications from many countries and sectors in addition to water and wastewater and is reported in Chapter 3. A detailed tabulation of the main papers reviewed is provided in Appendix 1.

A survey of water utilities within the GWRC was carried out, to check the 'appetite' and requirements for the risk management tool and guidelines. A summary of the results is given in Chapter 4 and a copy of the questionnaire and the main results in Appendix 2.

[2] GWRC: non-profit organisation that was established to serve as the collaborative mechanism for 12 world-leading water research organisations.

From the research mentioned above, a 'functional specification' was produced, to help the project steering group to decide the main features that should be included in the tool. The steering group developed the specification through an iterative process as the tool was developed. The functional specification is presented in Chapter 5.

1.2 Phase Two

The tool was built as the functional specification was developed, with the tool being subjected to a range of tests for functionality as it was developed. A detailed guidelines document was produced, identifying a common risk management process and explaining the theory behind the tool. A quick-start guide was also written to guide the user through the main stages of the tool.

The project CD contains the products of the Phase Two exercises. These include the risk management tool and the two sets of guidelines: a quick-start guide and detailed guidelines. An overview of the tool is provided in Chapter 6 and an overview of the guidelines can be found in Chapter 8 of this document.

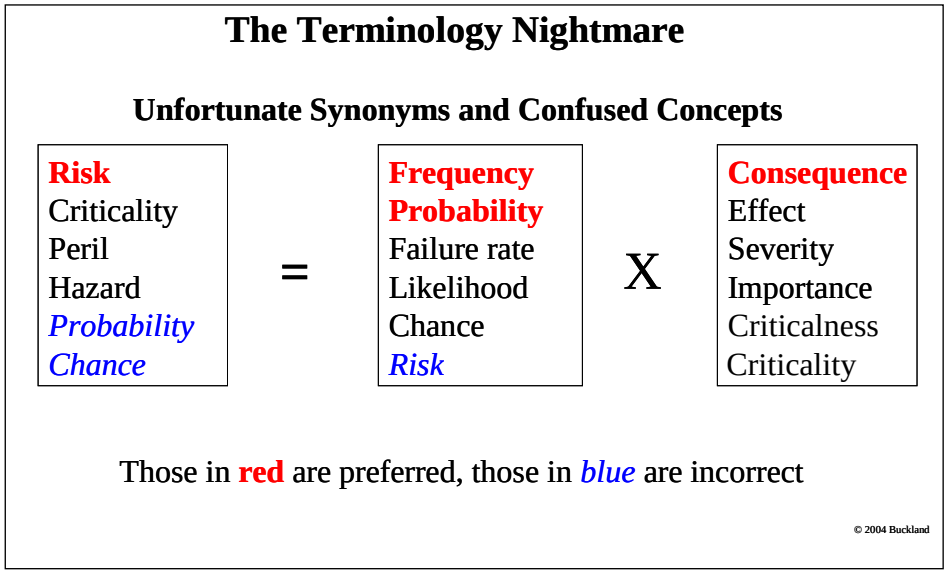
2 Definition of Risk

2.1 Introduction

'Risk' is quoted in many situations, formal and informal. There are many terms used to define risk, many of which are incorrect or unclear. The illustration in Figure 1 shows a selection of terms and how they are used, including which are preferred and which are incorrect. (Illustration from Peter Buckland of Hunter Water and the WSAA, Australia).

In discussions with the international steering group, the contextual meaning of 'risk' was understood but it was difficult to find a definition that was technically correct. Differing personal use of terminology was probably as important as international differences in the meaning of words used.

Figure 1 Terms commonly used in defining risk



2.2 Definition of Risk

We found many definitions of risk, most of which include at least two elements: a description of a specific event – which is typically thought of as undesirable – and the probability of it happening. In this way, risk differs from uncertainty, because the probability is measured. Definitions generally take one of two forms: they are either simplified formulae, or a sentence describing a problem.

There was a strong consensus for a conceptual definition of risk, rather than a specified calculation or formula. The international steering group decided upon the following definition of risk:

Risk is a measure of
the degree of exposure to
the consequences that might result
from events that might happen.

The definition is quite long but contains all the features of risk in a language that has similar meaning to all those who were involved in the consultation. The main terms making up the definition of risk are explained below:

a measure of	**This shows that risk is defined in quantitative terms, which is necessary to compare and manage multiple risks across differing environments. Suitable measures include combinations of frequency and probability of the event occurring;**
the degree of exposure to	**This indicates that the event might not happen and if the event happens we might not be exposed to the full effects. For example there might be controls or mitigations in place or circumstances in which there is much greater exposure to the effects. In evaluating risks, distinction will be made between risks before and after mitigation. "Exposure" may therefore refer to "gross" or "net" risk;**
the consequences that might result	**Consequences, tangible and intangible, arise from events, although they do not necessarily arise every time the event happens. This indicates that whether consequences will arise from events is probabilistic.**
from events that might happen	**Indicates that the occurrence of the event, the set of circumstances capable of producing the consequences, is not certain but probabilistic.**

There is likely to be uncertainty in the estimates of probability and consequences, leading to uncertainty in the value of risk. Like any estimated quantity, the value of risk should be accompanied by an indication of the degree of confidence.

To assess risk, we need estimates of the probability of the causal event happening; of its consequences within the utility (such as unplanned maintenance costs, call-outs, etc.); and of its external consequences to customers, society, and the environment. In this project we are concerned with the consequences resulting from the event, not simply the probability of it happening (which would be the failure frequency).

There are uncertainties at every stage of risk assessment. It is difficult to give single estimates of risk that are accurate, although it is common practice. Where single estimates are used, they should be reported on a consistent basis, for example the lowest or highest estimate, a percentile estimate, best central estimate, or most likely outcome.

3 Literature Review

3.1 Introduction

3.1.1 Scope

The purpose of this review was to inform the development of the risk management tool by identifying the common features of risk-based analysis. It covered standards of practice and relevant literature on risk management tools and methodologies from an international perspective. The focus, however, was on practice in the USA, Australia and Europe. Globally, the concept of formal risk management – especially in the water sector – is still relatively new and whilst it is reasonably established in some countries, it remains in its infancy in others.

The review considered generic contexts and concepts of risk management within the GWRC, from which a common understanding and form for a risk management tool could be derived. It aimed to identify whether a combination of best practice and invention could be employed or if a new risk management approach needed to be developed. The commercial availability of tools and methodologies was assessed and information on categories of risks, assessment and evaluation processes and mitigation options was gathered.

Risk management is widely practiced in sectors outside the water industry and the literature review also offered an opportunity to incorporate knowledge and experience from those sectors.

3.1.2 Method

This review focuses on publications presenting complete methodologies and frameworks, and on published tools. The most comprehensive examples of these are discussed in this chapter, with additional information given in Appendix 1.

Whilst there is a great deal of literature available on risk management, it was difficult to find detailed information on specific tools, frameworks and methodologies. This is probably due to the commercial value of risk management tools and the sensitive nature of risk management issues within both industry and government. The same lack of detail was a problem when

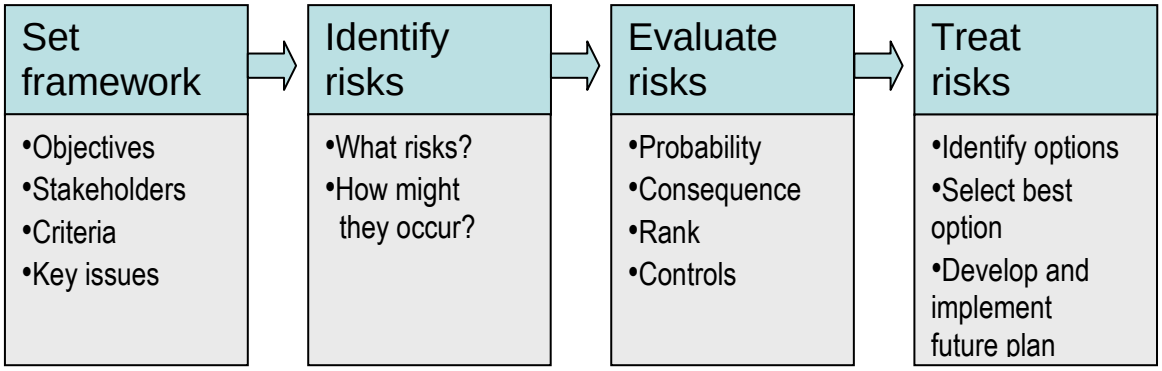
reviewing process elements at all levels of guidance. Overall, it appears that there is a relatively even spread of information available across the GWRC nations but the suitability of this information varies depending on its source.

The reviewed literature included refereed journals, the web-sites of professional associations and organisations for asset and risk management, national standards organisations, government publications and material from members of the international steering group. A separate search was made into the availability of commercial risk management tools, although limited detail on commercial tools was available without purchase.

3.2 The Risk Management Process

It is evident from the literature that many risk management methodologies are available, incorporating a variety of principles and processes both internationally and across sectors. An example of one such methodology is given in the International Infrastructure Management Manual (Figure 2). This four-step process is a simple, but comprehensive, means of approaching risk management.

Figure 2: An example risk management process from the International Infrastructure Management Manual



Source: International Infrastructure Management Manual, 2002

Setting a framework (Establishing a Context): This is the defining step of the methodology in that it creates a context for the entire process. This stage ensures that the process is compatible with the utility's overall business plan and identifies any key issues, standards or regulations which must be addressed, which will make this step different across industries and countries.

Identifying Risks: There may be generic categories of risk such as business or financial risks, but the individual risks will vary greatly, depending on how the utility is run and the context in which it is set. A detailed register must be made of the apparent risks, defining the situation in which they might occur. This will aid awareness of the number of risks that are apparent and will provide a good base for evaluation of these risks should they occur. At this stage it might also be possible to estimate the extent to which future risks will differ from past risks –

for example the impacts of climate change or population growth may impact upon and change the nature of current risks.

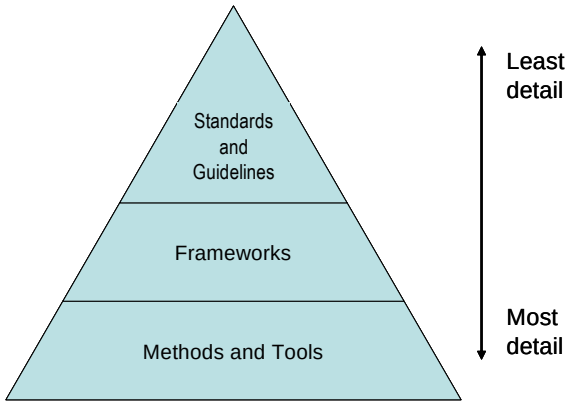
Evaluating Risks: Once risks have been identified, they are evaluated in terms of the likelihood that they will occur as a result of a defined event. The consequences that follow are also assessed and risks are ranked based on their magnitude. Control measures which could reduce the magnitude of a risk are also identified at this point.

Treating Risks: Various mitigation options are considered and the most appropriate option, typically that which will provide an economically beneficial risk reduction, will be implemented. Risks will be monitored and managed as mitigation options are developed in the future.

3.3 Levels of Guidance

Information on risk management is published at various levels from standards through to detailed methodologies and accompanying tools. Figure 3 shows how we have grouped the literature, based on its typical level of detail.

Figure 3: Grouping of the literature reviewed



3.3.1 Standards and Guidelines

Standards provide the least detail on how to carry out an assessment, but set the minimum features that should be present in a risk management approach. A common feature of standards is that they apply to all levels of an organisation and hence they tend not to include detailed guidance on application. They are often specific to countries, sectors or organisations and specify the way in which risks should be managed, but not the detailed method or tools that should be used. Examples of standards include ISO/IEC 17799:2005, which is an international standard primarily concerned with managing risks in the IT sector. Another is the AUS/NZS 4360, which is accepted internationally and is not limited to any specific

applications but serves as an umbrella across many more detailed specific application documents.

The standards reviewed split risk management into between four and eight steps. Assessment by impact, consequence and probability scoring is common and the concept of assessment by matrix also recurs. It should be noted that the majority of standards were appropriate for application at all levels of business, from operations to strategic management.

Guidelines may be adopted as standards within specific sectors. For example, PAS-55 is in a format similar to those used for other standards and could be adopted as a standard at some point in the future. Most of the guidelines identified in this review do not identify specific steps, but instead provide guidance on the main principles of risk management.

Appendix 1 lists the standards and guidelines reviewed, compares their main features and their applicability to this project.

3.3.2 Frameworks

Frameworks contain more detailed approaches than standards and guidelines, but still allow the user flexibility to decide what method to use to address individual steps. Frameworks may exist to support specific policies or regulations. They tend to be sector specific and several are of direct relevance to the water industry, covering infrastructure asset management and environmental management.

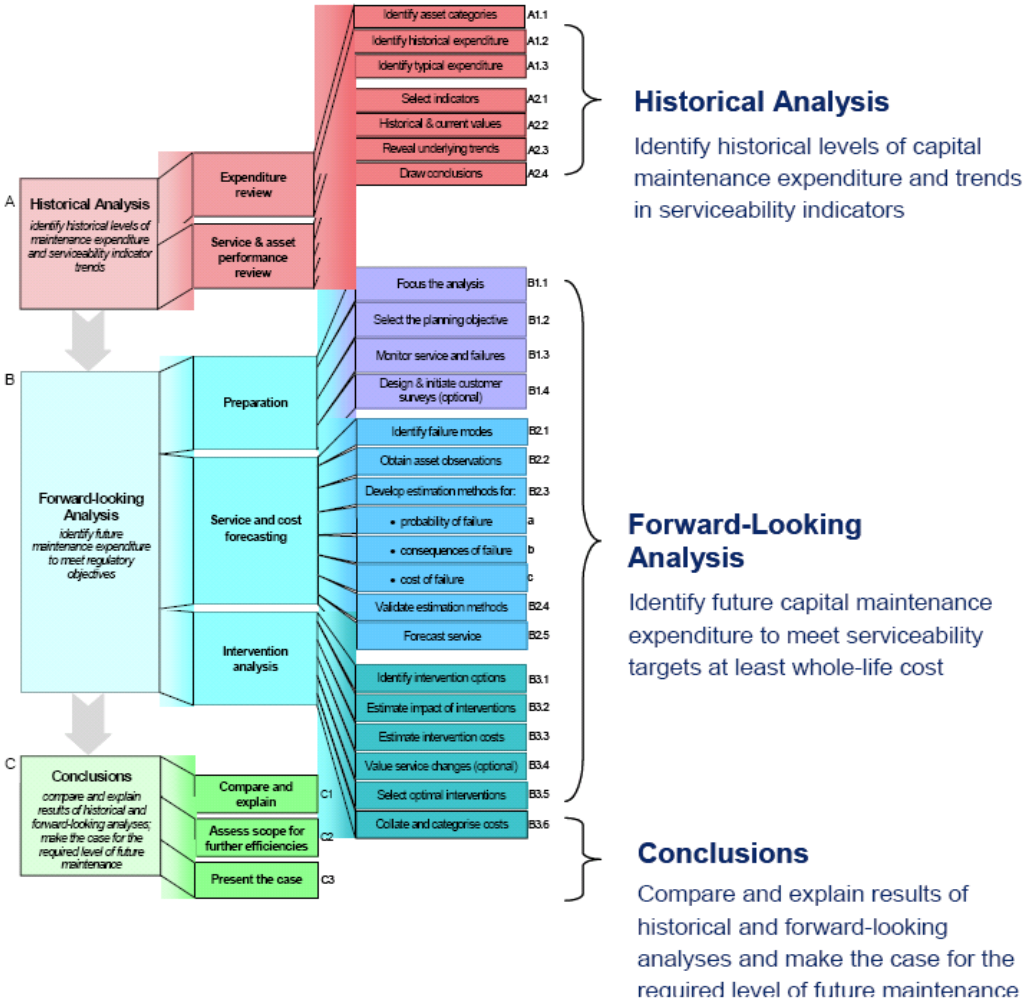
The UK water industry has a risk-based framework for asset management in the form of the UKWIR Capital Maintenance Planning Common Framework (CMPCF) (UKWIR, 2002). It is designed for use in medium to long-term capital maintenance planning and its focus is on the customer service impacts of asset deterioration as a key risk driver. It provides guidance to water utilities on how to evaluate and manage their risks and highlights the main aspects which must be considered in any risk management plan. The Framework, shown in Figure 4 has been established as a best-practice approach to investment planning in the UK water sector and provides a useful starting point in the context of developing a risk management framework for international use.

Although the CMPCF provides a useful starting point, the GWRC risk management tool is likely to need a more generic, higher-level model, which can incorporate a wider range of risk types and assessment approaches than those typically covered by the CMPCF, which is capital maintenance focused.

The frameworks reviewed had features similar to those of the standards and guidelines, many using a matrix to assess risk in terms of probability and consequence. Some, such as the CMPCF and International Infrastructure Management Manual, apply the main principles of risk management to wider asset management activities. Other frameworks focus on risk management *per se*, for example the UK's Defra Risk Management Strategy and the USA's EPA Risk Assessment and Principles. Both these examples are from the environmental sector.

Appendix 1 lists the frameworks reviewed and compares their main features and applicability to this project.

Figure 4: Steps of the Capital Maintenance Planning Common Framework



3.3.3 Methods and Tools

Methods and tools are similar in that both deal with the details of applying risk assessment. They differ from frameworks in that they provide more detail on recommended approaches to identifying and managing risk. Although many publications describe the theoretical process involved, few discuss the individual stages of a method in detail. Tools are often commercially available products and, apart from basic promotional literature, relatively little detail is available describing the methods embodied in them.

To the extent that we were able to review them, both methods and tools tended to break the process of identifying the probabilities and consequences of specified events into simple steps, regardless of the nature of the sector or the risk being managed.

Methods were identified for a wide range of sectors and some provided details to support standards and frameworks. For example, the Office of Government Commerce's Successful Delivery Toolkit provides a process based on the Treasury's Orange Book, reviewed in Appendix 1 with the Established Risk Management Guidelines.

Tools are typically based on a method (or an assumed method) and may vary in sophistication from simple tabular approaches (such as RiskBase 2000) to more complex assessment and

planning tools (such as APT tools), which calculate potential profit impacts and whole-life cost impacts, as well as assessing individual risks.

Appendix 1 lists the methods and tools that were reviewed and compares their main features and applicability to this project.

3.4 Findings

3.4.1 Risk Identification

The terminology varies widely but virtually all standards, guidelines, frameworks, methods and tools separate the identification of the probability of events occurring and their likely consequences.

The main body of a risk management process is based around identifying, categorising, analysing, quantifying and treating risks. There are many ways to do this, depending on the type of risk being considered. The foundations of all management processes include setting a context for application and a large part of this covers identification of the risks that need to be measured.

The literature sometimes refers to risk types and categories, such as: design and engineering; cost or financial; sufficiency of supply; headroom and outage; high consequence, low probability; operational; corporate and reputation; uncertainty; environmental; public health; and emerging (such as climate change) risks. The majority of these types of risk are in fact types of consequence or cause, which might be independent or linked to individual causal events. These risks could be interchangeable in part and could be combined or separated into a number of other risk categories. Therefore one of the main challenges in identifying and categorising risks is that the process remains inherently subjective.

Attention should be paid to emerging risks such as climate, which is topical for many governments and will become increasingly important as utilities start to consider adapting to climate change and meeting targets for reducing carbon footprints. This is an example of where risk management can be used to help to understand the effects of change external to the utility, which may be harder to assess than asset performance, which is under the utility's control.

3.4.2 Key assessment methods

Risk assessment methods vary from qualitative assessments based on the selected use of adjectives to detailed, quantitative statistical analyses. However, a number of different methods of measurement are common practice, irrespective of the sector or country in which they are used. The most common approach is the use of an assessment matrix, in which values of magnitude, impact or consequence are measured against probability or likelihood estimates.

The scoring and weighting of the risk variables typically depends on the category or type of risk measured, and also on the country and sector it is assessed in. Scores also vary depending on the definition of the variables and the context in which they are used. Other influencing factors, such as the size of the utility, ownership and regulatory regime, will also affect the weightings applied, depending on how a utility prioritises its business benefits.

Sensitivity analyses, cost-benefit analyses and whole-life costing estimates are also a common occurrence, providing a statistical element and supporting the quantification of risks. Attention should be drawn to these measures in particular, as they also support a forward-looking, sustainable approach to risk management.

The term 'risk tolerance' is often used to describe an organisation's willingness to accept a level of risk. Risks should be 'tolerated' where there is no economic case for their treatment or at the level of residual risk after the treatment is in place. The term acknowledges that it is difficult to eliminate risks, although it may be argued that utilities are unlikely to 'tolerate' risks if it is economic (or similarly justifiable) to treat them. In practice, even if there is an economic case for treatment, the risk might be tolerated for other reasons, for example not having the funding available to implement the treatment. In these circumstances there might be an implicit acceptance that performance or level of service is likely to decline in the future.

3.4.3 Key process elements

The number of elements and stages within the methods varied between 3 and 13. However, it was common to find that the steps could easily be grouped to create the four steps of the International Infrastructure Management Manual (shown in Figure 2). The risk management process is subjective to a large degree and it is not surprising to find such a range in the number of process steps. However, although the four steps are widely applicable and the majority of risk management processes reviewed could be applied at various levels of detail around them, some processes reviewed included a separate step for the reporting and feedback. This helps to protect them from a practical weakness that could result from insufficient management attention to the review phase; a substantial task if a large portfolio of risks is to be kept up to date. The original four steps could be expanded to five, providing more emphasis on monitoring and updating risks.

3.4.4 Common features

Recurring themes

Despite a lack of detail in the literature, some common themes emerged in identifying, assessing and managing risks. Assessments commonly include colour-coded risk matrices with scores based on probability or likelihood multiplied by consequence or impact estimates. Common features include:

- The incorporation of feedback and reporting stages with the aim of quantifying risks throughout an asset's life-cycle by introducing whole-life costing and life-cycle cost analyses.

- A risk register, in which details of each risk and its predicted magnitude are kept up-to-date, is seen as an integral part of the risk management process. It will ultimately aid risk owners with their mitigation decisions which will also be based around the level of risk that is justified on cost-benefit grounds – sometimes described as the level of risk a utility can tolerate (or is forced to tolerate) – in its current situation.

- Assignment of individual risks to a 'risk owner' who would subsequently manage its details within a 'risk register' based on a utility's ideal 'risk tolerance' levels.

An additional topic, not considered initially, is the classification of mitigation options. It was difficult to find detailed descriptions of mitigation options within the literature, perhaps because they are necessarily specific to the situation being assessed. It was more common to find risk mitigation options classified into several bands, for example:

- Transfer the Risk (to a third party by contracting out a service);
- Tolerate the Risk (watch the risk until it changes if it is not cost-effective to treat it);
- Treat the Risk (use options to contain the risk at an 'acceptable level');
- Share the risk (if the cost of a project is too large to shoulder yourself);
- Avoid/eliminate the risk (e.g. not proceeding with risky business ventures, or banning chemicals or processes that are too risky. The introduction of new technology may help to eliminate some risks but will ultimately create others).

Emerging themes

Some of the more recent developments in the literature include the consideration of environmental sustainability and the use of forward-looking analysis.

An emerging theme is the use of customer willingness-to-pay (WTP) studies to help to identify the demand for specific levels of service. This is useful in deciding on what treatments are justified and to help rank risk priorities relative to non-financial measures. The practice of using qualitative 'fuzzy-based' statistical techniques to assess risks is also gaining popularity in the more recent literature. In addition, the use of hazard analysis critical control point (HACCP) techniques outside the food industry appears to have become more widespread over recent years. However, its application is still quality-control orientated and is somewhat confined to the assessment of water quality.

3.5 Conclusions

3.5.1 Availability of tools and methods

- Detailed tools and methods are available, but either as commercial products or with limited circulation within specific sectors for which they have been produced.
- Some water utilities have their own tools and techniques for risk management, which tend not to be publicly available.
- There does not appear to be a widely available tool that is designed for the water industry and in common use worldwide.

3.5.2 Categorisation of Risks

- Although there are many ways of categorising risks, most categories are in fact types of consequence.

- One initiating event can lead to more than one consequence, although the magnitude of each might differ. The tool should therefore be able to assign multiple consequences to individual risks.

- It is important to agree on risk category and component definitions before beginning risk assessments, since a great deal of the risk identification, evaluation and mitigation can depend on how the risk owner defines the risk being dealt with. Categories help the user to consider all aspects of the risk and to break it into several measurable components, which helps to ensure consistency in assessments.

3.5.3 Risk management method

- Uncertainty is an important factor in risk assessment. Both probability and consequence can include an element of uncertainty and the extent to which it is handled is variable.

- In the assessment processes reviewed, matrices were commonly used to help identify and differentiate risks.

- The tool should adopt a stepped approach to guide the user through the risk assessment to follow the main stages of risk identification, assessment, analysis, evaluation and mitigation. Prior to these stages, a context in which to assess the risks must be outlined. This would define business objectives, highlight regulatory and non-regulatory standards and set the boundaries within which to carry out the assessment. But it is important to note that a risk is not 'controlled' until the treatment has been delivered.

3.5.4 Organisational issues

The literature shows that although there are a number of elements that must be included in a successful risk management tool, there are also organisational factors that will influence the success of the tool in use.

- Risk ownership: Risks (or groups of risks) are often assigned to a risk owner, who would ideally be an individual with a good knowledge of the company and its asset base/risk register. A risk owner is used to organise the overall management and monitoring of individual risks to ensure that any required treatment is delivered and that the risk assessment is updated if the probability or likely consequences change. It is important to note that this is a managerial discretionary option and, although useful, will not be used in every utility.

- Accounting for uncertainty: Reliable historical data and uncertainty analyses (where applicable) are important to support risk management decisions.

- Recording information: The foundation of an effective and sustainable management process depends on the effective maintenance of a comprehensive risk register.

- Portfolio risk management context: The total residual risk should be monitored from the risk register, and updated to reflect changes in the asset base and external circumstances.

- Risk Culture: A detailed risk management tool is not enough alone. The practical assessment of risk should be supported by the operative communication of the risk management process and the integration of this into corporate and stakeholder decision-making processes. The risk management process must be supported by all levels of staff and stakeholders to ensure transparency. This level of engagement promotes a corporate and social responsibility to include risk management in both short-term and long-term decision-making strategies.

4 Results of the Survey of Water Utilities

4.1 Introduction and Method

A survey of water utilities was undertaken, to help understand:

- Main reasons for investment;
- Current practice in risk management;
- Level of detail of asset information held;
- How investment planning approaches will change;
- 'Appetite' for risk management guidelines and tool.

The survey had 38 questions, to elicit an understanding of the context of risk management and hence many were not directly about risk. It was produced in English and French language versions and deployed through the internet site *Zoomerang*[3] so that it was easy to circulate to respondents worldwide. Members of the project steering group and the contractor's contacts were asked to send an e-mail requesting participation to all their water industry contacts, with the aim of attracting responses from water utilities in as many GWRC member countries as possible.

Rather than discuss the response to each question in turn, the results have been grouped into themes reflecting the aims of the survey. The questions reviewed in each theme are mentioned in square brackets.

A full questionnaire is provided in Appendix 2 together with a summary of the results.

4.2 Results and Discussion

4.2.1 Respondents

The survey was visited by 118 potential respondents. Of these, 35 completed the survey and submitted their results, and a further 12 were partially completed (and not submitted as completed). Responses came from 10 countries, but these were mostly well developed nations with relatively mature infrastructure bases.

[3] www.zoomerang.com

In the discussion below, question numbers are referred to in square brackets.

Four respondents declined to answer to the initial questions [Q1-Q5] and gave only partial responses to the remaining questions. Of these, some questions had been answered by selecting the responses to matrices in a pattern, and no interest in a risk management tool had been expressed. It was not possible to tell if these results were reliable and so they were excluded from the analysis.

There was a good spread of different asset types managed by the respondents, covering water and wastewater services [Q6]. All the utilities responding said they managed water distribution assets and two thirds also provided wastewater services. The size of the utilities also varied widely, based on population served and assets owned [Q7].

There was a broad spread of ownership models, covering all the anticipated sectors [Q8]. Those responding 'other' (31%) were municipal or city owned or public-private partnerships. The majority were operating in a regulated business environment (93%), with only two responding that price regulation did not apply [Q9]. All respondents said that water quality and environmental performance is regulated, mostly by Government or a specialist sector regulator.

One respondent commented that prices are set: "At a broad level with reductions applied in some areas to keep increases at what we consider to be reasonable levels." This is a good example of how risk management could help utilities understand the impact on service of changing the balance of funding from one part of a service to another. But this might also indicate the difficulty of matching investment to service risk if the result is a price rise that might not be considered 'reasonable' even if it is justified.

4.2.2 Investment drivers

Respondents were invited to rank a list of six reasons for investment. Maintenance and water quality improvement were the most important drivers of investment in the response, with three quarters ranking maintenance as the first or second reason [Q10].

A few respondents (10%) said they were not set standards for investment [Q11] but from those that were, about a half said that they met the current standards whilst the majority agreed that they needed to invest to meet the standards they are set. Almost half (48%) said that they did not meet the standards at some sites, and two thirds were concerned about meeting standards in the future. This is another area where an effective risk management tool would be of use. Utilities that are aware of the risks within their asset base can adjust management practices to suit changing standards of service.

Future expenditure is mostly determined by the utility proposing a budget based on its assessment of future needs [Q12], with three quarters saying they take customer service risk into account when deciding priorities, both by recent customer failures and by assessment of future customer service risk [Q13]. Asset age is used as indicator for prioritising asset replacement by a significant number of those responding (15 responses, 54%), of which two said that age was the only indicator.

4.2.3 Approach to asset planning

New assets are usually constructed on the basis of utilities' own assessment of future needs. Five respondents (14%) mentioned that regulator or municipality requirements are also important in determining what new asset will be built, but they should probably not be seen as the only respondents for whom this is true [Q14].

Almost all respondents (97%) said that affordability to customers is taken into account when considering an investment plan, but fewer (72%) are including willingness to pay [Q16, Q15]. Therefore, it would be useful if the tool could take into account customer affordability to some extent when considering risk mitigation options.

4.2.4 Current data holding capabilities

The majority of respondents (58%) keep details of assets as-built plus any modifications since construction. However, an additional 21% admit that the data is not kept up-to-date [Q17].

Data is mostly stored on central corporate systems (59%-90%) with less than 7% keeping records on paper. This is of benefit when transferring data into a model [Q18]. The majority of respondents (59%) would also agree that data kept on levels of service is linked to asset data in some way [Q19], providing at least some knowledge of how asset condition relates to service levels. However, only 31% say that financial data is linked to asset data in some way [Q20].

Question 21 was used to assess the current approach to operational maintenance, with many respondents using a combination of techniques and approaches to maintain their assets.

4.2.5 Current practice

The majority of respondents confirmed that their organisations had formal approaches to risk management, with most (83%) having formal financial risk management. About three quarters also assess service failure risks and other risks in some way [Q22]. However, a significant number (14 respondents, 52%) said that they were not being assessed to a published standard or guideline. Of those that were using such guidance, those cited included ISO 9000, ISO 14000, the UKWIR CMPCF, Sarbanes Oxley, Turnbull, and AS4360 [Q23]. Most of these have developed their approach to implementing the standards guidelines, with many incorporating the approach into formal business processes [Q24].

In the same respect, about a third of respondents said that there was no regulatory requirement to use risk assessment tools in their planning. Only 17% said they were expected to use them for all asset types [Q29].

The majority of respondents (64%) state that local operators assess risks and then pass the information on to a central base for action [Q25]. Almost half (45%) say that they assess the root cause of service failure for major incidents only, compared to 38% that assess for all types of failures on a routine basis [Q27] but almost half of the respondents (48%) express that links between asset failure and service failure are assessed for a variety of asset types [Q26]. The level of detail of risks measured is variable and this may present problems when using a tool if not compensated for in some way.

The data management techniques also varied. 55% say that managers and operators develop their own approach to meet a specified output, compared with 11% who say local managers or operators enter data onto a company system which then calculates the risk [Q28].

4.2.6 Future practice

The majority of respondents (71%) said that their asset management approach would need to change to meet their own needs, whereas 18% felt that change would be needed in order to meet regulatory requirements. The remainder did not expect their approach to change in the next five years [Q33].

Almost all respondents (93%) stated that if their planning approach changes, it will take more account of service risk and more than half (54%) said it would also take account of affordability and willingness to pay [Q34].

Bearing in mind that most respondents had already said that they are taking account of service risk, affordability, and willingness to pay, this implies that the approaches currently in use are still developing.

4.2.7 Appetite for a risk management tool and guidelines

Respondents were asked if they had any specific requirements for a risk management tool [Q30]. Of the 21 responses received, six stated that they had no specific requirements and others stated that they already owned a risk management tool. The 11 responses relating to the design of the GWRC tool were:

- ***"We are a small system, with few staff, so are looking for a simple tool that can achieve most of the benefits, with modest resources."***
- ***"Easy and operator friendly, not too labour intensive"***
- ***"Simple to use, but able to provide flexibility to allow trade-off between risk and cost."***
- ***"Yes, a tool that may enable us to assess asset risk due to natural and man made calamities like an earthquake."***
- ***"Transparent, contextually adaptable, quantitatively based, simple to apply, based on sound principles."***
- ***"Practical and meaningful."***
- ***"Yes, several e.g. combining reliabilities / assessing value (in a CBA sense) of risk mitigation."***
- ***"Risk tools need to incorporate social and environmental costs and consider CBA."***
- ***"Compliance with UKWIR Common Framework."***
- ***"Asset risk of failure and impact on customer. Project risk management and programme level risk assessment."***

A common opinion was that the tool should be easy to operate and should be applicable at different levels of business. The UKWIR Common Framework and COSO[4] were also mentioned as guidelines that the tool would need to comply with.

Although the tool needs to be simple, around half of the respondents (45%-52%) agreed that it was important for it to evaluate risks from individual asset levels, to whole pipe networks and whole treatment works and to also be able to link in with GIS [Q31].

In accordance with this, 52% of respondents answered that they would prefer to be given a method statement only, from which they could develop their own tool [Q32] through fear of receiving a tool which is too complex or labour intensive to use. However, 48% would prefer the tool and a detailed method statement, so opinion is relatively divided.

46% said a tool would be useful in the form of a framework with guidelines for application compared with 29% who wanted a stand-alone risk assessment tool in a spreadsheet [Q35]. The majority of respondents (67%) would use the tool for assessing a combination of asset types and events [Q36]. There is a general consensus that the tool would be of use, although to varying degrees.

4.2.8 Further involvement

Questions 37 and 38 were used to assess further interest in the project and to determine who would be contactable for the next phase of the project which involves telephone interviews and testing of the model.

4.3 Survey Conclusions

- The survey was mostly completed by mature utilities in developed countries.
- All appear to be familiar with risk management principles and techniques.
- Many utilities are already practicing risk management to some extent but the majority plan to continue developing and improving their approach.
- There is concern about future pricing and the possibility of re-balancing expenditure priorities.
- There was an emphasis on ‘forward-looking’ budget setting.
- There are concerns over future compliance with regulations and standards.
- Requirements state that the tool must be simple to learn, apply and use but also be readily adaptable to a variety of asset types and events by managers and operators alike.
- Guidelines are seen to be equally as important as the tool. This would allow utilities to develop their own approaches in line with the guidance, for example where partial coverage of the guidelines is already embedded in corporate systems.

[4] COSO: The Committee Of Sponsoring Organisations of the Treadway Commission. Enterprise Risk Management-integrated framework

5 Functional Specification

5.1 Introduction

The literature review and survey of utilities were used to write an initial specification of the risk management tool, which was then developed by iteration with the steering group. The main features of the functional specification are described below. Refer to the user guide documentation for more detailed information about each aspect of the tool.

5.2 Scope of the Tool

The tool is designed to demonstrate the process of assessing asset risks, in an asset management capacity only, but may have some scope for adaptation into other areas by the utilities themselves.

The tool is capable of operating with minimum data but also offers advantages where more detailed data is available. The steering group wanted the tool to be easy to learn and use for newcomers to risk management, but it should also have sufficient capability to be useful in utilities that already have grounding in risk management.

5.3 Delivery Method

To ensure consistency, it would be useful to specify the medium through which the tool will be applied. The use of widely available desktop software will enable the tool to be circulated within GWRC members without the need to purchase specialist software licences. After considering opportunities for using Java and Microsoft Access, the PSG chose Microsoft Excel as the platform.

The tool is built in Microsoft Excel 2003.

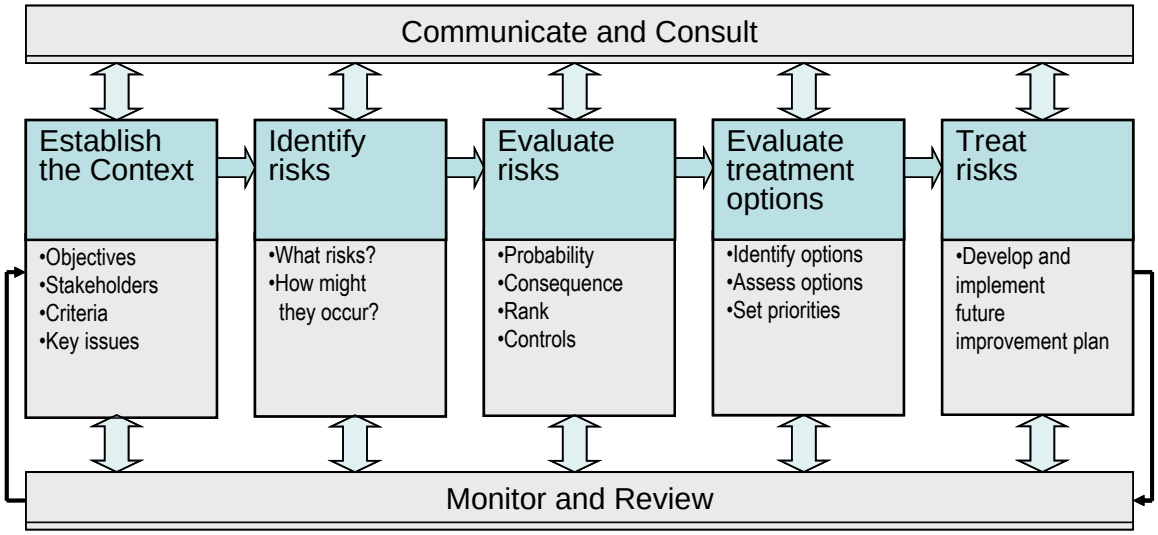
5.4 Overall Approach

The literature commonly presents a stepped approach to risk management, grouping the different activities that are required. This ensures that the risk management process is organised and transparent and can be followed by a wide range of employees. Risk managers can be guided through the process in a logical fashion, but the steps should also be clear enough to aid less experienced staff through the process, providing consistency of terminology and approach.

Many approaches in the literature have features similar to that in the International Infrastructure Management Manual, although the number of steps varied greatly. Where a published method had relatively few steps, there was often a hierarchical approach, with sub-steps providing the detail.

A hierarchical five-step approach was adopted for the tool, as described below and shown in Figure 5. This is based on a combination of the processes illustrated in the International Infrastructure Management Manual (2002) and the AS/NZS 4360: 2004 standard.

Figure 5: Five-step approach for the risk management process



Source: Developed from the International Infrastructure Management Manual, 2002 and the AS/NZS 4360: 2004

Establish the Context: This step establishes the context for risk management and sets the boundaries for risk assessment. It is important to list the utility's stakeholders and to also document the utility's objectives, such as customer service, environmental and financial performance, health and safety, and regulatory and public confidence, since these are the objectives against which risks will be assessed. The identification of the key issues can help to prioritise assessment of the major risks first.

Identify Risks: Risks are identified relative to the objectives that were set in the previous step and the main cause or scenario in which they occur is recorded. At this stage any relevant asset details would be recorded, so that the entry may be linked to other systems such as GIS or modelling tools.

Evaluate Risks: Details of the probability and consequences of the initiating event occurring are used to assign a financial value (where possible) to the initiating event. This step can also take account of controls that are in place and the level of confidence, or uncertainty, in the data. Once risks have been evaluated they may be reported in terms of their relative value, or by other criteria such as specific business consequences.

Evaluate Treatment Options: This stage involves identifying and assessing treatment options and setting priorities for treatment based on business objectives.

Treat Risks: The treatment stage covers the process of delivering the best (or most acceptable) treatment of the risk. This would involve planning and scheduling the delivery of the treatment.

Monitor and Review/Communicate and Consult: Since the nature of risk changes over time, it is important to maintain the accuracy of the risk database. This would involve checking that treatments have been delivered, and re-evaluating 'tolerated' risks (those where treatment was not justified). The review process incorporates all five stages; ensuring that issues such as lessons learned and calibration are taken into account.

The main functions for each stage are discussed below.

5.5 Establish the Context

This stage allows utilities to set their own business objectives and criteria and is essential for successful risk management. Owing to the differences expected in utilities' business plans, this process will be emphasised in the guidance accompanying the tool, rather than in the body of the tool itself.

5.6 Identify Risk

5.6.1 Business Consequences

From the literature review we identified types of consequence that are often used to categorise risks, in terms of impacts on objectives. All risks would then be evaluated in terms of these; for example asset performance might affect regulatory objectives, health and safety, and the environment, even if there was no impact on customer service or stakeholder confidence in the utility.

The tool includes the following business consequences on business objectives as standard, but may be edited by users:

- Customer service consequences
- Health and safety consequences
- Environmental consequences
- Regulatory consequences
- Direct financial consequences

5.6.2 How Might Consequences Occur?

Several consequences, which might affect several business objectives, may result from a single initiating event, so a risk becomes the exposure to a combination of consequences that might result from the event.

> The tool allows risks to be evaluated in terms of each *business consequence.*

An alternative would be for each risk to be entered into the tool once for each business consequence that applies, but this is an unnecessarily complicated approach that would make it harder to assess the overall risk.

For an initiating event, each consequence may have a different magnitude, with a different likelihood of occurrence.

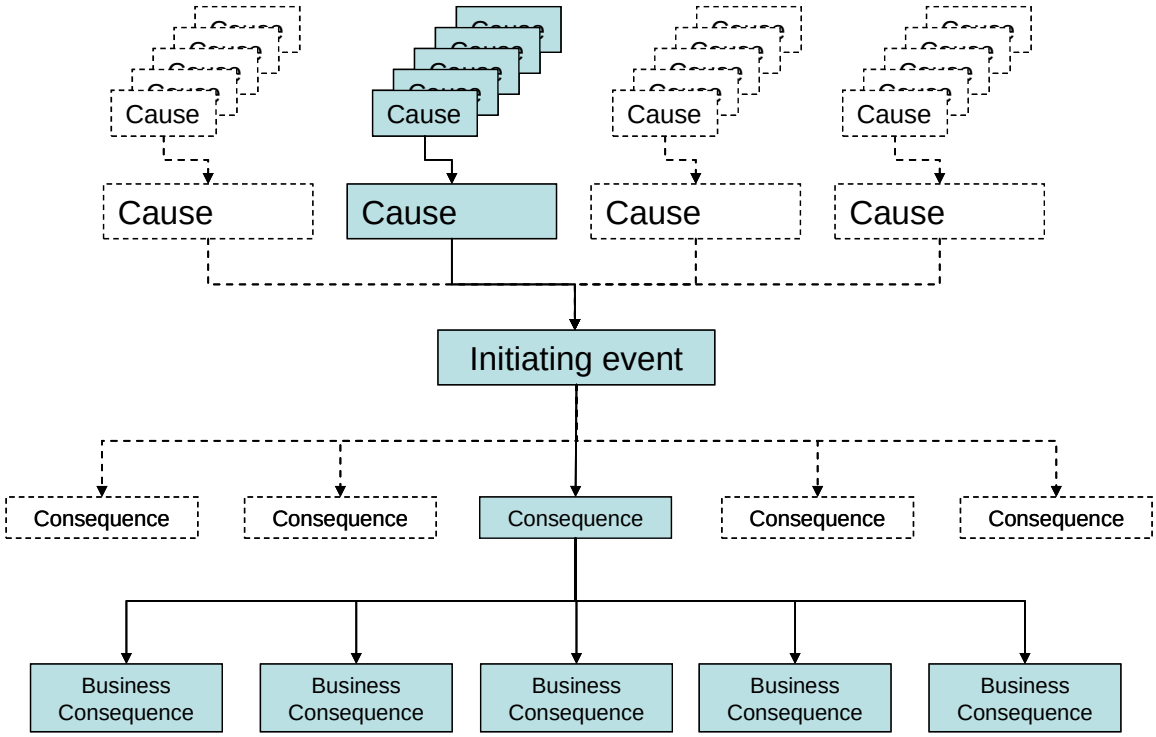
> The tool allows the magnitude of each business consequence to be assigned independently.

Many events can be attributed to combinations of causes or a root cause, which if addressed, would prevent the initiating event from occurring. It may be argued that the root causes are in fact the initiating events and all things resulting from them are consequences.

Causes may occur independently of each other, or several may occur together, leading to the initiating event, which in turn leads to one or more consequences. Figure 6 shows an example of the relationship between an initiating event, its causes and consequences for business objectives. There might also be secondary consequences.

The GWRC tool is intended to focus on the initiating event as the centre of the management chain and the immediate causes and consequences, as shown in Figure 6. To attempt to evaluate all potential causes of an initiating event could make the process unmanageable in the scale of this project, and hence these should be assessed as separate risks, as shaded in Figure 6. For example, the initiating event may be ‘sewer collapse’ from which there will be many consequences. There will also be a number of causes (traffic loading, corrosion, storm surges etc) but these will be assessed as separate risk chains because sewer collapses from traffic loading might have other consequences than sewer collapses due to corrosion.

Figure 6: "Hour-glass" family tree showing the relationship between root causes, an initiating event, and consequences.



The tool allows a single chain of causes (leading to a number of business consequences) to be identified for each initiating event.

5.7 Evaluate Risks

This section covers the analysis and assessment necessary to determine the size of the risk, preferably in quantified terms. This evaluation is necessary:

- To decide if the risk is significant enough to warrant the next process, Evaluating Treatment Options (see Section 5.8), and if so,

- The evaluation will be used in the Evaluating Treatment Options stage (see Section 5.8) to decide what treatment options are justifiable and optimal.

5.7.1 Value (or level) of Risk

The value of a risk is usually taken as the product of the probability or frequency and the value of the business consequences. So a risk event with an annual probability p=0.1 and a consequence value of 1000, is evaluated as:

$$\text{Risk} = 0.1 \times 1000 = 100.$$

The primary valuation of risk should be in financial terms, but users may also enter risk in 'points' for a limited part of the assessment.

We therefore need to determine, for each identified risk, the magnitude of the frequency of occurrence for the consequences and the magnitude of the consequences themselves.

5.7.2 Assessing Probability or Frequency

The most common approach to risk assessment is based on assessing the probability of an event happening, which is sometimes a function of the probability of asset failure, and the probability that the failure will lead to a specified consequence. For example not every sewer collapse event leads to a flooding or pollution incident. Therefore the tool must allow assessment of the probability of the initiating event occurring and the probability that it will lead to the business consequences, as well as identification of the chain of causes.

The tool allows the probability (or frequency) of the initiating event to be entered. This is done by entering a probability, which is displayed on screen as both probability and frequency.

The tool allows the probability (or frequency) of individual consequences to be entered in the same way as the probability of the initiating event.

The tool allows up to four causes to be entered for each initiating event, plus a root cause. The root cause is selected from a user-editable list.

Assuming that there may be more than one consequence of an initiating event, each consequence might have a different probability of occurrence.

Probabilities assigned to events are likely to be derived from models, records of previous events, or judgements and will be subject to varying levels of confidence. The addition of confidence limits or distributions could significantly add to the data requirements and complexity of the tool, which the survey suggests would make it less appealing to users.

The tool allows an incorporation of basic confidence estimates in the data inputs, from a user-editable list. Confidence estimates allow data ranges to be calculated, symmetrically around a central estimate.

5.7.3 Assessing the Consequences

Initiating events can affect several business objectives and it is important that they are assessed with this in mind to allow the full impact of the risk to be seen. The assessed consequences are reliant on the occurrence of the initiating event. Therefore, the consequences should be assessed in terms of their occurrence per event.

> The frequencies of the consequences are measured in terms of their occurrence per event (i.e. the initiating event) and not in terms of their occurrence per year (as per the initiating event).

Having identified the nature of the consequences, their probabilities and controls, they could be quantified in terms of their impact on each of the business areas. Allowing consequences to be assessed in terms of business impacts could help to ensure that risks are assessed with overall business objectives in mind.

> The consequences of the initiating event are split into two aspects: the primary consequence and any resulting business consequences. The tool allows the initiating event to be quantified separately to the resulting business consequences.

Different utilities may have different priorities with respect to their overall business objectives. It is important that all utilities are able to assess the risks according to their specific commercial environment.

> The tool allows a point score to be given to each business consequence. This can be used as a separate assessment mechanism or as a means of weighting the monetary values which are entered.

5.7.4 Ranking for Treatment Evaluation

The ranking of risks for treatment evaluation is important for successful management. By sorting the risks, the biggest may be 'brought to the top', allowing management attention to focus on them first when Evaluating Treatment Options (See Section 5.8.) Ranking for consideration of treatment options could be assigned by the product of probability and consequence, in financial terms or in terms of a 'score' assigned to each risk. It might also be possible to influence rank by taking into account the 'shape' of risk as defined by the relative values of probability and consequence and therefore the location on the probability and consequence risk plane. For example risks for which consequences are low may be allowed to materialise, with no preventive treatment, and then be treated after the initiating event has occurred, whereas risks for which consequences are high may be allocated high priority for evaluation of preventive treatment options.

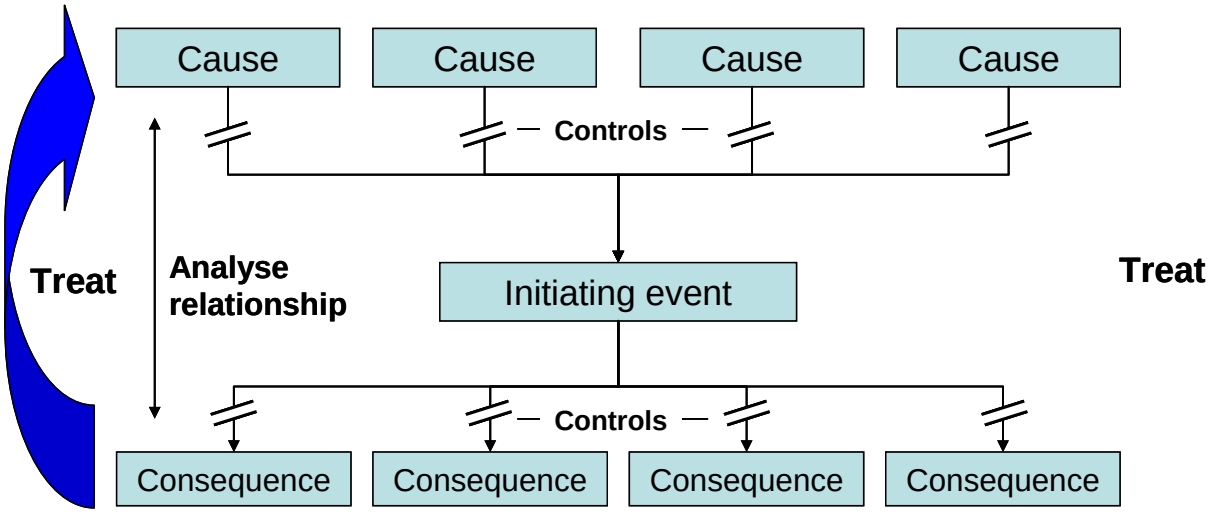
The tool allows quantified risks to be ranked, for evaluation of treatment options by a limited range of indicators.

5.7.5 Evaluating Risks and Options: Identifying existing controls and treatments

When the relationship between root cause, initiating event, and consequences has been evaluated, a range of treatments may be identified to eliminate root causes or introduce controls as shown in Figure 7. There will often be various criteria for choosing treatments and more than one treatment available, with each offering a different risk reduction and cost. The evaluation of treatment options (see Section 5.8) is necessary to determine the option best meeting the business criteria.

However, with any risk evaluation there will usually be existing controls in place, either through design or modification of equipment or through the existence of appropriate contingency plans. Users have to decide how they will take account of controls already in place. This is done either by entering the existing control as treatment, or more usually, assessing the risk as it is with the control in place. Indeed, many risks may be associated with the failure of existing controls and hence assessment with controls in place is the preferred option.

Figure 7: The relationship between controls and risk causes and consequences in the risk management process



The tool allows complex treatments, having more than one component, to be constructed.

The tool allows treatments to be identified in terms of their cost, effect on overall risk, and effectiveness over time.

5.8 Treatment of Risks

Having identified the risks, evaluated them (including existing controls) and decided which are significant enough to warrant consideration for treatment, the next step is to identify and evaluate available treatment options and establish which are viable for implementation.

5.8.1 Identifying options

Options for treatment will normally be selected on financial grounds, for example by calculating the financial value of the risk reduction provided by a treatment option and comparing that with the cost of that treatment option, i.e. a benefit/cost approach. The value of the risk might change over time, as might the cost of the treatment. One option which must always be considered is to 'do nothing', or 'tolerate' the risk. This option would be justifiable where the treatment cost is more than the risk reduction is worth.

By ranking the treatments in order of their relative risk reduction or financial benefit, risk reduction per money spent can be assessed. Prioritising treatment projects on the basis of benefit /cost ratio (providing it is > 1.0) is highly desirable to achieve the greatest overall risk reduction for the available funds. However, risk managers might want to be able to select options other than the calculated best option, for example where the preferred solution will take time to deliver and an interim control is required. In the water industry, it is essential that utilities include not only the evaluation of direct financial benefits and costs, but that they also consider the equivalent values of intangibles such as service level consequences in the benefit/cost process.

The tool allows treatments to be ranked in order of their financial benefit or overall risk reduction.

The tool allows users to choose their preferred options, rather than always 'forcing' the calculated best option to be selected.

From this section comes a justified and prioritised set of Risk Treatment "solutions", which pass to Section 5.9 (Risk Treatment) for funding, scheduling and implementation.

5.9 Risk Treatment

This is the treatment project funding and implementation phase. Treatment options which pass to this phase are already established above as viable investments. The Treat Risks process stage is the project management phase of risk management and will comprise an

amalgamation of capital works, maintenance strategies, operating procedures, contingency plans, staff training programmes, and reporting systems, amongst others. The expenditure on these options should be deemed justifiable on the basis of the risk reduction it provides.

5.10 Monitoring and Review/Communicate and Consult

Even when treatments have been identified, unless they have been delivered (or interim controls are in place), the exposure to the initiating event remains unchanged. Therefore an important aspect of risk management is to understand the extent to which treatments have been delivered, and the status of the controls that are in place.

Treating a risk does not usually eliminate it, but rather reduces it to a lower value residual risk.

> The tool allows identification of residual risk from the initial risk reduction provided by treatments.

In managing risks it will be necessary to understand how they change over time and the time dimension of any treatment. For example, a new water main might significantly reduce the probability of a burst that leads to an interruption to supply, but the risk might return as the pipe deteriorates. This would also apply to risks for which the treatment was determined as uneconomic or which have been tolerated for some other reason.

> The tool allows users to see the date of assessment so that entries may be updated over time. It reports the number of risk assessments that are more than two years old.

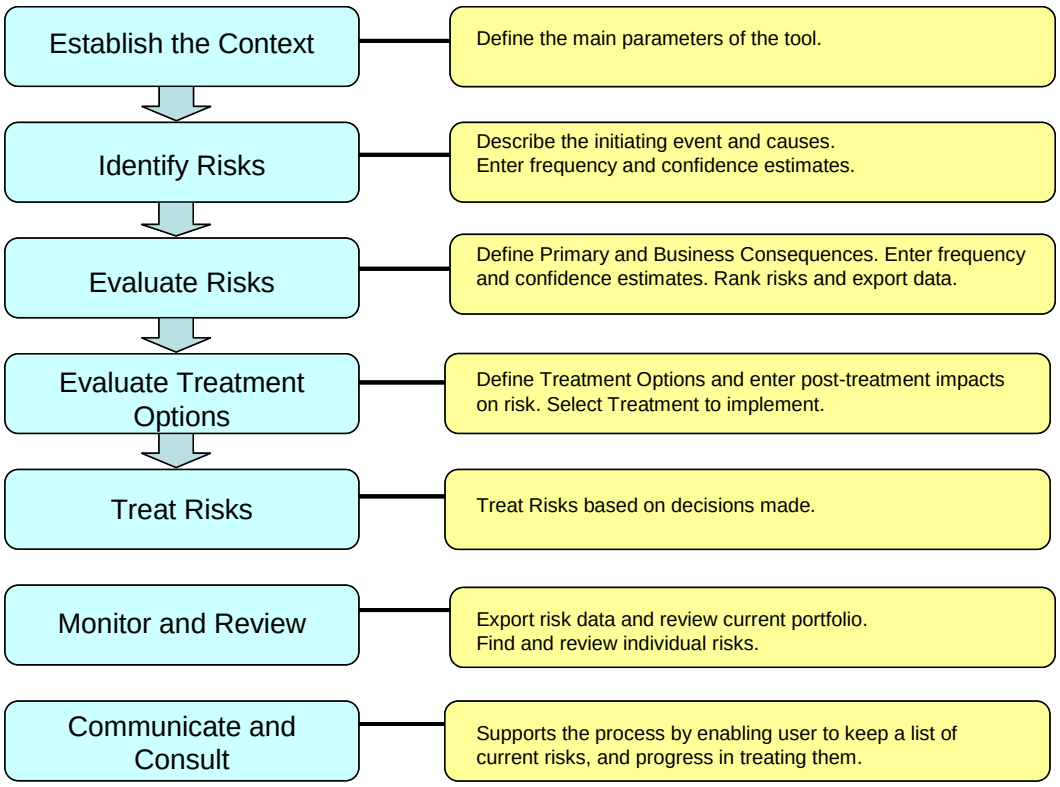
6 Overview of the Tool

6.1 Approach and Aims of the Tool

The aim of the tool is to facilitate the review and identification of risk and potential mitigation options, specific to water utility assets. The tool should aid users in quantifying and monitoring risk across all areas of the utility's asset management activities. It should also enable potential mitigating investments to be balanced against the probability of risks materialising and their consequential impact on the business and on levels of service to customers.

The tool demonstrates the accompanying guidelines (see Chapter 7) and the two should enable water utilities to adopt a common understanding of risk management principles and to implement a generic approach. The tool itself can be found on the CD accompanying this report.

Figure 8: Relationship between risk management steps and the main functions of the tool



6.2 Layout

The tool is spreadsheet-based (in Microsoft Excel) and there are four separate worksheet tabs displayed for use: Cover, About, Summary and Current Portfolio. There are numerous calculation worksheets which are normally hidden from view. The 'Cover' and 'About' tabs provide the project title, authors and disclaimer.

The 'Summary' tab controls the risk assessment process and the entering of data. The 'Current portfolio' sheet does not require any data input and is used solely as a way for the user to view the current portfolio. These two tabs are explained in more detail below.

6.2.1 Current portfolio

This sheet gives a summary of the current risks and available treatment options. The main details for each initiating event in the tool are displayed. These include the initiating event reference, name, description, asset reference and assessment date. The available treatment options for each initiating event are also displayed by reference and name. The treatment decision will appear in this section (e.g. 'do nothing') and a summary of the cost and time details is also produced before the summary of the total risk associated with the selected treatments.

This sheet calculates the risk profile as treatments are delivered, and the associated risk for each treatment option is shown for the assessment date and for 5 and 25 years after. The

details can be seen in the 'Risk profile' plot, contained in the 'Summary' sheet. A calculated Net Present Value (NPV) figure is also shown.

6.2.2 Summary

There are four main points in the Summary sheet. The first to note is the colour key for the tool. This helps to explain which data is for optional input and which is necessary for the tool to function.

There is a portfolio summary section, shown in the pink tables, which consists of 'General Statistics', 'Treatment Options' and 'Risk Profile' details. The general statistics table includes the number of risks within the current portfolio and the number that are categorised as 'live' and 'closed'. The treatment options table includes the number of treatment options that have been selected and the associated capital expenditure and benefit of those options. The Risk profile table details risk figures over time as seen in the 'Current Portfolio' sheet. The Risk profile is also graphically displayed to the right of the sheet. The tables and the graphical display will be automatically updated as the tool is populated with risks.

The main area of use consists of the five grey buttons located in the lower right-hand corner of the sheet. These are named:

- Setup;
- Edit or Create Risk;
- Evaluate Risks;
- Edit Create Treatment Option; and
- Evaluate and Select Treatment Options.

These give the user access to the forms in which all of the data should be entered. The four forms cover the five main steps of risk assessment, as shown in Figure 5. Guidelines for use of the tool are included in Appendix 3 and are summarised in Chapter 8.

7 Boundaries of the Tool

The tool is designed to demonstrate the assessment of risks relating to water utility assets. It exemplifies the risk management method, explained in the guidelines, but does not necessarily have all the features that will be required to produce a comprehensive risk management process. For example, it has not been designed to manage multiple users. It is the duty of the utility to implement a full risk management process appropriate to its own circumstances.

This chapter summarises the boundaries of the tool.

7.1 Capacity and Medium

7.1.1 Database functionality

The tool makes use of database functions in Microsoft Excel but it does not have full relational database functionality. The tool may be examined in order to understand the

methodology and may serve as useful specification for transferring the risk assessment methodology into a corporate database.

7.1.2 Linking risks

The tool is designed around independent risks and does not allow one risk to depend on another, or create chains of linked risks. It assesses risks from a single causal chain to a single initiating event, which in turn creates a primary consequence; assessed in terms of its impact on a number of business objectives.

7.1.3 Multiple risks solved by single treatment

In some cases a single treatment might address many risks, for example a new trunk main might alleviate the risk of losing supply from several different pumping station or pipe failure scenarios. The tool is only configured to address risks one at a time and will not link risks or highlight treatment options with multiple applications.

7.1.4 Application

The tool is intended to exemplify the risk assessment method in a way that could be used on a relatively small scale and has not been designed to handle large numbers of risks. Entering thousands of risks will result in slow calculations.

This suggests that to some extent there is a trade-off between performance and usability. However, the tool has the potential for use in both small and large utilities. Smaller utilities may benefit from using the tool in its current form and the tool has the ability to assess a reasonable number of risks before it becomes impractical. The number of risks termed ‘reasonable’ will vary depending on the detail entered but the tool will become noticeably slower after 1000 risks.

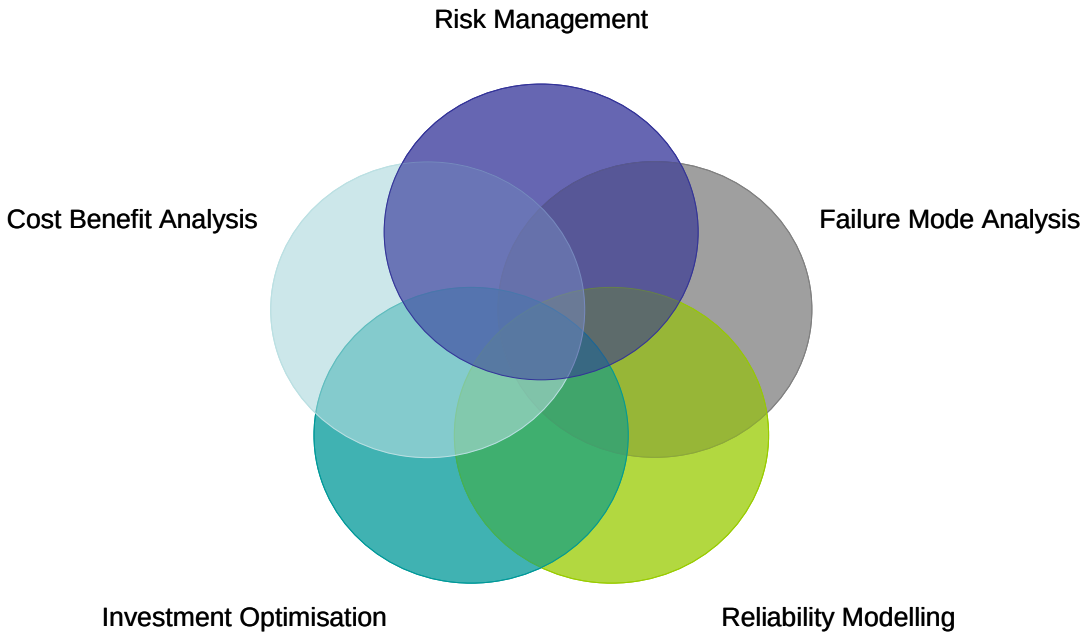
It is envisaged that larger utilities will use the theory from the tool in reviewing their own corporate databases and systems. Alternatively, larger utilities could use the tool to assess risks down to a certain level e.g. unit level. This will ensure that a manageable number of risks are processed.

7.2 Additional processes

Figure 8 shows five key processes of asset management. A comprehensive asset management plan will include all of these five processes to some degree and it is expected that all of these processes will interlink and overlap to some extent.

The risk management tool is intended to exemplify the risk management method, as well as practically assessing risks, to show how the method could be incorporated into a utility’s asset management strategy. The tool does not include the other four elements, as this was outside the scope of this study, but a more detailed description of why the tool omits them is given below.

Figure 8: Asset Management Elements

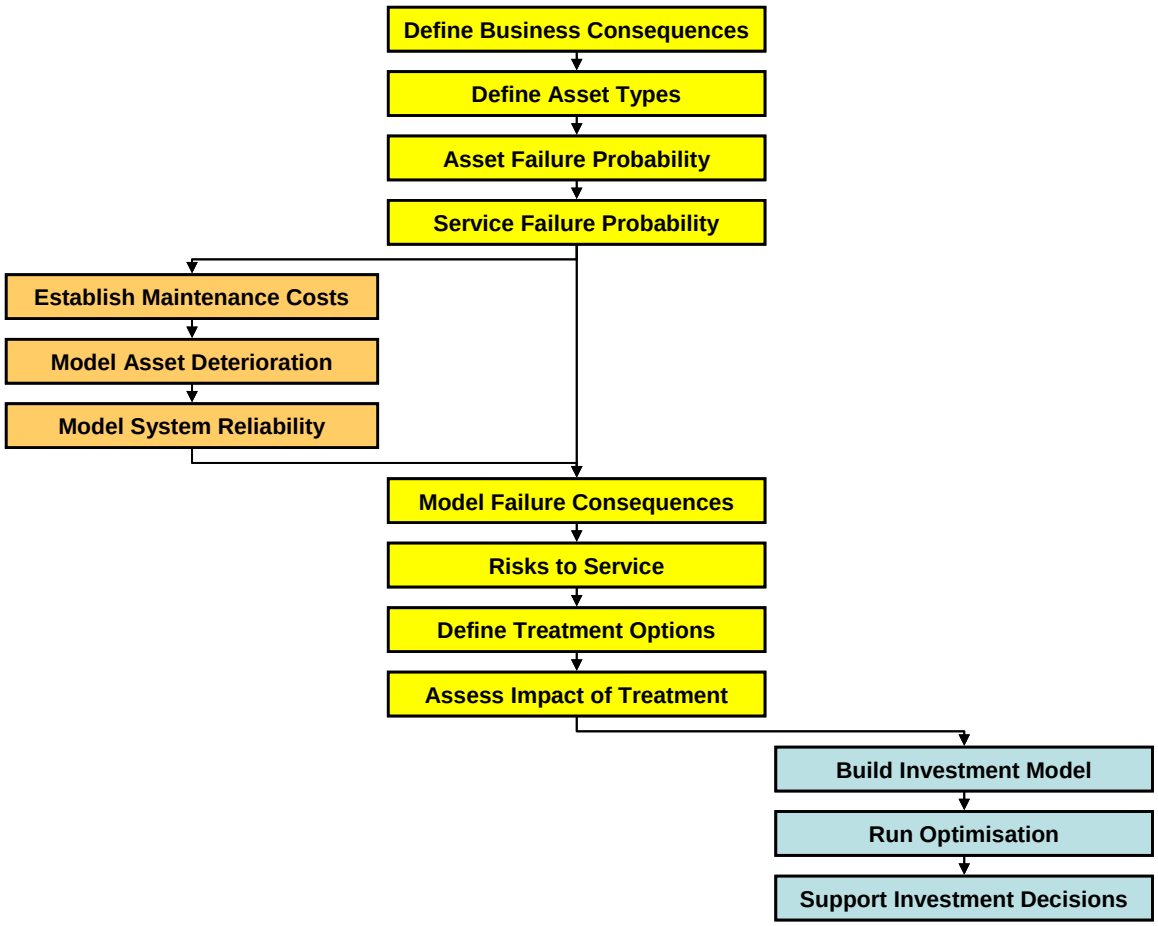


7.2.1 Asset deterioration, reliability modelling and failure mode analysis

This is a specialist exercise in its own right, which will produce a forecast of changing asset failure over time. Where the results indicate a potential service failure, the results of reliability modelling could be used as inputs to the risk assessment methodology to help assess the value of the service failure (see Figure 9). The tool includes input fields for the anticipated initiating events to be entered for each year of the review. It is possible that the initiating event could be equal to the instance of an asset failing, and that the forecast frequency of initiating events could be related to the failure rate forecast.

If asset reliability (or failure modelling) results are available, they could be used as the source of the failure rate forecast, in as much as they relate to failure in the same context as that of the risk assessment. Figure 9 shows how other elements of asset management fit into the processes within the risk management tool.

Figure 9: Incorporating the Risk Management tool (tool functions shown in centre yellow)



7.2.2 Investment optimisation

The risk assessment methodology allows many treatments for one risk to be assessed, in terms of their costs and impact on the risk. The results would provide a useful input to an investment optimiser (see Figure 9), since it helps users to identify various treatment options, their costs, timescales for implementation, and the level of risk reduction they provide. The tool does not carry out investment optimisation such as balancing costs and risks across the asset base, or automatically selecting the optimum date for implementation of a treatment, since this is a separate specialist field for which there are tools already available.

7.2.3 Cost Benefit Analysis

There is an UKWIR project, recently completed, with the focus of cost benefit analysis and this is currently being used to aid a GWRC benefit-cost analysis project. It was envisioned that, although there could be some cost benefit analysis within the tool, this was outside the scope of the risk management project. Cost benefit analysis, as well as each of the other elements, is large enough a subject to justify a separate tool.

The tool does a limited amount of cost benefit analysis; focusing on the cost and risk reduction values arising from implemented treatment options. The results of the analysis made by the tool could be easily extracted to help populate a cost benefit tool or investment optimiser and would be a beneficial input to an investment model (see Figure 9).

7.2.4 Sensitivity analysis

Sensitivity analysis is a means to determine the robustness of a mathematical model or data analysis exercise. For example, this could comprise a cost-effectiveness or decision-making exercise with a range of independent variables: cost, risk reduction, probability etc.

The tool incorporates some uncertainty by allowing confidence levels to be placed around the frequency and treatment option entries. This gives each calculation a minimum and maximum range. However, the calculations needed to attach in-depth sensitivity analysis to every aspect of the tool would be detrimental to its operation. It would be more beneficial for a utility to incorporate the analysis from the tool into its own corporate model; ensuring an appropriate level of sensitivity analysis for its needs.

7.2.5 Application

The tool was designed to assess risks pertaining to water utility assets only and its major focus is on the risks to serviceability. However, this does not mean that it has no further potential to assess corporate or other risks. The tool is based on generic risk management principles that could be transferred across management sectors and even industries.

There is every opportunity to use the risk management tool to link in with asset life reviews, reliability of failure mode modelling, and investment optimisation, thus making a valuable addition to a robust asset management strategy.

7.3 Business Management Process

7.3.1 Cross-checking

Since the tool is set up in a spreadsheet it has no multiple-user management and does not prevent two users from entering the same risk with different values. Utilities will need to apply their own quality management system to ensure that users adopt a consistent approach to risk assessment.

There is no sense-checking or cross-checking in-built but this only serves to highlight the need to follow the risk management process as a whole and not to rely solely on the tool for guidance. The tool is designed to work within the risk management process, but is not a substitute for it. For example, the tool does not implement treatment options and has no capacity for feedback and reviewing. This process must be added by the user.

7.3.2 Data Calibration/Tool Validation

As there is no sense-checking, modelled risks must be reviewed and evaluated by the user to ensure they are correct and make sense. It would be useful to conduct a periodic review of risks entered and, using a panel of suitable reviewers, try to highlight or possibly eliminate any duplicate or erroneous entries.

It would also be useful to sum the risks, treatment costs and consequences and compare them with the actual performance of the utility to provide an estimate of how accurate the risk

assessment is. If values are not comparable, guidance for entering the individual consequence values may be required.

7.3.3 QA processes

The 'monitor and review' and 'communicate and consult' interfaces of the risk management process are not implicitly included in the tool. The tool has no power to audit or review risks in a traditional management sense. This has to be done by the user and the guidelines will take the user through the whole risk management process; including operation of the tool.

It is important that the review and approval process is carried out thoroughly because populating the tool is not as important as ensuring that the risks being entered are credible. Entering hundreds of incorrect risks will give a false picture of the risks affecting the operation and management of the utility.

The tool is available to multiple users but it is recommended that a strict policy of document management and version control is employed to monitor the risks and general data entered. It is possible for the same version of the tool to be opened my multiple users at a time and it would be important to exercise simple controls such as the 'read-only' function. This would force additional users to create a new version if changes were saved.

However, this is a short-term measure and should be backed up by more robust document management procedures. It is strongly recommended that a procedure for use of the tool is developed and incorporated into any existing corporate QA processes and procedures.

8 Overview of the Guidelines

8.1 Approach and Aims of the Guidelines

The aim of the guidelines is to provide comprehensive instruction, both in the use of the accompanying tool and in implementing a robust risk management process. The risk management process is intended for international application, both in established water sectors and in international emerging markets.

The full guidelines detail common principles in risk management of water utility assets, showing best practice and conforming to relevant international standards. They guide the user through the theory of the risk management process. The full guidelines are explained below and are included in Appendix 4.

The quick-start guide is intended to lead the user through the practical risk management process and is based around the accompanying spreadsheet tool. The quick-start guide can be viewed in Appendix 3 and is explained in more detail below.

For ease of navigation and use, the two sets of guidelines have been combined into an electronic learning program[5], which is described below.

[5] Published by Mohive software.

8.2 Layout and Format

The guidelines and the quick-start guide have been created as Microsoft Word documents and these have been included in the Appendices, as stated above.

The electronic learning program combines the two sets of guidelines, allowing them to be displayed as different sections in separate chapters. The chapters follow the main five steps of the risk management process and process sub-steps are included as chapter sub-steps. The user can read the tool-specific instructions (i.e. how to use the tool for this step) to enable them to complete the practical risk management process with regard to populating the tool. The electronic guidance includes screenshots and images of the tool for illustration of the instructions.

However, the detailed theory is also displayed to encourage a wider understanding of the risk management process as a whole. It is recommended that those populating the tool have an understanding of the theory behind it. The risk management process extends before and beyond the limits of the tool and so the detailed guidelines are also strongly recommended.

The electronic learning program can be found on the accompanying CD-ROM along with the tool and the guidelines.

8.2.1 Quick-start guide

The quick-start guide follows the risk assessment process as dictated by the tool's functionality. This allows the user to enter and assess risks relevant to their utility and to consider any associated treatment options.

The layout of the guide revolves around the order in which data must be entered into the tool. The guide includes all stages of the risk management process but refers to the full guidelines where the tool has no applicable calculations (e.g. Communicate and Consult interface).

8.2.2 Detailed guidelines

The full guidelines are laid out within tables in a series of A3 sheets. The columns should be used to navigate the steps and sub-steps of the tool. The rows are used to navigate the detail of the steps.

In the first column is the title of the step, which is followed by the detailed theory behind the step, practical examples, a description of what must be entered into the tool and details of the calculations programmed into it.

9 Testing of the Tool and Guidelines

9.1 International Testers

9.1.1 The Tool

One of the final questions in the survey to water utilities was to establish which participants would be willing to test the tool once it had been developed. A number of participants responded positively. From these, a representative group was selected. It was decided that it

would be a better test of the tool to send it to a number of utilities of different size, maturity and country of location.

After this initial round of testing, the tool was made substantially more robust in its ability to cope with a wide variety of users and risks. This was largely due to the addition of a good error-tracking system. The first round of testing was useful to identify problems that may not have been apparent when following a set path with the tool from the risk management guidelines.

9.1.2 Guidelines

Copies of the quick-start guide and detailed guidelines were also sent out with the initial tool prototype. Feedback was positive but it emerged that the quick-start guide was being seen as more useful in accompanying the tool. The detailed guidelines are large in size and offer little practical advice in setting up and operating the tool and are therefore more useful for explaining the risk management theory behind the practical application.

It was decided that the quick-start guide should be combined with the detailed guidelines in such a way that the user would not have to read the theory behind the tool before operating the tool, but that it was still available for reference. It is recommended that the theory is still read because the tool is designed to exemplify the risk management method and should not be used as a stand-alone product. Therefore, the two sets of guidelines have now been combined into a more navigable online guidelines document, ensuring that the content is kept intact whilst making allowance for individual preferences.

It was noticed that there were a number of comments from testers and peer reviewers on the terminology within the tool and the guidelines. Differences were especially highlighted between American and British terminology and the glossary has been modified to accommodate this. More detailed instructions and explanations have also been added to the online guidelines to ensure that the tool can be utilised internationally.

9.2 Workshop Testing

The tool has been tested and audited throughout the project and every time the tool was changed, it was tested. However, it was seen as impractical to distribute the tool after every minor alteration and it was felt that it would be chaotic to have such a large number of prototypes circulating when the tool was still in its development stages. Therefore, the second major testing period was tied into the final project workshop. This was convenient as there were a number of attendees from the UK, Europe and America.

The morning of the workshop was given to a presentation of the project and its outputs. In the afternoon, attendees were given copies of the tool and were asked to follow a basic risk assessment through from start to finish. Generally, the tool stood up well and a few minor issues that were highlighted during the trial, such as colour and terminology differences have since been addressed and rectified.

We would recommend a similar approach of presenting the risk management tool and theory, followed by sessions of testing the tool when training users within individual utilities.

9.3 Project Steering Group

It is important to note the invaluable contribution that the project steering group and peer reviewers have made to the development and testing of this tool and guidelines.

The tool and accompanying guidelines have been distributed for trial and review before every project steering group meeting, allowing them to be evaluated by a panel of peers at every stage.

It is probably in a large part due to this that the tool has stood up to questioning and evaluation so well at the workshop and the LESAM[6] conference in Lisbon.

9.4 Conclusions of Testing

Overall, the tool and its accompanying guidelines have withstood rigorous testing and appraisal. The response has been positive and both the tool and the guidelines have been shown to meet their initial brief.

The result is a detailed but generic approach which can be used by companies of various sizes and maturity, and a set of guidelines which will allow the user to operate the tool and also to understand the theory behind it.

10 Conclusions

- Overall the tool and its guidelines have withstood rigorous testing and appraisal by an international panel of experts.

- The tool has achieved what was set out, not only in the initial project brief, but also in the results of the survey of water utilities and the functional specification. The main aim was to produce a comprehensive tool and guidelines which could apply to utilities of all shapes and sizes. The results of the survey showed that although a detailed tool was required, it also needed to be simple to operate. The tool utilises a series of simple entry forms, which hide the detailed spreadsheet calculations behind and can be applied to utilities of various sizes.

- The guidelines have been positively received and are robust enough to accompany the tool which exemplifies the method. The survey of water utilities showed that the guidelines were seen as being equally important as the tool. Therefore, the guidelines produced were comprehensive and were combined into an interactive-style electronic format for an easier way to study a detailed subject.

- The cross sector approach, as taken in the literature search, has bred the potential for multi-sector application. The detailed but generic nature of the tool and guidelines give them the potential for use outside the water industry as the water utility specifics within the tool are all user-editable.

[6] International Water Association (IWA) event. Leading Edge conference on Strategic Asset Management (LESAM). October 17-19, 2007. Lisbon, Portugal.

- The project has been supported by an international panel of peers. As a result of this, the tool has the potential for application outside the UK. Risk management is a global concept and the tool is generic enough to be adapted for application in utilities of various sizes, maturity and nationality.

We recommend that, for the purpose of this project, the tool is applied to water utility assets, though it has the capacity for multi-sector use. It is highly recommended that the tool is used as a practical way of applying part of the risk management theory and that it is embedded into the overall corporate asset management system.

Appendix 1 Summary of literature reviewed and references

Risk management standards

Established standards and guidelines

Many countries already have established risk management standards. Before we could consider the framework for a risk management tool, it was important to take note of the standards applicable in the various GWRC member nations.

The standards have been split into two groups. In the first instance (Table 1), established risk management standards that are commonly applied have been listed. The tables describe the structural elements of the standards and how they are currently applied.

Table 2 shows standards that have influenced the development of risk management standards and principles, but which are not necessarily implemented within the water industry.

It was difficult to extract explicit steps from these standards as they have been formatted to provide guidance for good governance and have thus been incorporated in principle into the more established standards in Table 1. Many of these standards are also very industry-specific, being difficult to assimilate into water-industry standards.

List of Existing Risk Management Frameworks

Frameworks have been separated from methodologies based on the level of guidance that they provide. The methodologies discussed in Table 4 provide a comprehensive risk management process. The frameworks listed in Table 3 provide a further set of guidelines on how to implement the risk management processes described and are usually based, to some extent, on implementing a set of policies or regulations.

Table 3 lists the major components of the frameworks and also provides a description of their transparency and potential for use in the water industry.

The number of stages within the listed frameworks varied from three to 12 but included various other elements within them. Some were designed as regulatory assessments whilst others were self-assessment frameworks and guidelines. The Majority of the frameworks were designed to be used at a strategic or project level to govern day-to-day operational activities. A number of the frameworks were also based around predefined standards such as the AS/NZS 4360.

List of Existing Risk Management Methodologies

A number of risk management frameworks and tools were identified, that have been adopted in practice as well as a number of commercially available tools that are available for purchase. The most applicable frameworks and tools are summarised in Table 3 and Table 4 respectively.

Table 4 lists the most comprehensive methodologies that were reviewed. In this case, the main elements of the methodology are discussed and a description of the area and level at which they are implemented is provided to show their potential for use in the water industry.

The number of elements within the methodologies listed varies between four and nine. There is a focus on capital maintenance strategies and the prediction of asset failure. Most of the methodologies are intended for implementation at strategic and operational management levels.

List of Existing Risk Management Tools

Table 5 provides a brief analysis of the risk management tools that already exist globally, across all sectors. Details of their main means of assessment are listed, as well as a description of their potential for universal application and their current availability.

The number of stages within the tools varied between 3 and 9. However, further details of scoring and weighting techniques were difficult to ascertain due to the commercial nature of the tools and the resulting secrecy that comes with a patented product available for purchase.

Table 1: Established Risk Management standards

Standard/Organisation	Sector/ Country	Type	Elements	Measurement	Current Use
AUS/NZS: 4360 Standard for Risk Management	Water and general industry/ Australia and New Zealand (Internationally accepted)	Self-assessment based on national standard guidelines	7 main elements incorporated. 5 main steps to the process	Multiply Likelihood and Consequence values	Used at strategic, operational and event level. Level is classified in context at start of process
ISO/IEC 17799:2005 International Organisation for Standardisation	Information systems/Global	Risk management code of practice framework	Non-specific. Presented as a code of practice	Identify objectives and controls for risks in various sectors of information security	International standard of practice for business information systems
HM Treasury The Orange Book (Management of Risk-Principles and Concepts)	Risk Management/UK	Overview of a risk management model and guidelines for implementation	Stages not explicit but there are 4 main sections broken down into many smaller steps	Likelihood vs. Impact matrices followed by 5 ways to address risks and 4 ways to treat them	Aimed towards strategic, programme and operational levels
Federation of European Risk Management association (FERMA) Risk Management Standard	Risk Management/ Europe	Standards of risk management as defined by the members of FERMA	8 main elements of assessment incorporated into 7 steps	Assessment of probability and consequence within a 3x3 or 5x5 matrix	Published by AIRMIC, ALARM and IRM for use in general risk management for a number of different risks
CAN/CSA-Q850-97 Risk Management, guideline for decision-makers	Risk Management/ Canada	Standards and process of risk management	6 main stages to process, incorporating many elements	Risk analysis, evaluation and control based around main stages	Implemented across corporate management. Policy and program planning and operations
The Committee Of Sponsoring Organisations of the Treadway Commission (COSO). Enterprise Risk Management-integrated framework	Finance and Accounting/ USA	Standards of risk management and framework for implementation	8 interrelated components derived from management of organisation practices and integrated with the management process	Based around the 8 main components, at 4 different levels of business management	Internationally recognised standard. Based around strategy, operations, compliance and reporting

Table 2: Guidelines which have influenced established standards

Standard/Organisation	Sector/ Country	Type	Elements	Measurement	Current Use
Turnbull Guidance Financial Reporting Council. Internal Control, Revised Guidance	Business sector/ UK	Standards and principles of effective risk management	No specific elements to process. General guidance on managing risk in business practice	Controls are set up and reviewed periodically. Reporting is essential	Used as general guidance for business practice
Dey Report Guidelines for improved Corporate Governance	Business management/Canada	Guidelines for effective corporate governance	No explicit steps. Contains a series of recommendations on how to achieve effective governance	Management should monitor and review practice effectively	Used as general guidance principles for practice in management
Sarbanes-Oxley Act Signed into law by President Bush, 2002	Act of law in business principles/ USA	Act of law passed with reforms affecting corporate governance	Reporting of internal controls and deviation from them, including fraud	SEC-registered annual reports need to contain an Internal Control Report	An American Act to try and prevent future occurrences such as those in Enron
Committee on Corporate Governance Post Cadbury and Greenbury Report	Corporate, business and insurance sectors/ UK	Standards for good governance	No stages as such. General guidance on good corporate governance principles	A series of auditing practices would monitor governance	Used as guidance in corporate and business sectors
Basel II International Convergence of Capital Measurements and Capital Standards	Business and Finance sector/ France	Standards of risk management	4 main assessment steps based around key definitions	Complex formula and cost information. Compare losses to identify capital requirements through risk weight function treatment	Heavy use in the business, banking and finance sectors
PAS-55 Publicly Available Specification. The Woodhouse Partnership Ltd. and the British Institute	General Management/UK	Specification for good governance. Accredited	Non-explicit stages. Multiple methods of assessment within a single process	Top-down and bottom-up methods. Combine scorecards and matrices with monetary values	Already used by industry regulators (gas, electricity) as checklist for good governance

Table 3: Existing Risk Management Frameworks

Organisation/ Framework	Sector/Country	Type	Stages	Measurement	Scoring	Accessibility	Applicability
IAM International Infrastructure Management Manual	Asset Management/Global	Self assessment guidelines/ framework	4 main assessment stages/5 steps in framework	Risk rating table/Benefit-Cost Analysis/Gap Analysis	Based on criticality or severity and likelihood or probability of risk	Generic Principles. Taken from an internationally-available asset management manual	Based at a managerial/strategic level to be implemented in everyday practice
Ofwat/ UKWIR Capital Maintenance Planning: A Common Framework (CMPCF)	Water Industry/UK	Regulatory assessment framework	3 main stages comprising of 8 smaller stages and 18 key components	Historical analysis and forward-looking estimates of asset failure probability and consequences	Probability, consequences and costs of failure compared to intervention	UKWIR series of 4 documents aimed at the UK water industry	Regulatory governance from Ofwat. Objectives set for implementation at all levels of business but based on UK principles
Yorkshire Water Services Capital Maintenance: A Good Practice Guide (LEADA)	Water Industry/UK	YWS' framework for assessment	6 main assessment stages	Qualitative Impact Matrix, Asset Trees, Willingness-To-Pay studies, Risk Profile and Deterioration Modelling	Scores and weightings based on WTP, probability and cost are added to Trees	Part of the LEADA methodology belonging to YWS but based around Common Framework Principles	Based around the UK water industry, in the guise of a good practice guide for Capital Maintenance. WTP and customer-orientated
Defra Risk Management Strategy	Environment, Food and Rural industries/UK	Objective-driven guidelines	8 main management steps	Combine risk scores in a colour-coded matrix	Use of adjectives and assigned scores based on impact and likelihood. 4 mitigation options	Widely-available assessment process, fairly generic principles but based outside of the water industry	Aims and objectives set at a ministerial level, for implementation at a strategic level. Based on meeting objectives set
UKWIR/ WSAA Asset Management Workshop Presentation	Yarra Valley Water/Australia	Overview of YVW's standards-driven assessment tool	6 main steps in assessment process	Computer-based tool. Includes a Risk Register and risk characterisation and calculation. Includes a spend-optimisation tool	Business consequences, exposure and likelihood are scored and combined in a matrix. 10 yr NPVs are calculated	YVW compliance with Quality ISO9001, Environmental Management ISO14001, Occupational Health and Safety ISO4801 and Water Quality HACCP-9000	Based around structure of AS/NZS 4360 standard. Project management risks and corporate risks.

EPA Risk assessment principles and practices	Environmental Management/USA	Overview of risk assessment guidelines for objective-driven environmental decision-making	Not explicit, there are a number of methods to choose from	Variety of methods dependant on state of data. Range from simple look-up tables and screening to dispersion models and uncertainty analysis	Scale of severity of risk is measured and Monte Carlo method is used for uncertainty	Widely available guidelines but centred on the environment. Number of analysis techniques based on scale of risk and state of data	References drinking water standards so partly applicable. Based around strategic management and day-to-day implementation
Hazard Analysis Critical Control Point AWWARF: implementation for distribution system protection	Water quality assessment in the water industry/USA	Guidelines for implementation	12 main steps to process	Hazard identification and assessment by simple semi-quantitative scoring in tables	Scorings based on likelihood and severity estimates	HACCP process is widely recognised and publicised	Focus in the water industry is based on water quality only due to the principles of the HACCP
Causality Actuarial Society Overview of Enterprise Risk Management	Risk Management/ Canada-Global	Overview of self-assessment framework	7 iterative stages based on the AS/NZS 4360 standard	A lot of statistics-based analyses. Assessment based on historical data and direct assessment of likelihood of occurrence	Number of economic measures including value added and statistical risk measures and Monte Carlo for simulation	Published methodology is easily accessed and based around the AS/NZS 4360 standard	Works around hazard, financial, operational and strategic risks. Designed for all levels of business
New South Wales Treasury, Asset Management Committee Total Asset Management Manual and Guidelines	Government Agencies/Australia	Self-assessment guidelines	5 main assessment stages/5 steps to framework	Various. Fault Tree and Sensitivity Analyses for risk management. Scoring and matrices for general risk assessment	Risks are scored and categorised based on estimates of severity and probability	Widely-available but aimed towards compliance with the AS/NZS 4360 standard	Aimed at strategic management of government-owned assets. Purpose is to improve value from public assets

Table 4: Existing Risk Management Methodologies

Organisation/ Methodology	Sector/ Country	Type	Stages	Measurement	Scoring	Accessibility	Applicability
AMRAE and CLUSIF RM & RSSI (Risk Manager et responsible securite du systeme d'information)	Business and Security Risk Management/ France	Overview of general management process	4 main stages	General recording, monitoring and reviewing processes	Not explicit but based on money and various indicators such as Law, Financial and Image impacts	Article readily available but published in French	Applied to industrial and management service groups. Based at a managerial or strategic level
Institute of Risk Management A Risk Management Standard	Risk Management in the public sector/UK	Self-assessment methodology	7 main stages	Mainly qualitative with a lot of description	Based on assessments of likelihood and consequence	Published methodology. Only constraints are on data within standard	Uses terminology from ISO/IEC Guide 73. Strategic view of financial, operational, political, knowledge management and compliance risks
University of Cambridge Secretariat: Risk Management in Faculties, Schools and Departments	Risk Management in the University of Cambridge/UK	Overview of a Risk Management Process	9 main stages	Risk register and risk indicators used to prioritise risks within a matrix	Based on use of adjectives and multiplication of impact and severity (1-5) to create an overall severity score (out of 25)	Customers and environment are excluded as risks belong to an academic institution. Stages and examples of matrices are available	Management process at a corporate level, for implementation in day-to-day activities
Aqua. Journal of Water Supply Failure risk management of buried infrastructure	Water Industry/Canada	Overview of self-assessment process	5 main stages	Matrix characterisation and statistical processes based on fuzzy techniques	Fuzzy risk determined through algorithm from consequences and possibility of failure	Published methodology and statistical analysis procedure for fuzzy data	Based around water industry buried assets. Management at a strategic level
Office of Government Commerce Successful Delivery Toolkit	Risk Management in Commerce/UK	Overview of a Risk Management Process based on the Treasury's Orange Book	9 main stages	Risk Owners to update Risk Register based on qualitative and quantitative prioritisation and Risk Tolerance	Not explicit but based on both qualitative and quantitative measures	Published study based on the HM Treasury's Orange Book	Operational and Strategic risks in depth. Set at governmental level for use in strategic and day-to-day management
AWWARF Applicability of Reliability-Centred Maintenance	Water Industry/USA	Overview of maintenance-oriented methodology	7 main stages	Criticality analysis, consequence estimation and matrix-based analysis with quantification	Percentages, scorings, rankings and monetary figures	Published by AWWARF and easily accessible.	Focused on capital maintenance in the water industry. Strategic management on a day-to-day basis
Western Australian Government Risk Management Guidelines from Risk Cover	Risk Management in public sector bodies/Australia	Template of information requirements and risk management guidelines	4 main stages	Assessments based on consequence, likelihood, existing controls and risk acceptance criteria	Ratings and scorings based on risk reference tables. 3 mitigation options	Published guidelines available but lack of detail due to Risk Cover's commercial status	Management in the public body sector based on governmental recommendations

Institute for Research in Construction Decision Making and Investment Planning	Construction Management/ Canada	Series of 10 asset management documents, some focused completely on risk	4 main stages in risk management process	Assessment of condition and failure probabilities to create a renewal priority index	Options scored against severity and probability. 5 mitigation options	Published series of articles, widely-available	Little information on how to implement. Mainly theoretical, covers strategic and operational management

Table 5: Existing Risk Management Tools

Tool/Organisation /	Sector/Country	Stages	Measurement	Scoring	Applicability	Availability
Hazop v. 6.0	Risk Management/ UK and USA	5 stages	Use key words to brainstorm risks. Follow with worksheets and matrices imbedded in tool	Devised by creators, based around deviation from objectives set	Used mainly to identify health and safety issues arising at an operational level. Can be used to review procedures.	Demos are available for download. Full version must be integrated by company and is quoted on contact
MACRO and APT models The Woodhouse Partnership Ltd. And National Grid, Railtrack, IAM amongst others	Various sectors/Europe	3 main stages but number varies based on choices made during management process	Depends on type of risk assessed. Likelihood and estimated impact of risk calculated then mitigation considered	Calculate effects on profits each year as well as qualitative measures. Includes Whole-Life Costing and Net Present Value estimates	Considers all types of risk, including positive ones	Demo of model on website with examples of assets and risks to try. 7 suites of training modules and software tools available.
Cost-Risk Optimisation The Woodhouse Partnership Ltd.	Maintenance Studies/UK	5 main stages	Computer-based program where asset details, including failures and costs, are input	Various. Monetary values and frequency failures based partly on discounted cash flow methods	Emphasis on costing Reactive vs. Preventative maintenance procedures.	No example of tool but principles and methodology are available. CRO part of the MACRO tools
Risk Based Maintenance Benefit Cost Demo Hunter Water Corporation	Water industry/ Australia	5 elements to assessment process	Spreadsheet-based maintenance oriented risk assessment	Based on cost of risk before and after valued mitigation options	Emphasis on costing maintenance options, useful for specific risks	Unknown availability, spreadsheet provided by HWC
RiskBase 2000: Generic Version User's Guide by Risk Cover	Risk Management/Australia	5 main steps	Matrix and tables used to prioritise risks and cost-benefit analysis is included in the process	Scored and rated based on risk details input into the model	Based on compliance with AS/NZS 4360: 2004	Methodology is available but little detail on tool specifics due to commercial properties
MEHARI* V3 Risk Analysis Guide CLUSIF Club de La Securite d'Information Francais	Risk Management/ France	8 main steps with 7 assessment criteria after identifying the risk	Specific matrix employed for each criteria	Varies based on type of assessment matrix used	Used and approved by general asset managers and CLUSIF members	Methodology is patented and difficult to access detailed information. High level of detail in method itself
Oxand La Gestion Durable des Infrastructures	Risk Management/ France	7 main steps	Modelling of asset conditions, monitoring assets and simulating asset deterioration	Not explicit due to commercial nature	Used by EDF, ANDRA, French Autoroutes, TOTAL	Patented method No detailed information. High maintenance requirement.
Failure Modes and Effects Analysis (FMEA) Implementation by the US Coast Guard	Risk Management and its use by the Coast Guard/USA	9 main steps	Matrix and tabular assessment of specified principles	Various: Adjectives, scores and monetary values (cost of failure)	Principles of failure mode analysis; can be transferred into the water industry	Methodology is available but little detail due to commercial properties

Supporting bibliography

The tables below provide a summary of literature that was reviewed but not used in the detailed assessment described above. Either there was insufficient detail in the publication or there was sufficient overlap between it and other publications that were reviewed for it not to be necessary to include it in the main review.

Additional bibliography of methods

Organisation/ Methodology	Sector/ Country	Type	Stages	Measurement	Scoring	Accessibility	Applicability
Yorkshire Water Services Discolouration Risk Model	Water Industry/UK	Self-assessment through fault tree hierarchy	Not Explicit	3 scored and weighted risk trees; interruption, discolouration and hydraulic effects	Based on pair-wise comparison techniques. Combined with risk reduction % and expenditure	Focused on one principle. Conceived by YWS for their use	Based on operational risks, seen from a strategic level
Institute for Research in Construction Analytical Hierarchy Process	Construction Management/ Canada	Using paired-comparison techniques to determine relative importance of subjective values	Not explicit	Use of pair-wise comparison to determine importance of risk, cost and condition in capital maintenance strategies	Relative importance and severity of risk. Scored figures from a compiled scale are given	Presentation format but easily accessible	Little detail on actual application but based around strategic and operational asset management
Institute for Research in Construction Life Cycle Cost Analysis	Construction Management/ Canada	LCCA to assist municipal infrastructure decision-making	Not explicit	Quantitative measures based on discounted cash flow methods and cost-benefit analyses	Use of LCCA, Net Present Value and Future Value figures to aid decision-making	Detailed information not available but general process is accessible	Little detail due to commercial nature of figures, no examples of application
FERMA and IRM Emergent Risks	General Risk Management/ Europe	Overview of risk management process for emerging risks	3 main steps	Matrix-based assessment of impact and consequence	Scoring based on impact and consequence of risk	Accessible methodology published by FERMA and IRM	Detailed methodology but concentrated on emergent risks
Institute for Research in Construction Risk-based life cycle assessment and multi-criteria decision-making	Construction Management/ Canada	Life Cycle analysis and risk-based multi-criteria selection processes combined with a look to cleaner technologies	Not explicit. 2 processes are discussed separately	2 processes based around one concept: implementing green technology into decision-making	Weighted policy alternatives, and sensitivity weighting. Uncertainty measured using probability theory and fuzzy set theory	Main steps of methodology can be seen easily	Green management in the construction industry. Little detail on implementation; guidelines or examples
The Woodhouse Partnership Ltd. Joined up Asset Management	Risk Management/ Europe	Overview of a Criticality Ranking technique	Not explicit but based around the assessment of risks through links with KPIs	Risk assessment based on frequency and consequences, which are scored based on KPI priorities	Criticality weighted scoring, driven by prioritisation of consequences around KPIs	Published methodology and case studies of its use	Based on a strategic level management plan. Considers operational risks mainly with an emphasis on customer service

AMRAE and CLUSIF RM & RSSI (Risk Manager et responsible securite du systeme d'information)	Business and Security Risk Management/ France	Overview of general management process	4 main stages	General recording, monitoring and reviewing processes	Not explicit but based on money and various indicators such as Law, Financial and Image impacts	Article readily available but published in French	Applied to industrial and management service groups. Based at a managerial or strategic level
Institute of Risk Management A Risk Management Standard	Risk Management in the public sector/UK	Self-assessment methodology	7 main stages	Mainly qualitative with a lot of description	Based on assessments of likelihood and consequence	Published methodology. Only constraints are on data within standard	Uses terminology from ISO/IEC Guide 73. Strategic view of financial, operational, political, knowledge management and compliance risks
University of Cambridge Secretariat: Risk Management in Faculties, Schools and Departments	Risk Management in the University of Cambridge/UK	Overview of a Risk Management Process	9 main stages	Risk register and risk indicators used to prioritise risks within a matrix	Based on use of adjectives and multiplication of impact and severity (1-5) to create an overall severity score (out of 25)	Customers and environment are excluded as risks belong to an academic institution. Stages and examples of matrices are available	Management process at a corporate level, for implementation in day-to-day activities
Office of Government Commerce Successful Delivery Toolkit	Risk Management in Commerce/UK	Overview of a Risk Management Process based on the Treasury's Orange Book	9 main stages	Risk Owners to update Risk Register based on qualitative and quantitative prioritisation and Risk Tolerance levels	Not explicit but based on both qualitative and quantitative measures	Published study based on the HM Treasury's Orange Book	Operational and Strategic risks looked at in more depth. Set at a governmental level for implementation in strategic and day-to-day management
Aqua. Journal of Water Supply Failure risk management of buried infrastructure	Water Industry/Canada	Overview of self-assessment process	5 main stages	Matrix characterisation and statistical processes based on fuzzy techniques	Fuzzy risk determined through algorithm from consequences and possibility of failure	Published methodology and statistical analysis procedure for fuzzy set	Based around water industry buried assets. Management at a strategic level
AWWARF Applicability of Reliability-Centred Maintenance	Water Industry/USA	Overview of maintenance-oriented methodology	7 main stages	Criticality analysis, consequence estimation and matrix-based analysis with quantification	Percentages, scorings, rankings and monetary figures	Published by AWWARF and easily accessible.	Focused on capital maintenance in the water industry. Strategic management on a day-to-day basis

Institute for Research in Construction Decision Making and Investment Planning	Construction Management/ Canada	Series of 10 asset management documents, some focused completely on risk	4 main stages in risk management process	Assessment of condition and failure probabilities to create a renewal priority index	Options scored against severity and probability. 5 mitigation options	Published series of articles, widely-available	Little information on how to implement. Mainly theoretical, covers strategic and operational management
AWWARF Risk Communication for emerging contaminants	Water industry/ USA	Guidance for developing effective risk management strategies	8 main steps to follow	Assessment of contaminants	Not explicit, little detail	Published by AWWARF but little detail within	Based in the water industry around guidance for management
STP Nuclear Operating Company Risk-informed reliability-focused decision analysis	Nuclear power industry/USA	Overview of process guidelines	3 main phases to follow	Ranking and prioritization of proposed changes to equipment. Incorporate data into cost-benefit analyses	Estimated price of replacement recorded	Published methodology and case studies of successful implementation within industry	Based on proposed changes to balance-of-plant, effectively a capital maintenance plan. Management at a strategic level
STP Nuclear Operating Company Risk-informed reliability-focused decision analysis	Nuclear power industry/USA	Overview of process guidelines	3 main phases to follow	Ranking and prioritization of proposed changes to equipment. Incorporate data into cost-benefit analyses	Estimated price of replacement recorded	Published methodology and case studies of successful implementation within industry	Based on proposed changes to balance-of-plant, effectively a capital maintenance plan. Management at a strategic level
AWWARF and EPA Integrating UV Disinfection into existing water treatment plants	Water industry/ USA	Overview of different approaches, analysing risk in multi-barrier treatment is highlighted here	7 main steps in process, based on FMEA	ranking by severity/frequency /detection in matrix/table	risk of failure, contamination, impact to socio-environmental receptors	Published methodology and details on FMEA and regret analyses. FMEA is more appropriate	Quite specific to health risks but applicable at strategic and operational level
World Economic Forum Global Risk 2007, A global risk network report	Risk Management/ Switzerland-Global	Overview of recent advances in risk management and some global standards	Steps not explicit	Assessment of the severity of risk, no specifics of measurement format	Likelihood and severity of risk measured and impact in US$ is estimated	Published in English language, accessible information on a general methodology	Based around 'core risks' which cover most business considerations
Public Risk Management Organisation (PRIMO) Une association dédiée a la gestion dans le secteur public local	Risk Management/ France-Europe	Overview of current risk management practice in Europe	N/A	Assessment of preparedness for risks and awareness of risks	Specifics not mentioned. Interesting study into Europe's approach to risk management. 860 interviews and 609 analysed	Published in French with English translation available. Results of interviews shown graphically	A general overview, no specific methodology presented

AWWARF Financial and Economic Optimization of Water Main Replacement	Capital Maintenance/ USA and Australia	Review of Hunter Water data for past 4 years with risk management concepts	3 main elements to process	Failure analysis, econometric modelling and maintenance and contingency planning	Probability multiplied by consequence to give risk by per annum expenditure	Easily accessible, published by AWWARF	Aimed at capital maintenance planning initiatives
Virginia Transportation Council Risk-based asset management methodology for highway infrastructure systems	Highway maintenance/ USA	Risk-based highway maintenance repairs with a focus on intelligent decision-making	4 main stages	Risks are classified by type and severity and examples are used to produce a consequence scale	Scored by priority and effect and weighted according to probability and consequence	Methodology and details of scoring theory are accessible	Aimed at capital maintenance planning initiatives
AWWARF Quantifying Public Health Risk Reduction Benefits	Public health industry/ USA	Overview of quantification of reduced health (cancer) risks	7 main stages of assessment	Top-down and bottom-up dual modelling approach. Monte Carlo used for uncertainty. WTP studies for reduced health risk	Probability and population exposed with cost. Whole Life Costing ideas	Easily accessible, published by the AWWARF	Based in the health industry but ideas and methods are applicable in the water industry
Volunteering Australia and The Commonwealth Dept. of family and community services Running the Risk?	Risk Management in non-for profit organisations	Step-by-step account methodology and examples of tools	4 main stages of risk management and 4 mitigation options	Estimates of risks fed into tables and matrices	Risks based on likelihood and consequence estimates	Easily accessible methodology and steps shown in detail	Aimed towards volunteer sectors and not-for-profit organisations
US EPA Risk Characterisation Handbook	Drinking water focus/ USA	Overview of risk assessments for a variety of contaminants	4 stage paradigm	Case studies shown at end, after assessment through loading estimations	Concentrations of contaminants in water	Easily accessible and very detailed case studies along with method	Focuses on health risks as a result of contaminant-loading. Very specific
Orange County Sanitation District Condition assessment: should you risk it?	Sanitation/USA	Overview of a risk-based condition assessment	3 main stages	Assessments of probability and consequence of failure	Looks at the probability and resulting cost of asset failure	Published case study of methodology design and implementation	Little detail of operating abilities

Additional Bibliography of Frameworks

Organisation/ Framework	Sector/Country	Type	Stages	Measurement	Scoring	Accessibility	Applicability
IAM International Infrastructure Management Manual	Asset Management/Global	Self assessment guidelines/framework	4 main assessment stages/5 steps in framework	Risk rating table/Benefit-Cost Analysis/Gap Analysis	Based on criticality or severity and likelihood or probability of risk	Generic Principles. Taken from an internationally-available asset management manual	Based at a managerial/strategic level to be implemented in everyday practice
Ofwat/ UKWIR Capital Maintenance Planning: A Common Framework (CMPCF)	Water Industry/UK	Regulatory assessment framework	3 main stages comprising of 8 key components	Historical analysis and forward-looking estimates of asset failure probability and consequences	Probability, consequences and costs of failure compared to intervention	UKWIR series of 4 documents aimed at the UK water industry	Regulatory governance from Ofwat. Objectives set for implementation at all levels of business but based on UK principles
AWWARF Risk Analysis Strategies for Credible and Defensible Utility Decisions	Water industry/USA, Canada and UK	Self-assessment and benchmarking guidelines	Not explicit, article presents various tools and methodologies that are available	Various methodologies, tools and frameworks are listed	GIS-based data and an accurate data set are highlighted. No specifics as various methods are listed	Lists of existing methods from a previous literature search. Article itself is widely-accessible. Listed literature varies	Recommendation that water utilities embed risk management within their organizational cultures to become more strategic and forward-thinking
Yorkshire Water Services Capital Maintenance: A Good Practice Guide (LEADA)	Water Industry/UK	YWS' framework for assessment	6 main assessment stages	Qualitative Impact Matrix, Asset Trees, Willingness-To-Pay studies, Risk Profile and Deterioration Modelling	Scores and weightings based on WTP, probability and cost are added to Trees	Part of the LEADA methodology belonging to YWS but based around Common Framework Principles	Based around the UK water industry, in the guise of a good practice guide for Capital Maintenance. WTP and customer-orientated
UKWIR/ WSAA Asset Management Workshop Presentation	Yarra Valley Water/Australia	Overview of YVW's standards-driven assessment tool	6 main steps in assessment process	Computer-based tool. Includes a Risk Register and risk characterisation and calculation. Includes a spend-optimisation tool	Business consequences, exposure and likelihood are scored and combined in a matrix. 10 yr NPVs are calculated	YVW compliance with Quality ISO9001, Environmental Management ISO14001, Occupational Health and Safety ISO4801 and Water Quality HACCP-9000	Based around structure of AS/NZS 4360 standard. Project management risks and corporate risks.
EPA Risk assessment principles and practices	Environmental Management/USA	Overview of risk assessment guidelines for objective-driven environmental decision-making	Not explicit, there are a number of methods to choose from	Variety of methods dependant on state of data. Range from simple look-up tables and screening to dispersion models and uncertainty analysis	Scale of severity of risk is measured and Monte Carlo method is used for uncertainty	Widely available guidelines but centred on the environment. Number of analysis techniques based on scale of risk and state of data	References drinking water standards so partly applicable. Based around strategic management and day-to-day implementation
Hazard Analysis Critical Control Point AWWARF: implementation for distribution system protection	Water quality assessment in the water industry/USA	Guidelines for implementation	12 main steps to process	Hazard identification and assessment by simple semi-quantitative scoring in tables	Scorings based on likelihood and severity estimates	HACCP process is widely recognised and publicised	Focus in the water industry is based on water quality only due to the principles of the HACCP

New South Wales Treasury, Asset Management Committee Total Asset Management Manual and Guidelines	Government Agencies/Australia	Self-assessment guidelines	5 main assessment stages/5 steps to framework	Various. Fault Tree and Sensitivity Analyses for risk management. Scoring and matrices for general risk assessment	Risks are scored and categorised based on estimates of severity and probability	Widely-available but aimed towards compliance with the AS/NZS 4360 standard	Aimed at strategic management of government-owned assets. Purpose is to improve value from public assets
AWWARF Compliance Guidance and Model Risk Management Program for Water Treatment Plants	Water industry/ USA	Guidance for establishing risk management plans	4 main stages but difficult to extract exact steps from large article	Asset inventory plays key part. Risk of exposure is measured and ranking of priorities is used	Risk of exposure scored and ranked. Difficult to extract further details	Published manual is accessible but guide itself is very long and difficult to extract data from	Methodology aimed towards management practice. Risk of exposure would translate as risk of failure
Defra Risk Management Strategy	Environment, Food and Rural industries/UK	Objective-driven guidelines	8 main management steps	Combine risk scores in a colour-coded matrix	Use of adjectives and assigned scores based on impact and likelihood. 4 mitigation options	Widely-available assessment process, fairly generic principles but based outside of the water industry	Aims and objectives set at a ministerial level, for implementation at a strategic level. Based on meeting objectives set

Additional Bibliography of Tools

Organisation/Tool	Sector/Country	Stages	Measurement	Scoring	Applicability	Availability
Hazop v. 6.0	Risk Management UK/USA	5 stages	Use key words to brainstorm risks. Follow with worksheets and matrices imbedded in tool	Devised by creators, based around deviation from objectives set	Used mainly to identify health and safety issues arising at an operational level. Can be used to review procedures.	Demos are available for download. Full version must be integrated by company and is quoted on contact
MACRO and APT models The Woodhouse Partnership Ltd. And National Grid, Railtrack, IAM amongst others	Various sectors/Europe	3 main stages but number varies based on choices made during management process	Depends on type of risk assessed. Likelihood and estimated impact of risk calculated then mitigation considered	Calculate effects on profits each year as well as qualitative measures. Includes Whole-Life Costing and Net Present Value estimates	Considers all types of risk, including positive ones	Demo of model on website with examples of certain assets and risks to try-out. 7 suites of training modules and software tools available in total
Cost-Risk Optimisation The Woodhouse Partnership Ltd.	Maintenance Studies/UK	5 main stages	Computer-based program where asset details, including failures and costs, are input	Various. Monetary values and frequency failures based partly on discounted cash flow methods	Large emphasis on costing maintenance procedures. Reactive vs. Preventative costs	No specific example of tool but principles and methodology are available. CRO tool would be part of the MACRO tool

Risk Based Maintenance Benefit Cost Demo Hunter Water Corporation	Water industry/ Australia	5 elements to assessment process	Spreadsheet-based maintenance oriented risk assessment	Based on cost of risk before and after valued mitigation options	Emphasis on costing maintenance options, useful for specific risks	Unknown availability, spreadsheet provided by HWC
RiskBase 2000: Generic Version User's Guide by Risk Cover	Risk Management/Australia	5 main steps	Matrix and tables used to prioritise risks and cost-benefit analysis is included in the process	Scored and rated based on risk details input into the model	Based on compliance with AS/NZS 4360: 2004	Methodology is available but little detail on tool specifics due to commercial properties
MEHARI* V3 Risk Analysis Guide CLUSIF Club de La Sécurité d'Information Français	Risk Management/ France	8 main steps with 7 assessment criteria after identifying the risk	Specific matrix employed for each criteria	Varies based on type of assessment matrix used	Used and approved by general asset managers and CLUSIF members	Methodology is patented and difficult to access detailed information. High level of detail in method itself
Failure Modes and Effects Analysis (FMEA) Implementation by the US Coast Guard	Risk Management and its use by the Coast Guard/USA	9 main steps	Matrix and tabular assessment of specified principles	Various: Adjectives, scores and monetary values (cost of failure)	Principles of failure mode analysis which can be transferred into the water industry	Methodology is available but little details of actual method and calculations due to commercial properties
Oxand La Gestion Durable des Infrastructures	Risk Management/ France	7 main steps	Modelling of the of asset conditions, monitoring of the asset and simulation of asset deterioration	Not explicit due to commercial nature	Used by EDF, ANDRA, French Autoroutes, TOTAL	Method is patented and difficult to access detailed information about. High maintenance required
NorthGate's STRUMAP Dwr Cymru Welsh Water Application	Decision-support for network infrastructures UK	Not explicit	Identify links between incidents and network problems to prioritise maintenance plans	Exact details unknown, based on capital maintenance principles	Used by 250 people in 24 organisations, not solely the water industry	Little detail available due to its commercial nature
Orchid software Risk Management Group, Sussex Police application	Risk Management in Sussex Police/UK	13 main stages of assessment	Prioritise risks in a colour-coded matrix based on estimates of impact and likelihood	Exact details unknown, Risk Controller is assigned to monitor	Used by a number of industries, concept of risk used is not very specific	Little detail available due to commercial properties
CRAMM Overview of CRAMM and its use by SIEMENS	Security Risk Management/Global	3 main stages	Trees, Matrices and other unspecified processes. Use of a ready-built database is implied	Mainly qualitative due to nature of security risks. Adjectives and monetary values	Compliance with BS7799: 2005. Preferred security risk management system by a number of big-name organisations	Little detail of actual tool due to commercial nature
APT-SPARES The Woodhouse Partnership Ltd.	Slow moving spares evaluation/UK	Not explicit	Item-by-item or batch-review process to highlight spares to be kept	Qualitative and quantitative	Can assess risk of asset failure such as pump failure but quite specific	Fact sheets and case studies of implementation but little detail of tool itself

APT-MAINTENANCE The Woodhouse Partnership Ltd.	**Risk Management in Railtrack/UK**	**Not explicit**	**Rule-based task analysis, systematic failure modes and quantitative cost/risk modelling**	**Various methods, little detail given**	**Based around Capital Maintenance principles**	**Case study and fact sheets but little detail on the tool itself**
Futron Futron Integrated Risk Management Application (FIRMA)	**General Risk Management/ USA**	**Unknown**	**Web-enabled application database with fault trees and failure history data**	**Risk of failure measured but no specifics available**	**Fairly generic in risk management concepts but little detail**	**Little data unless purchased**
Hazop Hazop application by the US Coast Guard	**Coast Guard/ USA**	**5 main steps**	**Use Hazop worksheets to compile record**	**Scoring not specified**	**Hazard analysis at operations level**	**Little detail due to commercial nature**
Q-Warp Decision-support tool by Institute for Research in Construction	**Water distribution systems/ Canada**	**Not explicit**	**Can perform sensitivity analyses and can generate multiple risk scenarios**	**Can handle qualitative and quantitative data.**	**Based around capital maintenance objectives**	**Some details of structure and methodology but limited due to commercial nature**
Petroleos De Venezuela SA/ The Woodhouse Partnership Ltd. Combined Case Study	**Risk Management in an Oil and Gas Company/UK and South America**	**Not explicit**	**Route-cause analysis and cost-risk optimisation methods amongst others**	**Qualitative and Quantitative. Calculations of production losses to net benefits**	**Risk of failure and preventative vs. proactive maintenance costs are the main themes**	**Case study is reviewable but little detail of methodology implemented**

Additional Commercial Tools

The following commercial tools are listed for reference. These tools were selected from a large number, to show the scope of pricing of tools currently available.

URL link	Accessibility	Price of purchase
http://www.horwathrisk.com/	**Brief PDF available, contact for more info.**	**Unknown**
http://www.myriskmanagementplan.org/	**Short demo covering basics is available.**	**Unlimited use by one company is $139**
http://nonprofitrisk.org/cares/cares.htm	**For non-profit organisations only.**	**$89 unlimited use**
http://www.sharetradingeducation.com/BooksEbooksToolsHomeStudyChartingData/AtkinsonMoneyRiskManagementPortfolioTools.aspx	**Available for purchase, trial available if registered. Might have to be a trader to access.**	**$125 for money and risk bundle (UK currency version)**
http://www.riskshield.net/Product.aspx?item=5	**Contact for full version, trial available if registered.**	**Free trial, contact for full version pricing.**
http://www.riskshield.net/Product.aspx?item=11	**Contact for full version, trial available if registered.**	**Free trial, contact for full version pricing.**
http://www.palisade.com/risk/default.asp	**Free trial available, order full version.**	**£595-£1380 for full version. Free quick trial version and PDF downloads.**
http://www.qudos-software.co.uk/riskinfo.html?gkey=risk%20management%20tool	**Zip file tour of program; free, no registration required.**	**Pricing info available on website.**
http://www.quantrix.com/r-section-2	**Demo, trial and full version available as well as FAQs and description of features etc.**	**$990 professional edition.**
http://www.method123.com/risk-management-kit.php	**Available to buy kit and other project kits.**	**$19 for risk management kit alone. Project management kits vary ~$295.**

Additional References

Country	Title	Institute/Organisation	Author	Date
USA/Australia	Asset Management: A Risky Business!	Brown and Caldwell (consultants) with Hunter Water (Australia)	Harlow, Ken and Young, Kevin	unk
USA/Australia	What's so different about Australian Asset Management?	Seattle Public Utilities	Kelly, Elizabeth	Mar 2005
Australia	A risk-based approach to asset management: wastewater overflows in the conveyance systems	Water Corporation, Perth	Wisdom, S and Cargeeg, G	unk
Australia	Asset Management worldwide: the lessons learned	Water Asset Management International	Byrne, Roger	Dec-05
Australia	New developments in investment planning and project evaluation	Water Asset Management International	Cox, James	Jun-05
USA	A national asset management steering council: the time has come	Water Asset Management International	Causey, Paul	Sep-05
USA	WATER INFRASTRUCTURE Comprehensive Asset Management Has Potential to Help Utilities Better Identify Needs and Plan Future Investments	US General Accounting Office (GAO)	Various	May 2004
USA	Overview of Infrastructure Asset Management and Risk-Based Investment Decisions - a view from both sides of the Atlantic Ocean	AWWA	Aikman, Ian; Doherty, Dennis	unk
USA	Risk and Opportunity in Upgrading the U.S. Drinking Water Infrastructure System	University of Virginia	Rogers, J and Garrick, L	Unk, 2001 or later
Canada	Decision models to prioritize maintenance and renewal alternatives	Institute for Research in Construction	Vanier, D	June 2006
Canada	A Framework for Municipal Infrastructure Management for Canadian Municipalities	Institute for Research in Construction	Vanier, D	September 2006
Canada	Innovations in Infrastructure Asset Management: The Need for Business Process Re-engineering	Institute for Research in Construction	Vanier, D	unk
Canada	Chapter 7: Towards Sustainable Municipal Infrastructure Asset Management (from Handbook on Urban Sustainability	Institute for Research in Construction	Vanier, D	unk
Canada	Why industry needs asset management tools	Institute for Research in Construction	Vanier, D	Jan 2001
Canada	Municipal Infrastructure Investment Planning (MIIP) Report: A Primer on Municipal Infrastructure Asset Management	Institute for Research in Construction	Vanier, D	May 2004

USA	Risky business: two case studies in asset risk management	Water Asset Management International	Harlow, Kenneth	Mar-05
UK	Risky Business?	Water Services	Pollard, S	Vol. 105, no. 5, [np]. Oct 2002
New Zealand	New Zealand Risk Management Guidelines	Civil Aviation Authority	Unk	November 2004
UK	The real cost of Asset Information: How better costs less	Institute of Asset Management	R Wallsgrove, Sarras	unk
UK	Asset Management Benchmarking to Deliver Sustainable Improvements	unk	R Byrne, R Edwards and J Wilson	unk
UK	Reliability-based maintenance and condition monitoring	Asset Management Consulting Ltd (AMCL) and Network Rail	M C J Pilling and L Wilkinson	unk
UK/Europe Group	Can we delay the replacement of this plant?	The Woodhouse Partnership Ltd.	Colin Labouchere	2000
USA	Asset Management: complex problems require sophisticated analytical approaches	Water Asset Management International	Vanrenterghem-Raven, Annie	March 2006
UK	Closing the loop: sustainable implementation of improvements.	The Woodhouse Partnership Ltd.	John Woodhouse	2004
UK/Global. S. African Case Study	SASOL experiences in cost/risk optimisation	The Woodhouse Partnership Ltd. And SASOL SSF pty.	John Woodhouse and Willie Le Roux	2003
UK	MAINTEC 2000: Risk-based decisions at the heart of a modern Asset Management Structure.	The Woodhouse Partnership Ltd.	Harvey Jones and Andrew Bower	2000
UK	Managing Maintenance in the National Grid Company. An Overview of maintenance management and a practical application of MACRO in the electricity supply industry.	The Woodhouse Partnership Ltd. (model) and The National Grid Company (case study).	Peter Jay and Terry McCormick	unk
UK	What shutdowns, why and when?	The Woodhouse Partnership Ltd.	John Woodhouse	2000
USA	Balancing Multiple Water Quality Objectives	AWWARF	Phillippe A. Daniel	1998
USA	Costs of Infrastructure Failure	AWWARF	Various	2002
USA	Estimating Health Risks From Infrastructure Failures	AWWARF	Various	2006
Australia	6: Risk management tools and activities	NSW Department of State and Regional Development	unk	unk
USA	Framework for developing water reuse criteria with reference to drinking water supplies.	AWWARF	Various	2003-04

USA	Linking water utility data and residences in the national birth defects prevention study.	AWWARF	Various	2004
USA	A preliminary assessment of water utility monitoring needs under the safe drinking water act.	AWWARF	Various	1989
USA	Security Risk Assessment Methodology for Transmission	Sandia National Laboratories	Sandia National Laboratories	unk
UK	The CAA Safety Risk Management Process	Civil Aviation Authority	Civil Aviation Authority	unk
UK	Accounting, Hybrids and the Management of Risk	The centre for analysis of risk and regulation: An ESRC Research Centre	Miller, Kurunmaki and O'Leary	Nov-06
UK	The Attractions of Risk-based Regulation: accounting for the emergence of risk ideas in regulation	ERSC Centre for Analysis of Risk and Regulation	B. M. Hutter	Mar-05
USA	Risk Communication in Action: Environmental Case Studies	US EPA	EPA	Sep-05
USA	2D Monte Carlo versus 2D Fuzzy Monte Carlo health risk assessment	Journal: Stochastic Environmental Res Risk Assessment	Kental and Aral	2005
USA	Characterizing Risk	US Coast Guard	USCG	unk
UK	An Asset Management Model for UK Railway Safety-Literature Review and Discussion Document	Health and Safety Laboratory	Brownless, G.	2005
UK/United Nations	Financial Risk Management Instruments for Renewable Energy Projects. Summary Document.	UNEP and SEFI	UNEP	2004
UK	Risk Analysis and Management in the Water Utility Sector-A Review of Drivers, Tools and Techniques	Institution of Chemical Engineers, Trans IChemE	Pollard, S. J. T et al.	2004
UK	Risk Register Management	Strategic Risk/Sussex Police	Linda Manley	unk

Appendix 2 Survey Questionnaire and Graphs of Results

Zoomerang Survey Results

Global Water Research Coalition: Tool for Risk Management of Water Utility Assets
Response Status: Completes
Filter: No filter applied
Jun 18, 2007 5:25 AM PST

Your Details (please note the statement on confidentiality on the Welcome page)

1. Your Name
29 Responses
2. Your e-mail
29 Responses
3. Job/role title
32 Responses
4. Name of Utility
32 Responses
5. Country
32 Responses

Please tell us about your utility

6. Does your utility manage:			
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**Yes**	**No**
Water distribution assets?	Water distribution	31	0
	Water distribution	100%	0%
Water treatment works?	Water treatment	28	2
	Water treatment	93%	7%
Sewer networks?	Sewers	20	9
	Sewers	69%	31%
Sewage treatment works?	Sewage treatment	20	9
	Sewage treatment	69%	31%

7. Size of Utility (please answer to the best of your knowledge or state 'unknown')
30 Responses

8. Ownership (please select one)				
State (government) owned and managed	State (government) owned and managed		5	17%
State owned, managed under contract	State owned, managed under contract		2	7%
State owned, managed by state owned company	State owned, managed by state owned company		5	17%
Privately owned and managed	Privately owned and managed		8	28%
Other, please specify	Other, please specify		9	31%
Total	**Total**		29	100%

9. Regulatory Regime (please select one)					
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**Direct regulation by Government**	**Regulated by local municipality**	**Specialist sector regulator**	**N/A**
Price Regulation	Price Regulation	6	12	10	2
	Price Regulation	20%	40%	33%	7%
Water Quality Regulation	Water quality regulation	21	1	8	0
	Water quality regulation	70%	3%	27%	0%
Environmental Regulation	Environmental regulation	20	3	7	0
	Environmental regulation	67%	10%	23%	0%

The asset management challenge

10. What is your main reason for investment? Please rank the list below in order, where 1 = primary reason.							
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**1**	**2**	**3**	**4**	**5**	**6**
Replacing existing assets to maintain the same standards and quantities	Maintenance	15	6	2	1	2	1
	Maintenance	56%	22%	7%	4%	7%	4%
Improving water/wastewater quality standards	Improving quality	8	9	4	3	2	2
	Improving water/wastewater quality standards	29%	32%	14%	11%	7%	7%
Improving availability of water/increasing network coverage	Water availability and coverage	2	5	10	5	5	0
	Improving availability of water/increasing network coverage	7%	19%	37%	19%	19%	0%
Improving wastewater network coverage	Sewerage availability and coverage	0	4	3	6	2	7
	Improving wastewater network coverage	0%	18%	14%	27%	9%	32%
Coping with an increasing population	Population growth	3	1	8	7	9	0
	Coping with an increasing population	11%	4%	29%	25%	32%	0%
Coping with increasing consumption per-capita	Increasing consumption per-capita	1	0	1	6	7	13
	Coping with an increasing consumption per-capita	4%	0%	4%	21%	25%	46%

11. Overall, how would you rate your current level of service? (With respect to standards on quality, availability etc.)						
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**disagree strongly**	**disagree**	**neither agree or disagree**	**agree**	**agree strongly**
We need to invest in order to meet the standards we are set	Need to invest to meet standards	1	6	6	11	5
	Need to invest to meet standards	3%	21%	21%	38%	17%
We currently exceed the standards we are set	Currently exceed standards	0	3	10	13	4
	Currently exceed standards	0%	10%	33%	43%	13%
We fail to meet the standards at a few of our sites	Fail to meet standards at a few sites	6	8	2	12	1
	Fail to meet standards at a few sites	21%	28%	7%	41%	3%
We are concerned about meeting standards in the future	Concerned about meeting future st'ds	1	5	5	15	3
	Concerned about meeting future st'ds	3%	17%	17%	52%	10%
We are not currently set specific standards	Not set specific standards	18	5	3	2	1
	Not set specific standards	62%	17%	10%	7%	3%

Your utility's current approach to asset management planning

12. How is the total expenditure determined? (Please select the most relevant option.)				
We are told a budget and have to prioritise investment within it			4	14%
We propose a budget based on previous expenditure			3	11%
We propose a budget based on an assessment of future needs			21	75%
Total			28	100%

13. Priority for replacing existing assets is determined by: (Select all that apply)				
The age of the existing assets			16	55%
The recent breakdown history of the assets			21	72%
Recent customer service failures caused by the assets			23	79%
An assessment of the future likelihood of asset breakdown, even if they have not yet broken down			21	72%
An assessment of the future customer service risk, even if service is currently good			21	72%
Other, please specify			6	21%

14. Construction of additional assets is determined by: (Select one)				
Government (or local government) decisions to provide additional capacity	Government (or local government) decisions to provide additional capacity		1	3%
Our own assessment of future needs, such as population growth	Our own assessment of future needs, such as population growth		24	83%
Other, please specify	Other, please specify		4	14%
Total			29	100%

15. Do you normally take into account customer willingness to pay for investment in changing levels of service?				
Yes			21	72%
No			8	28%
Total			29	100%

16. Do you normally take into account affordability to customers when considering your investment plan?				
Yes	Yes		28	97%
No	No		1	3%
Total			29	100%

Data holding and linkages

17. Data on fixed assets (e.g. an asset register):				
Are not kept up-to-date	Are not kept up-to-date		6	21%
Provide full details of assets as-built	Provide full details of assets as-built		6	21%
Provide full details of assets as-built, plus modifications since construction	Provide full details of assets as-built, plus modifications since construction		17	59%
Total			29	100%

18. Please comment on how these data are recorded:						
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**Are not kept in any form of database**	**Are mostly stored on paper**	**Are mostly stored on local electronic systems**	**Are mostly stored on central corporate systems**	
on fixed assets:	On fixed assets	0	1	4	24	
	On fixed assets	0%	3%	14%	83%	
on operational activities (repairs, maintenance etc.):	On operational activities (repairs, maintenance etc.)	0	1	8	20	
	On operational activities (repairs, maintenance etc.)	0%	3%	28%	69%	
on level of service (e.g. pressure problems, water quality):	On level of service (e.g. pressure problems, water, quality)	0	2	10	17	
	On level of service (e.g. pressure problems, water,	0%	7%	34%	59%	

	quality)					
financial data:	Financial data	0	0	3	26	
	Financial data	0%	0%	10%	90%	
19. Data on levels of service:						
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**Strongly disagree**	**Disagree**	**Neither agree or disagree**	**Agree**	**Strongly agree**
are mostly not linked to asset data in any way	are mostly not linked to asset data in any way	4	13	5	5	2
	are mostly not linked to asset data in any way	14%	45%	17%	17%	7%
are mostly linked to asset data through manual review of trends	through manual review of trends	5	8	7	8	0
	through manual review of trends	18%	29%	25%	29%	0%
are mostly linked to asset data through geographical analysis (e.g. proximity mapping between databases)	through geographical analysis (e.g. proximity mapping between databases)	6	8	2	10	3
	through geographical analysis (e.g. proximity mapping between databases)	21%	28%	7%	34%	10%
are mostly linked directly to asset data through joins between databases	through joins between databases	4	9	8	5	3
	through joins between databases	14%	31%	28%	17%	10%

20. Data on financial impacts:						
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**strongly disagree**	**disagree**	**neither agree or disagree**	**agree**	**strongly agree**
are mostly not linked to asset data in any way	Are mostly not linked to asset data in any way	2	7	9	8	3
	Are mostly not linked to asset data in any way	7%	24%	31%	28%	10%
are mostly linked to asset data through manual review of trends	through manual review	4	7	9	9	0
	through manual review	14%	24%	31%	31%	0%
are mostly linked to asset data through geographical analysis (e.g. proximity mapping between databases)	through geographical analysis (e.g. proximity mapping between databases)	5	10	7	6	1
	through geographical analysis (e.g. proximity mapping between databases)	17%	34%	24%	21%	3%
are mostly linked directly to asset data through joins between databases	through joins between databases	6	9	5	6	3
	through joins between databases	21%	31%	17%	21%	10%

Current approach to maintaining assets

21. Which of the following statements is most true about the operational maintenance of:						
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**repaired only when they break down, collapse, or burst**	**done according to time-based schedules (e.g. weekly, monthly etc.)**	**planned using statistical reliability-centred maintenance techniques**	**one or more of the options is combined with active monitoring techniques to help identify imminent failures**	**don't know**
Water Treatment Works:	Water treatment works	2	10	7	7	1
	Water treatment works	7%	37%	26%	26%	4%
Water Pipelines:	Water pipes	9	5	2	13	0
	Water pipes	31%	17%	7%	45%	0%
Sewage Treatment Works:	Sewage treatment works	1	7	6	3	4
	Sewage treatment works	5%	33%	29%	14%	19%
Sewers:	Sewers	5	3	3	8	2
	Sewers	24%	14%	14%	38%	10%

Current approach to risk assessment

22. Does your utility follow any formal approach to risk assessment?			
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**Yes**	**No**
for financial risks?	For financial risks	24	5
	For financial risks	83%	17%
for service failure risks?	For service failure risks	21	8
	For service failure risks	72%	28%
for other types of risk (if so, what)?	For other types of risk (if so, what)?	15	5
	For other types of risk (if so, what)?	75%	25%

23. Are these risks assessed to any published standard or guideline?				
Yes	Yes		13	48%
No	No		14	52%
Total			27	100%

24. If specific standards or guidelines are followed, in what way have they been adopted? (you may select more than one option)				
We have devised our own approach to adopt the main principles of the standard or guideline	Devised own approach to adopt main principles		18	86%
We have had formal training in use of the standard or guideline	Had formal training in standard or guideline		4	19%
The standard or guideline has been incorporated within formal processes and compliance is monitored by audits	Incorporated within formal processes		13	62%
Accreditation has been gained from a recognised certification agency/accreditation body	Accredited		4	19%

25. Who carries out risk assessments? (please select one)				
Local operators and managers do their own assessments and keep the results locally	Local operators and managers do their own assessments and keep the results locally		10	36%
Local operators and managers do their own assessments, but these are passed to a central point for action	Local operators and managers do their own assessments, but these are passed to a central point for action		18	64%
Total			28	100%

26. Do you currently assess the linkage between asset failure and service failure? (Please select one)				
No, not at all	No, not at all		1	3%
For contingency planning purposes	For contingency planning purposes		6	21%
For critical asset types	For critical asset types		8	28%
For combinations of asset types and events	For combinations of asset types and events		14	48%
Total			29	100%

27. Do you currently assess the root cause of service failures? (Please select one)				
No, not at all	No, not at all		0	0%
For major service failures/incidents only	For major service failures/incidents only		13	45%
For major and minor failures, on a sample basis	For major and minor failures, on a sample basis		5	17%
For all types of failure on a routine basis	For all types of failure on a routine basis		11	38%
Total			29	100%

28. How is service risk assessed? (Select all that apply)				
Managers and operators develop their own approach, to meet a specified output	Managers and operators develop their own approach, to meet a specified output		19	70%
We use a proprietary technique to doing the assessment	We use a proprietary technique to doing the assessment		3	11%
We have trained (or nominated) risk assessors to do it	We have trained (or nominated) risk assessors to do it		4	15%
Operators or local managers enter data on a company system, which then calculates the risk	Operators or local managers enter data on a company system, which then calculates the risk		4	15%
Other, please specify	Other, please specify		5	19%

29. Does your regulator (or Government or owner) require you to use risk assessment tools in your planning?				
No, not at all	No, not at all		10	34%
Yes, for contingency planning purposes	Yes, for contingency planning purposes		3	10%
Yes, for critical asset types	Yes, for critical asset types		2	7%
Yes, for all asset types	Yes, for all asset types		5	17%
Yes, for combinations of asset types and events	Yes, for combinations of asset types and events		6	21%
Other, please specify	Other, please specify		3	10%
Total			29	100%

Types of risk assessment tool that would be useful

30. Do you have any specific requirements for a risk assessment tool?
21 Responses

31. To what extent do you require a tool to:					
Top number is the count of respondents selecting the option. Bottom % is percent of the total respondents selecting the option.		**not required at all**	**no special need**	**important**	**very important**
evaluate individual risks at asset level?	evaluate individual risks at asset level?	2	4	10	13
	evaluate individual risks at asset level?	7%	14%	34%	45%
evaluate risks for whole pipe networks?	evaluate risks for whole pipe networks?	1	7	8	13
	evaluate risks for whole pipe networks?	3%	24%	28%	45%
evaluate risks for whole treatment works?	evaluate risks for whole treatment works?	1	8	7	13
	evaluate risks for whole treatment works?	3%	28%	24%	45%
be able to link in with GIS?	be able to link in with GIS?	1	7	6	15
	be able to link in with GIS?	3%	24%	21%	52%

32. Would you prefer to be given a method statement only? (i.e. without the tool, so that you could then develop your own tool from the published method)				
Yes	Yes		14	52%
No	No		13	48%
Total			27	100%

Plans for future risk assessment. Please select the options that most apply to your utility.

33. Our asset management planning approach:				
is not likely to change in the next five years;	is not likely to change in the next five years;		3	11%
is likely to be changed to meet our own needs;	is likely to be changed to meet our own needs;		20	71%
will have to be changed in order to meet regulatory or Government requirements.	will have to be changed in order to meet regulatory or Government requirements.		5	18%
Total			28	100%

34. If our approach changes, it will take more account of (select all that apply):				
Risk to service;	Risk to service;		26	93%
Affordability;	Affordability;		15	54%
Willingness to pay;	Willingness to pay;		15	54%
Other, please specify	Other, please specify		8	29%

35. New planning tools to help us to take account of service risk would be useful in the form of:				
a framework with guidelines for application;	a framework with guidelines for application;		13	46%
a stand-alone risk assessment tool (e.g. in a spreadsheet);	a stand-alone risk assessment tool (e.g. in a spreadsheet);		8	29%
a method statement for building into existing systems;	a method statement for building into existing systems;		4	14%
any tool would have to be approved by our regulator/financial governing authority before we could use it;	any tool would have to be approved by our regulator/financial governing authority before we could use it;		0	0%
not at all;	not at all;		0	0%
Other, please specify	other, please specify		3	11%
Total			28	100%

36. Risk assessment techniques, if available, would be used for:				
not at all;	not at all;		0	0%
for contingency planning purposes;	for contingency planning purposes;		1	4%
for critical asset types;	for critical asset types;		1	4%
for all asset types;	for all asset types;		5	18%
for combinations of asset types and events;	for combinations of asset types and events;		19	68%
Other, please specify	Other, please specify		2	7%
Total			28	100%

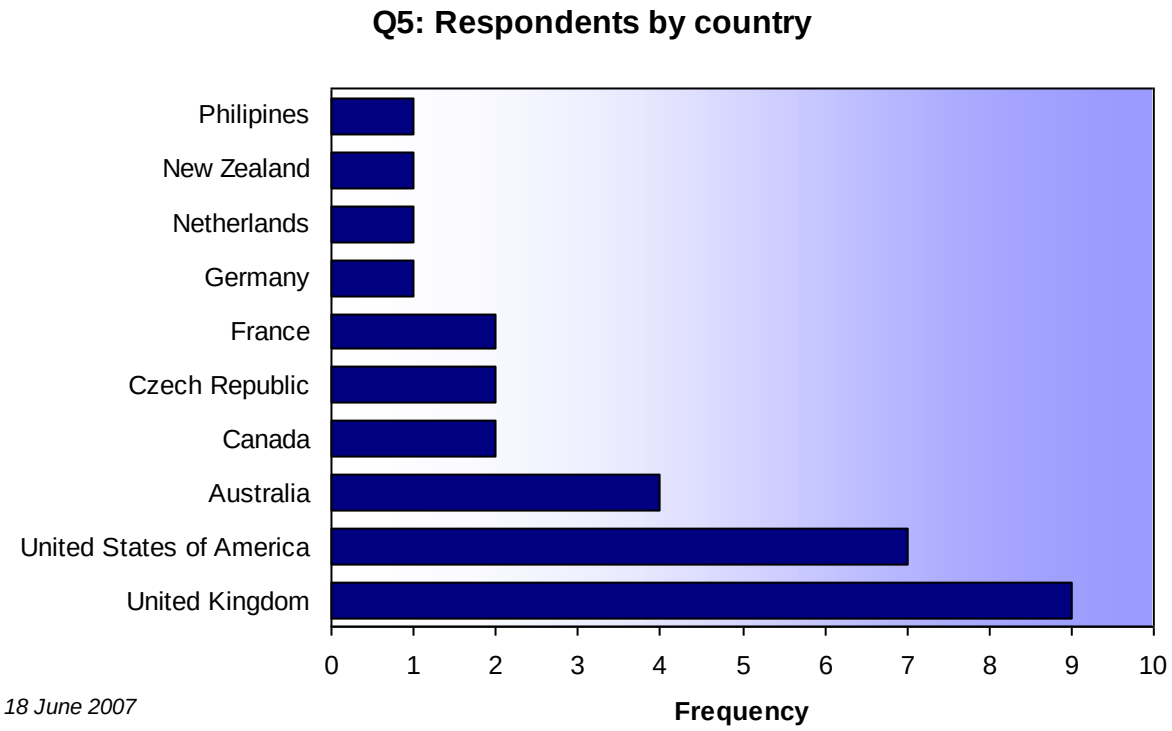
Ongoing work. Finally, we'd like to contact a selection of respondents to discuss their approach, and set up a group to test the risk management tool.

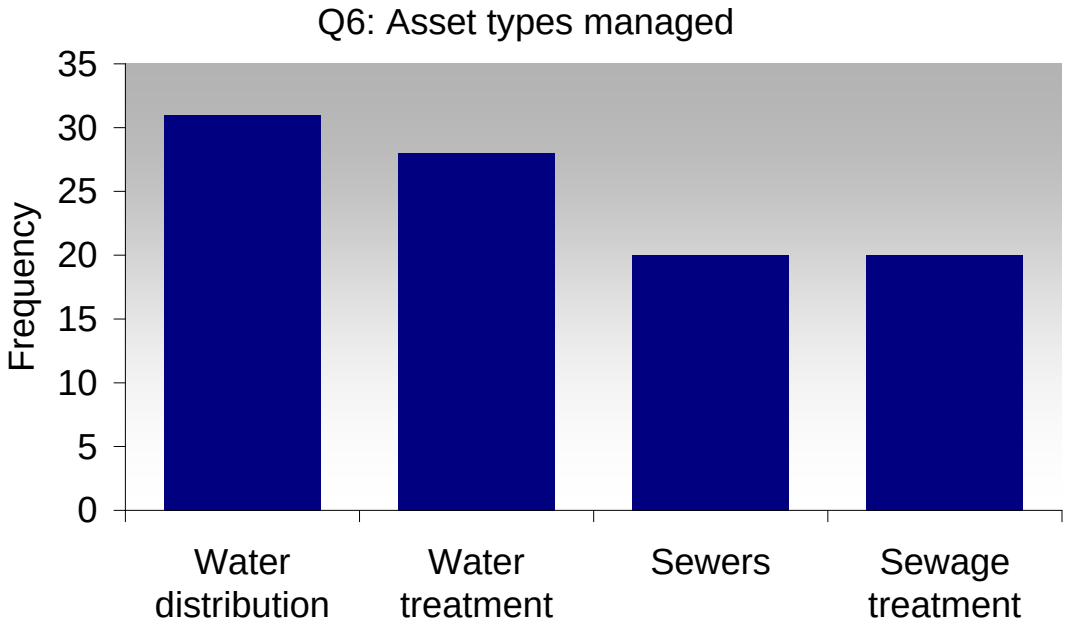
37. Telephone interview: Would you like to be included in the telephone interviews about risk management approaches? (A limited number of utilities will be selected for interview, from those that volunteer to be involved.)				
Yes	Yes		17	63%
No	No		10	37%
Total			27	100%

38. Testing: Would you like to be included in testing the tool that we develop (in August or September 2007)				
Yes	Yes		18	67%
No	No		9	33%
Total			27	100%

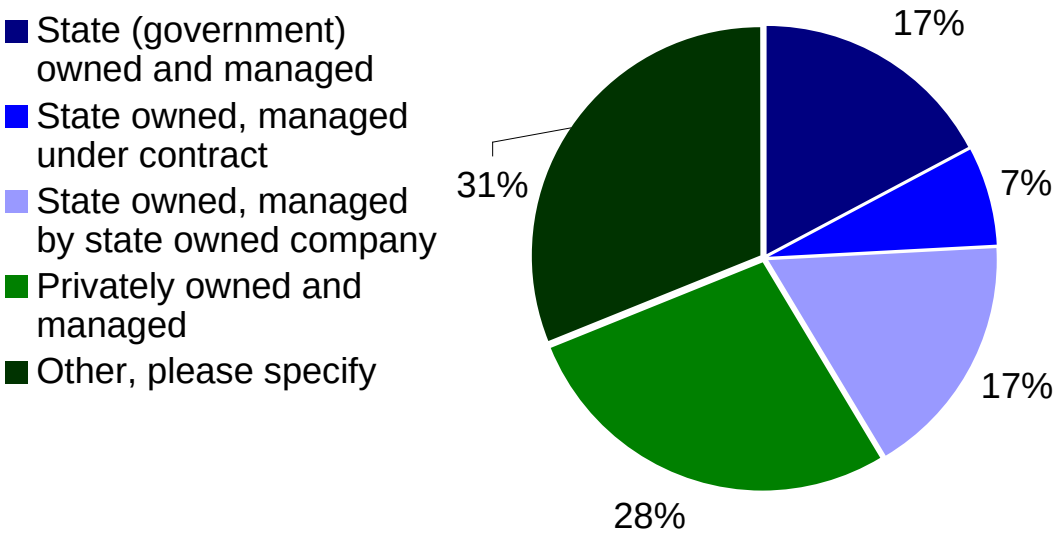
Graphs of survey results

The responses to a selection of the survey questions are presented below in graphical format. Note that for presentational purposes the wording of the question has been simplified in many of the graphs.

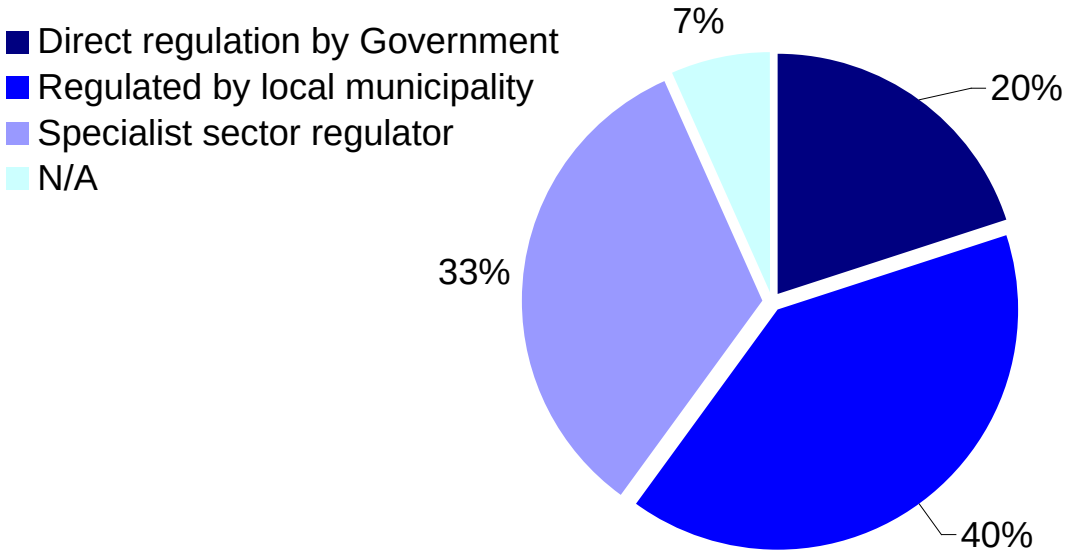




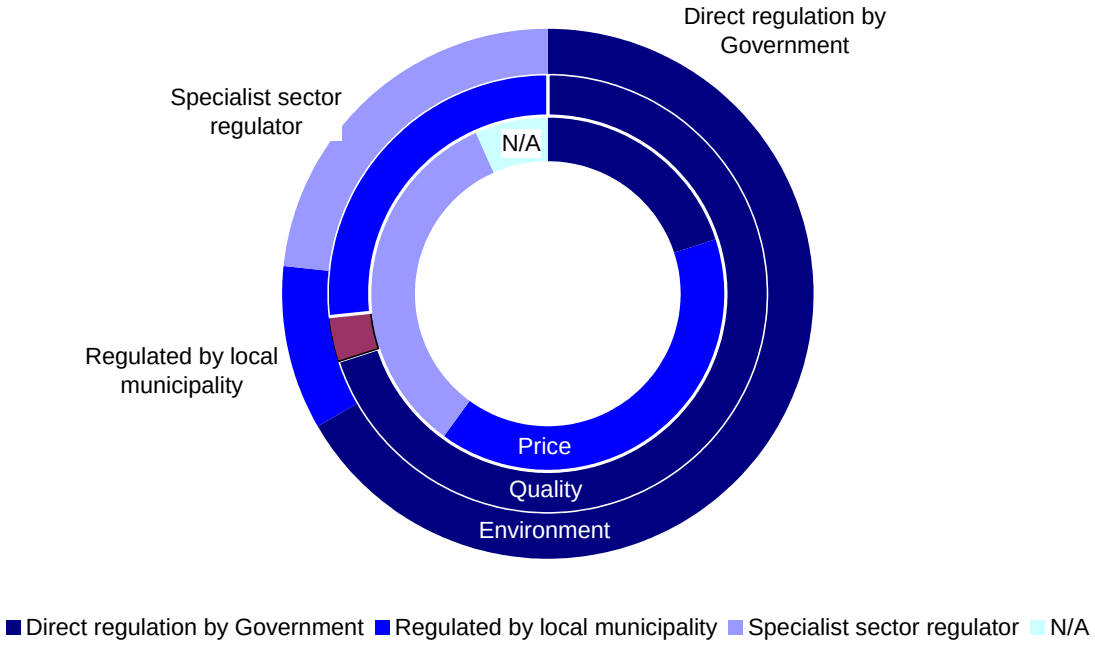
Q8: Asset ownership

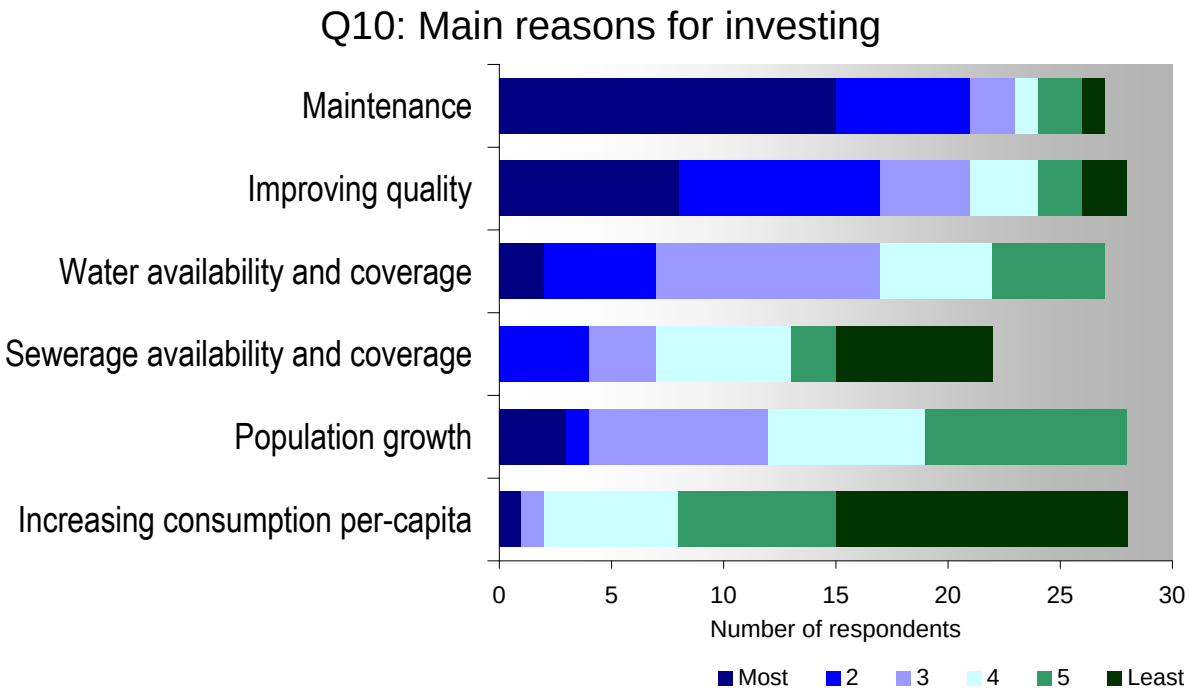


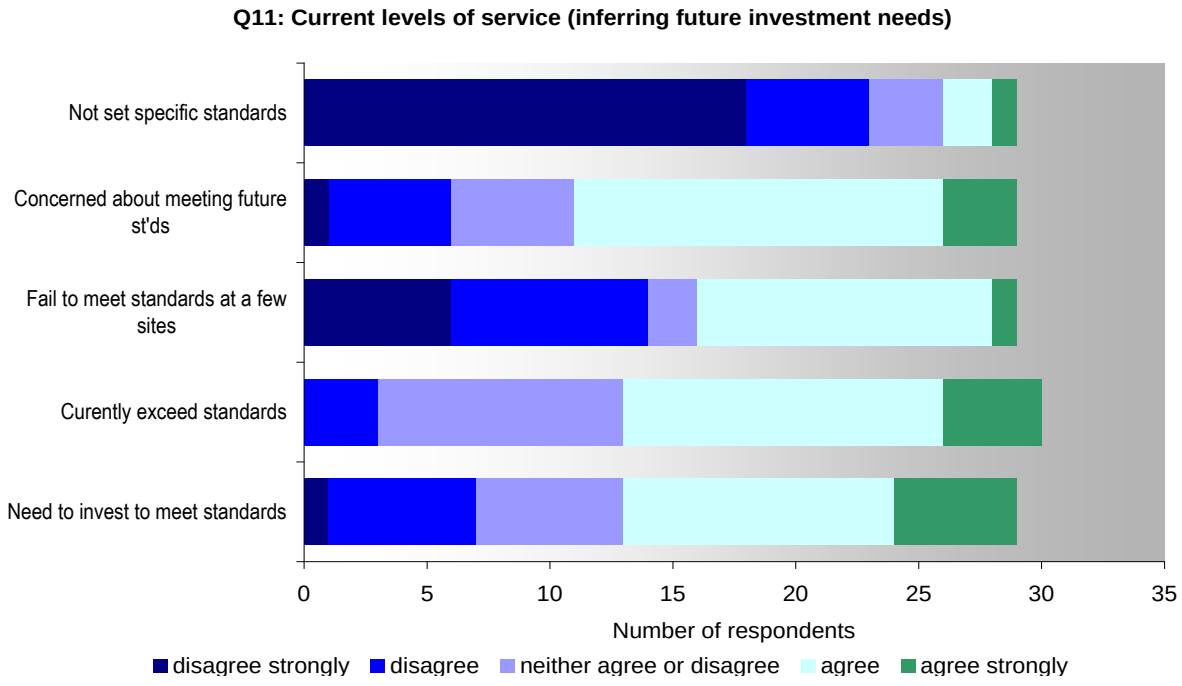
Q9: Regulatory regime (price)

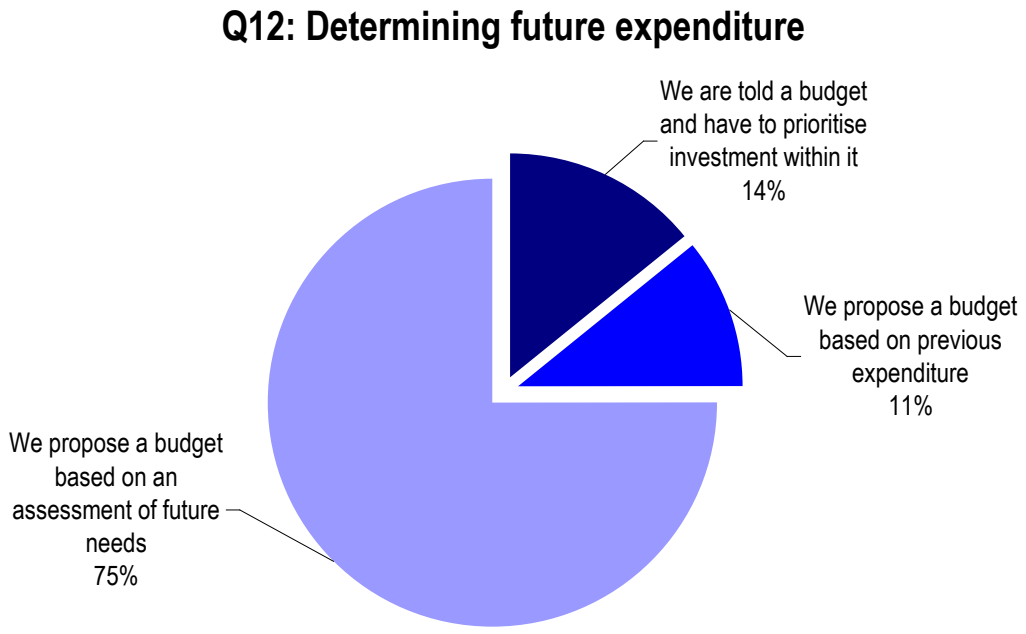


Q9: Regulatory regime

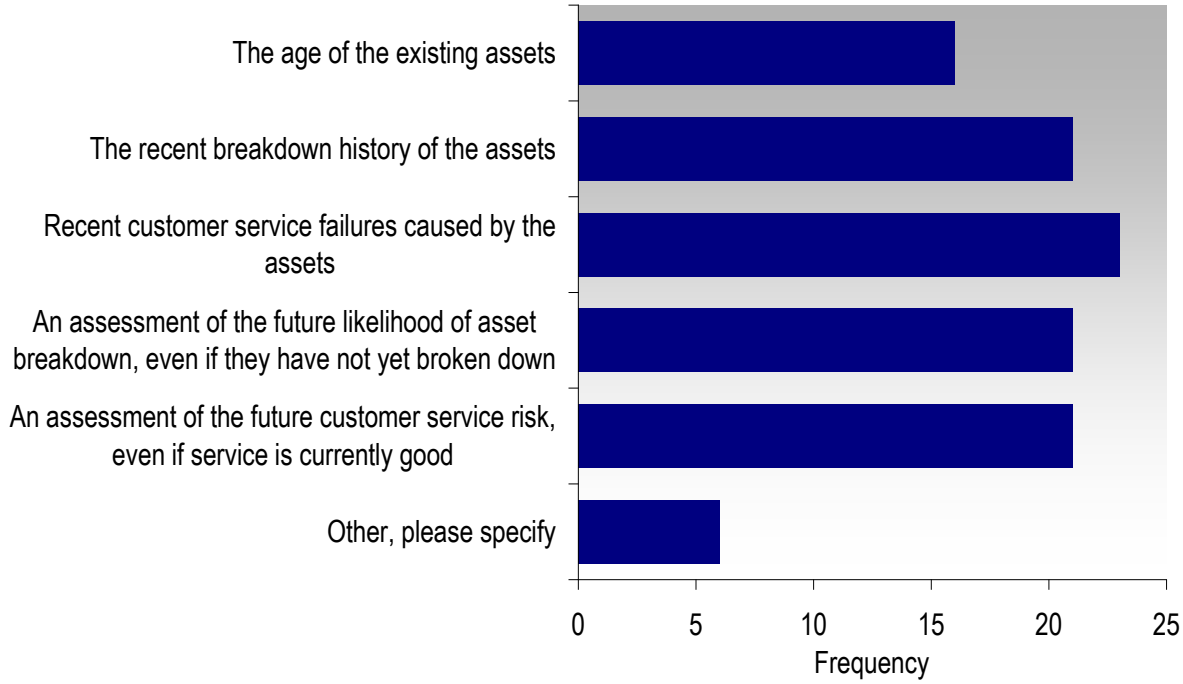




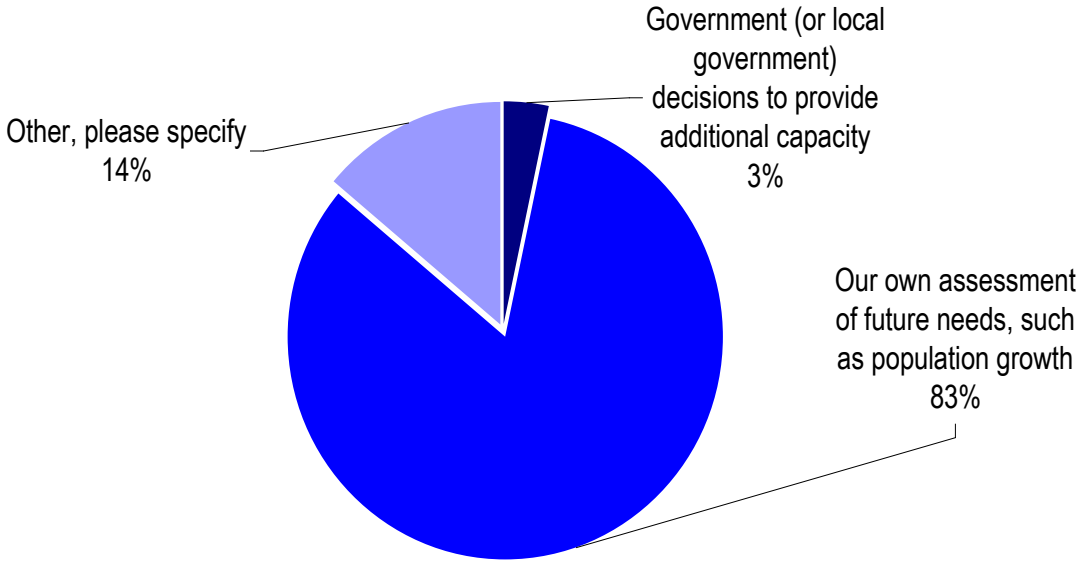

Q11: Current levels of service (inferring future investment needs)
Not set specific standards
Concerned about meeting future st'ds
Fail to meet standards at a few sites
Curently exceed standards
Need to invest to meet standards
0
5
10
15
20
25
30
35
Number of respondents
disagree strongly
disagree
neither agree or disagree
agree
agree strongly


Q12: Determining future expenditure
We are told a budget and have to prioritise investment within it 14%
We propose a budget based on previous expenditure 11%
We propose a budget based on an assessment of future needs 75%

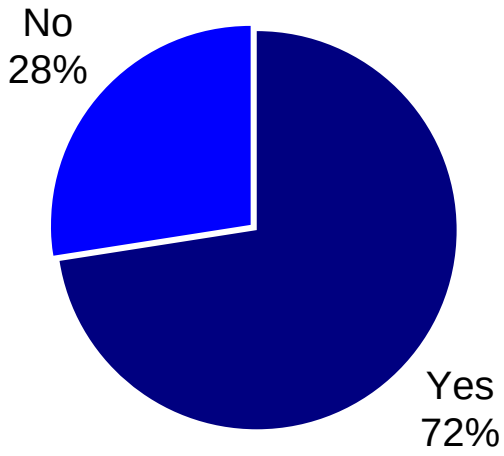
Q13: Prioirity for replacing existing assets is determined by...



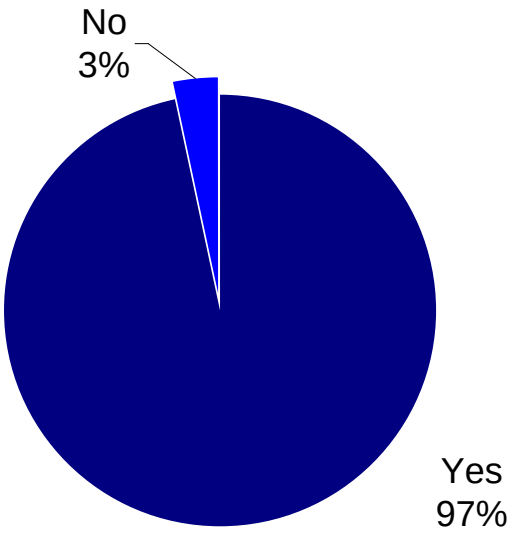
Q14: Construction of additional assets is determined by...



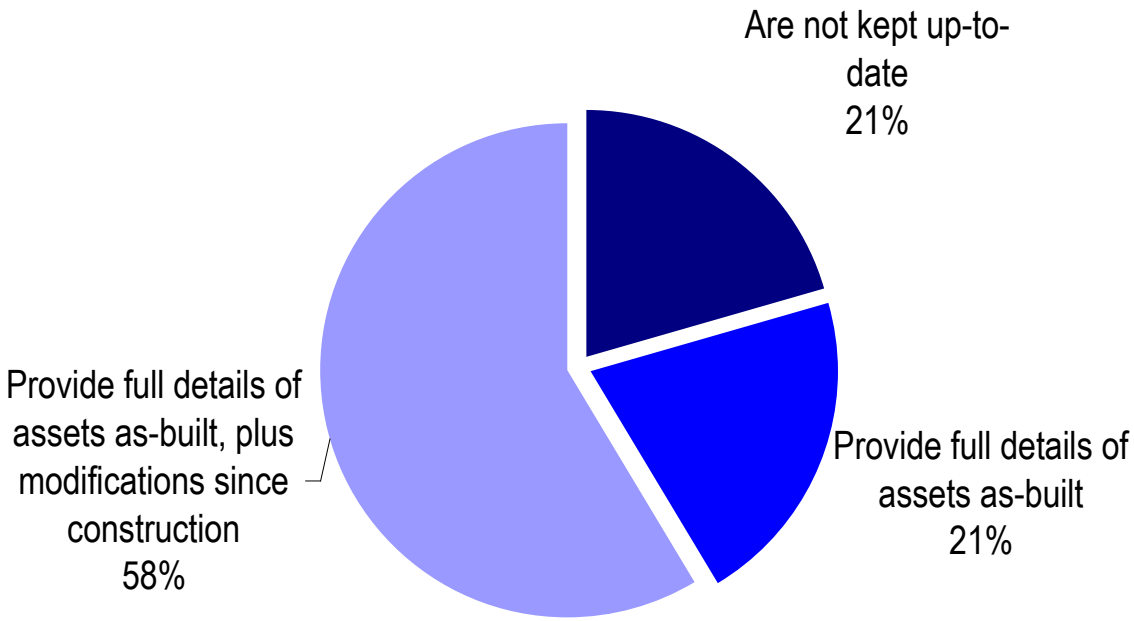
Q15: Do you take nomally take into account customer WTP
for investment in changing levels of service?



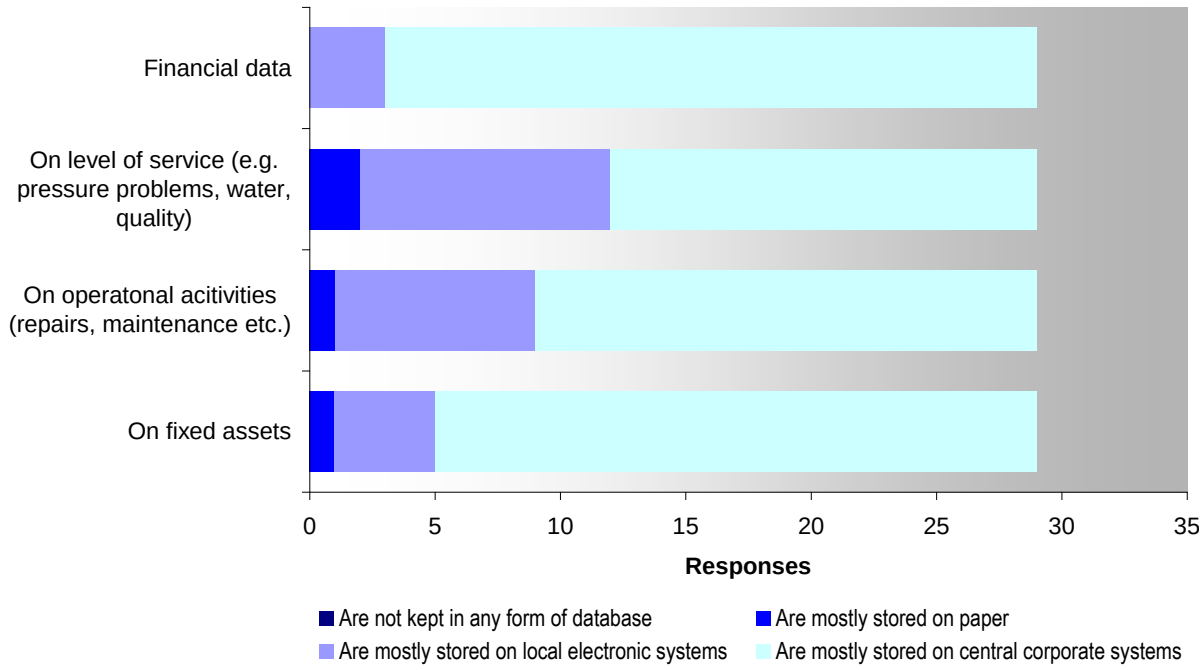
Q16: Do you normally take into account affordability to customers when considering your investment plan?



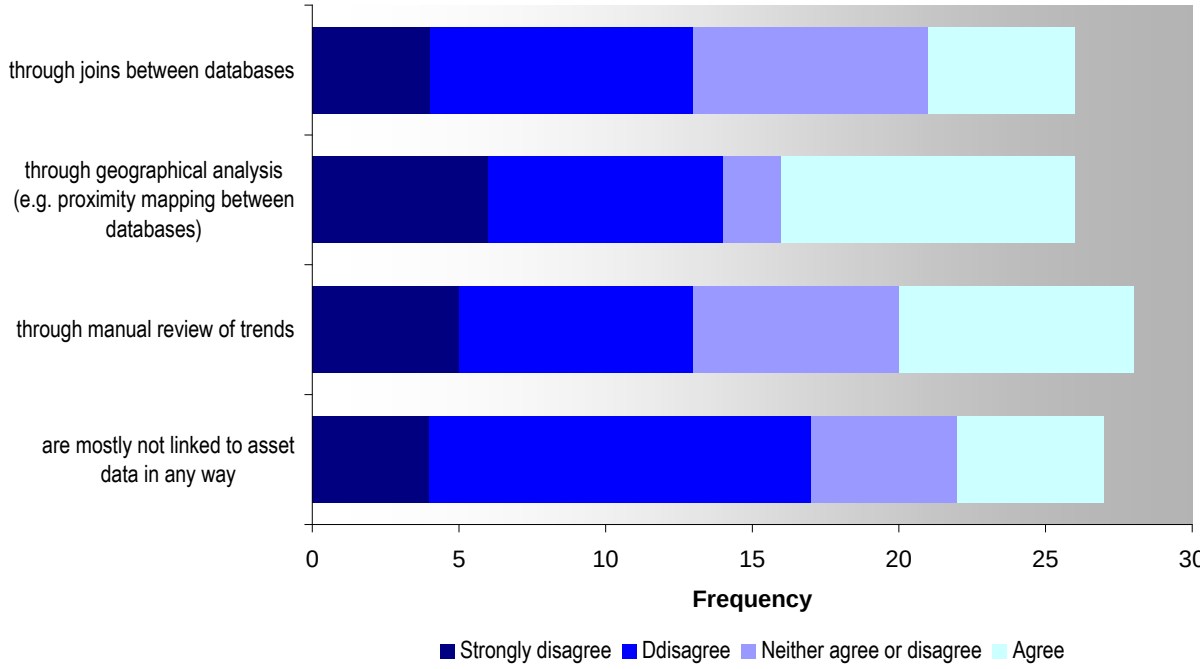
Q17: Data on fixed assets:



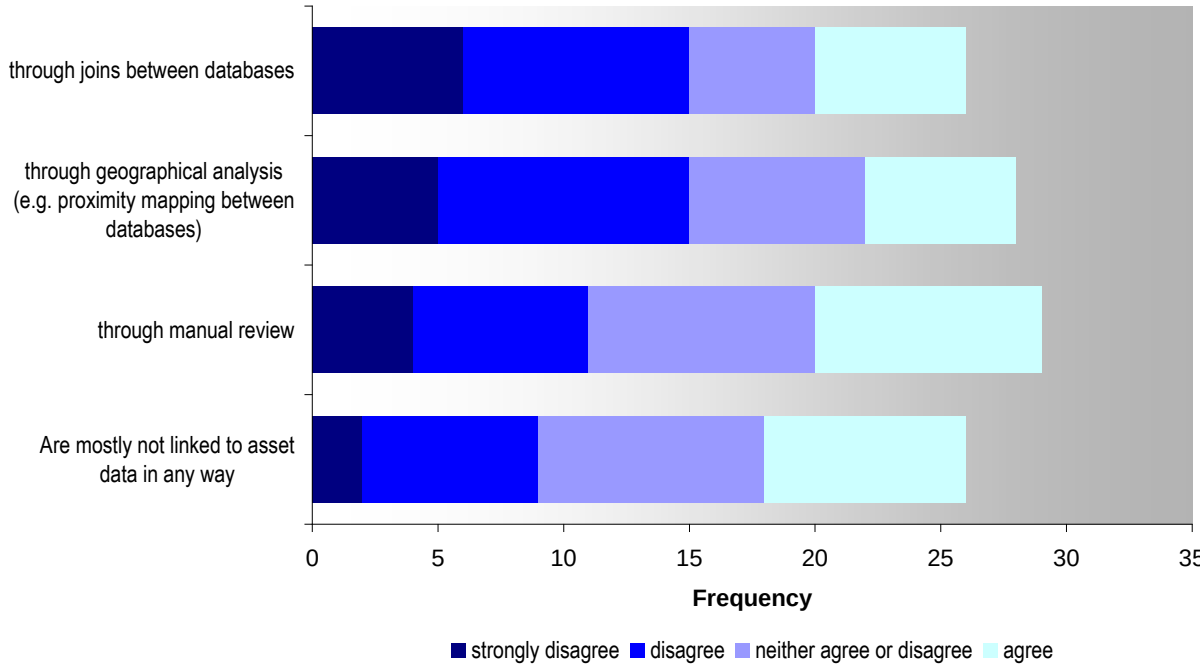
18 Please comment on how these data are recorded:

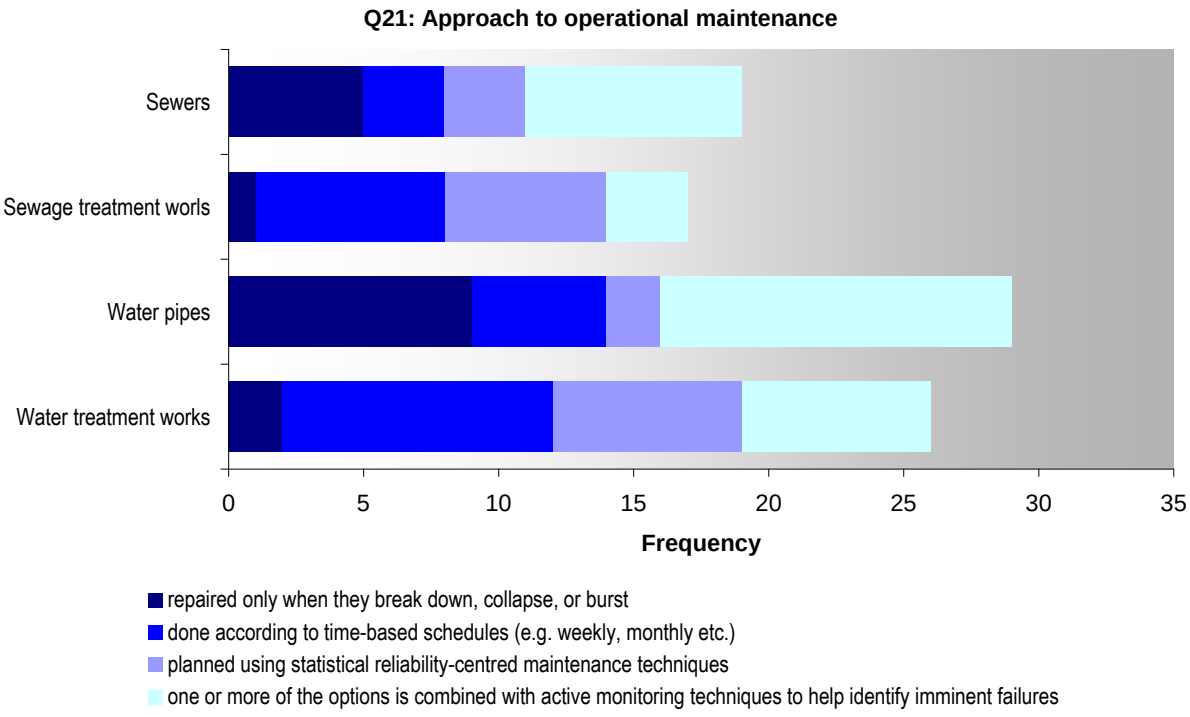


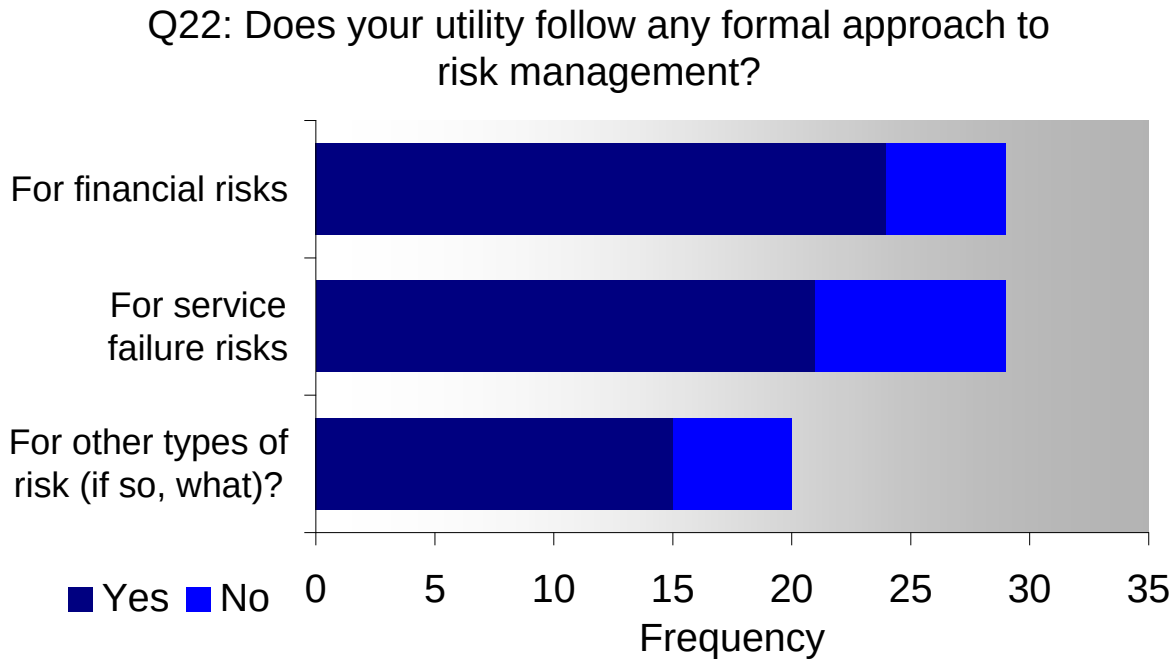
Q19: Data on levels of service are mostly linked to asset data...



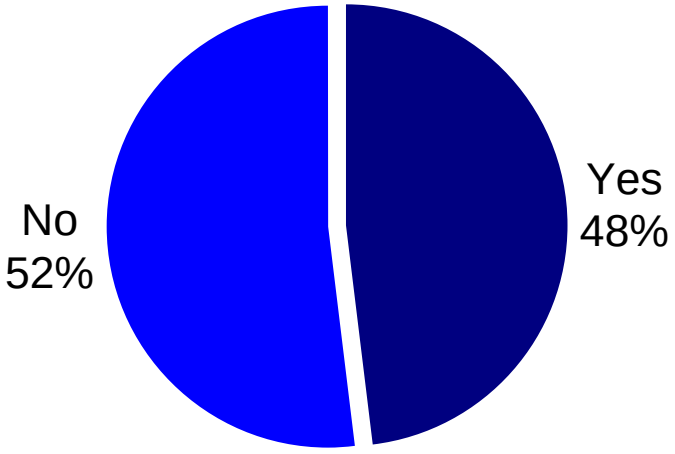
Q20: Data on financial impacts are mostly linked to asset data...



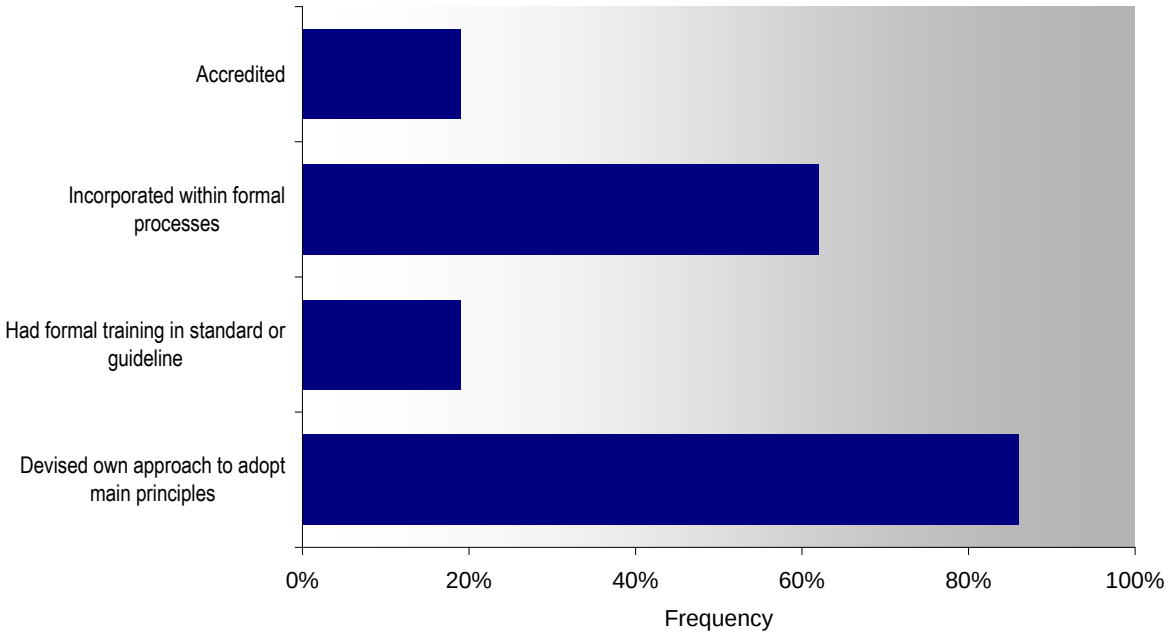

Q21: Approach to operational maintenance
Sewers
Sewage treatment worls
Water pipes
Water treatment works
0
5
10
15
20
25
30
35
Frequency
repaired only when they break down, collapse, or burst
done according to time-based schedules (e.g. weekly, monthly etc.)
planned using statistical reliability-centred maintenance techniques
one or more of the options is combined with active monitoring techniques to help identify imminent failures


Q22: Does your utility follow any formal approach to risk management?
For financial risks
For service failure risks
For other types of risk (if so, what)?
Yes
No
0
5
10
15
20
25
30
35
Frequency

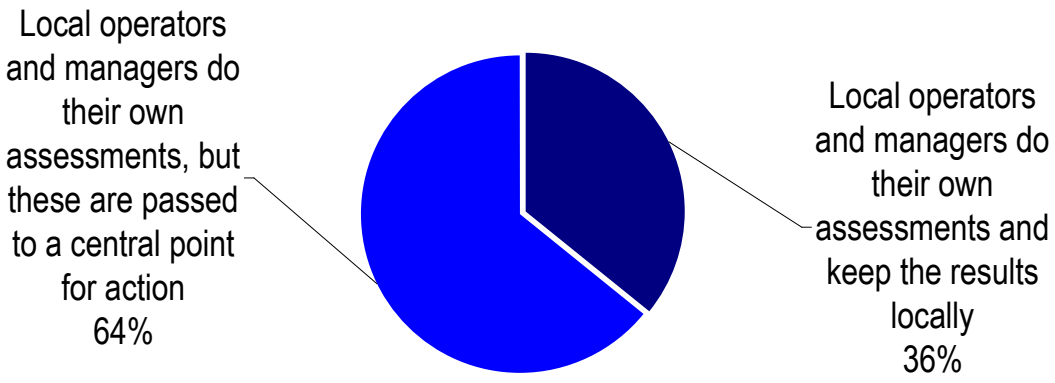
Q23: Are these risks assessed to any published standard or guideline?



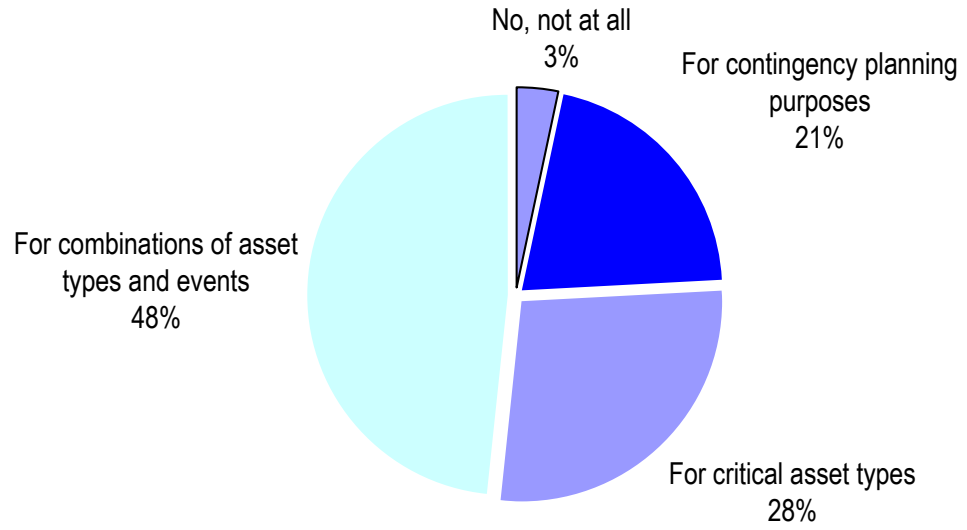
In what way have standards or guidelines been adopted?



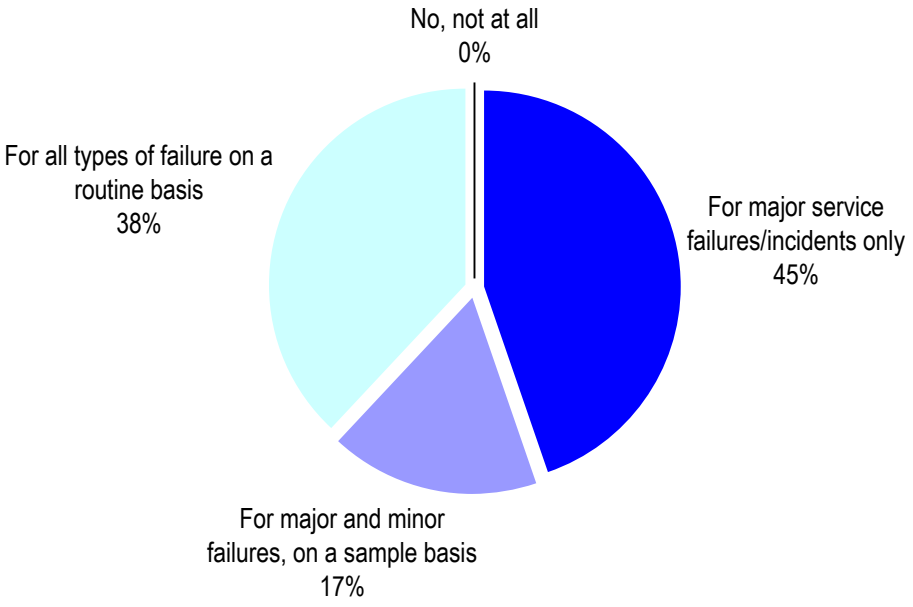
Q25: Who carries out risk assessments



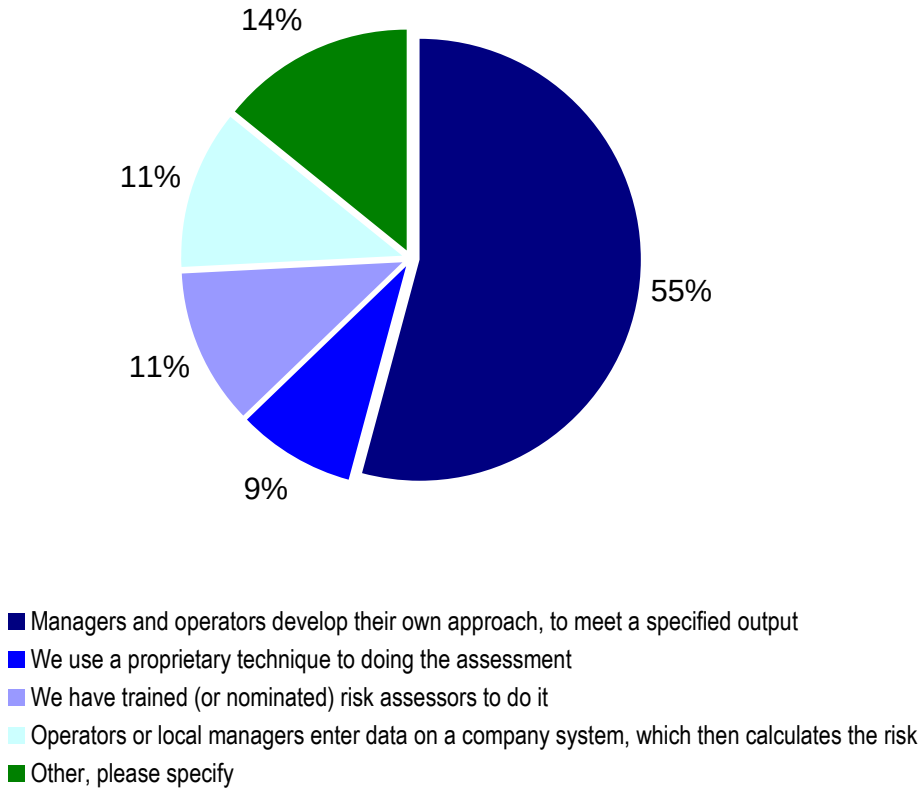
Q26: Do you currently assess the linkage between asset failure and service failure?



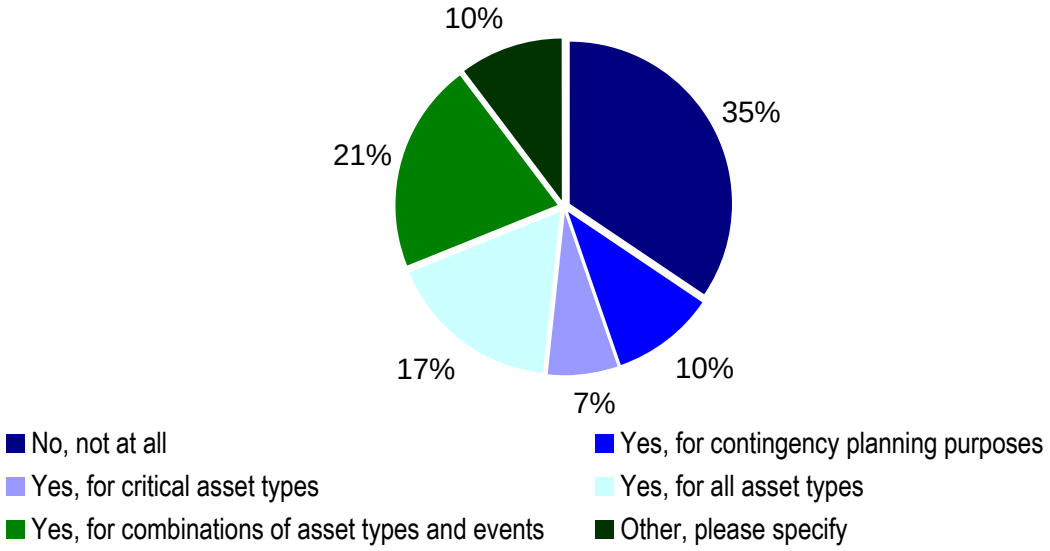
Q27: Do you currently assess the root cause of service failure?



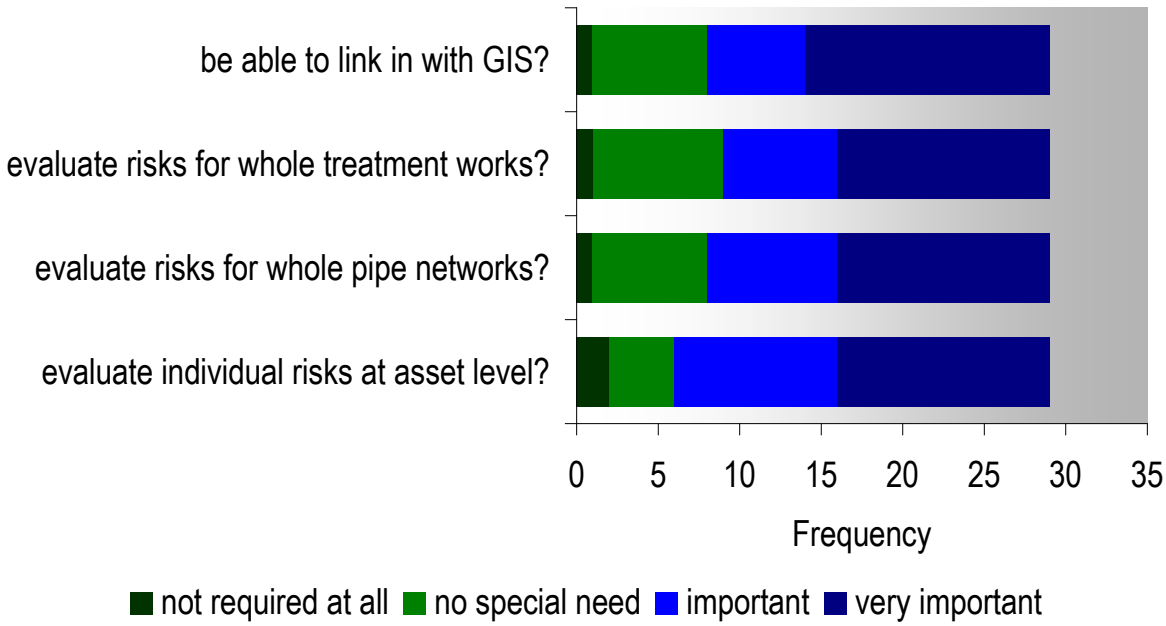
Q28: How is service risk assesed?



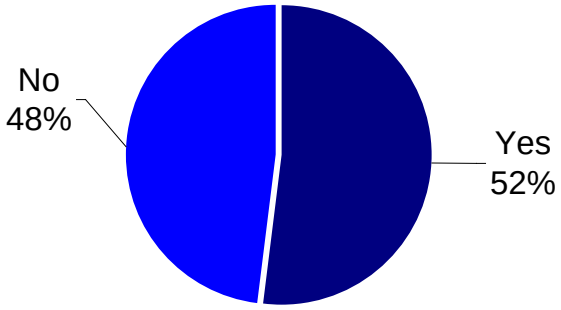
Q29: Does your regulator (or Government or owner) require you to use risk assessment tools in your planning?



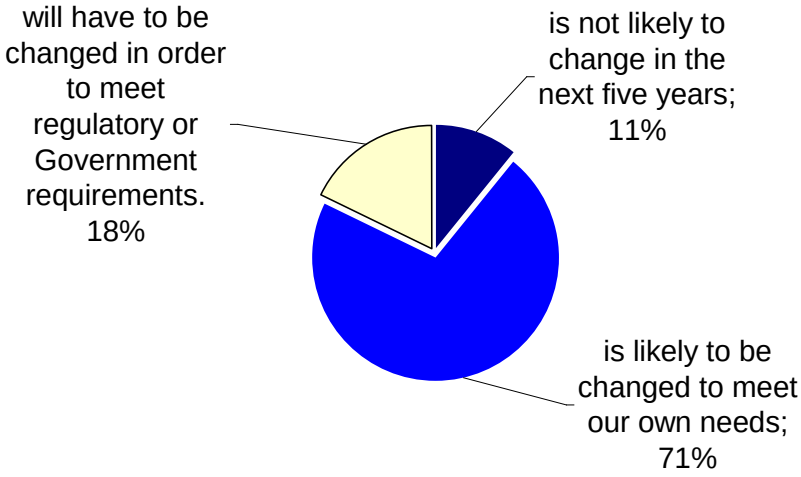
Q31: To what extent do you require a tool to:



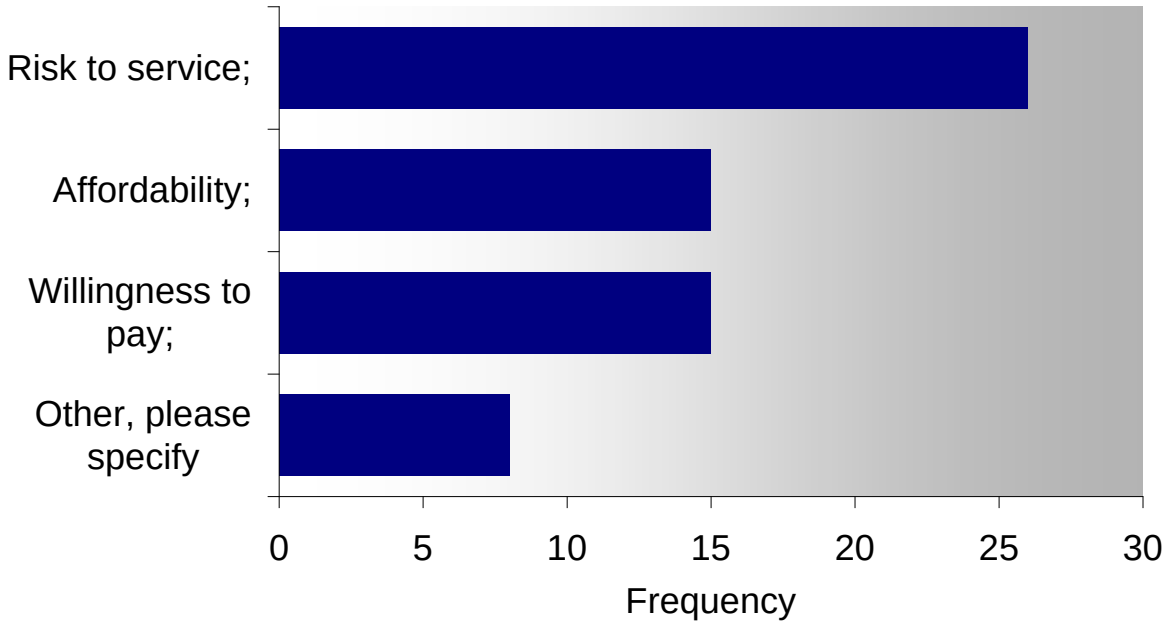
Q32: Would you prefer to be given a method statement only?
(i.e. without the tool, so that you could then produce your own tool from the published method)



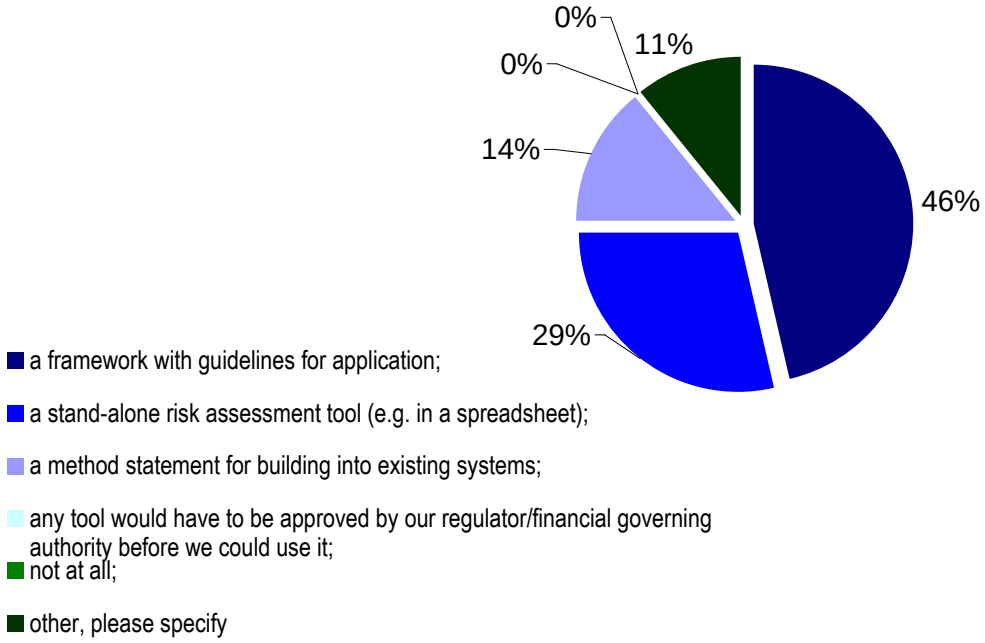
Q33: Our asset management planning approach:



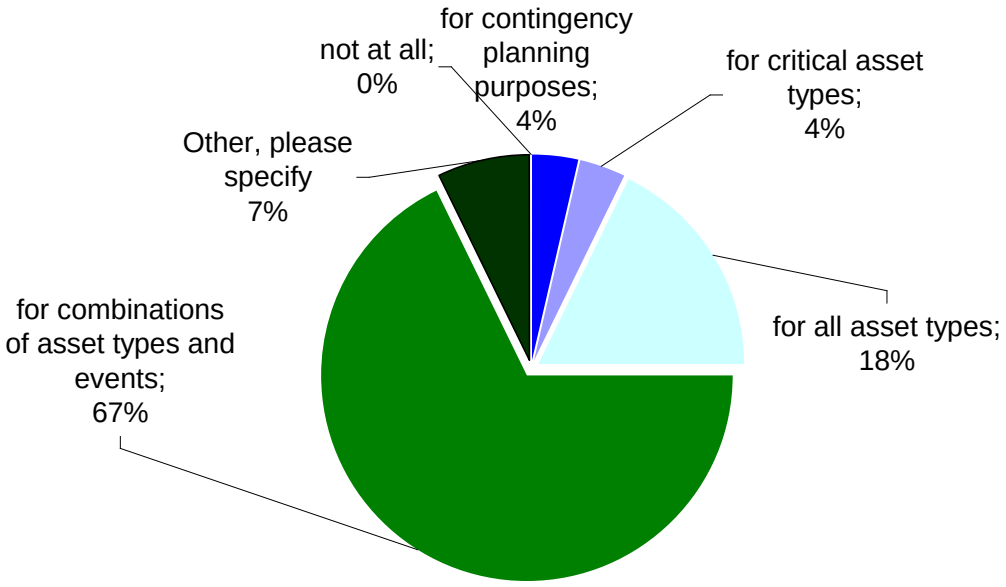
Q34: If our approach changes, it will take more account of:



Q35: New planning tools would be useful in the form of



Q36: Risk assessment techniques, if available, would be used for:



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