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Capital maintenance: summary of issues from the interviews

WICS

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Executive summary

Indepen have carried out an investigation for the Water Industry Commission into the extent to which there is a full understanding of the long-term investment requirements associated with maintaining services levels in a cross-section of regulated industry sectors.

Through a series of structured interviews with asset managers and practitioners, the extent to which current levels of expenditure on asset renewal – termed capital maintenance in the water sector – are appropriate was tested. The focus was on establishing whether there was sufficient information on - and understanding of - asset condition, performance, life cycles and investment needs to be confident that service levels could be maintained.

The interviews, conducted on a non-attributable basis, provided a wealth of information on how the different industries have sought to tackle the difficulties of establishing the level of expenditure required to maintain the assets, given the inherent complexity of the infrastructure, the fact that many assets are inaccessible and that there is little experience of 'end of life' for some long-life assets.

There was a consensus that there should be better dialogue between government, regulators, companies and stakeholders on this topic.

The approaches associated with 'ethically based regulation' (EBR) as proposed by Professor Hodges of Oxford University would be helpful in this regard[1]. WICS believes that an EBR approach would facilitate a more open dialogue between the stakeholders on the long term needs and this would help to establish a consensus on what the maintenance requirement is and how it should be financed.

There was no consensus among those interviewed as to whether the current levels of expenditure on asset renewal, either across different industry sectors or within sectors, were insufficient, adequate or excessive to maintain service levels in the long term. This indicates a risk that customers are bearing. Given the inadequate understanding of need and the lack of an open dialogue, this is unsurprising. The uncertainty was seen as being greater with respect to future requirements, suggesting unresolved inter-generational issues. To address these, we need to a better understanding of what information is required and whether such information is available or obtainable. Only if there are changes to the regulatory framework and different approaches by others can we ensure that these issues will be addressed.

In summary, the interviews reveal that across the regulated sectors there is an incomplete understanding of the level of expenditure required to maintain service levels over the long term. There is a consensus that the regulatory frameworks do not provide incentives for

[1] EBR is discussed in a paper on the WICS website www.watercommission.co.uk/UserFiles/.../Roundtable%20event%20output.pdf

companies to address this. This does not mean necessarily that more investment is required to maintain today's assets: it does require a better understanding of the long-term maintenance needs and a means whereby these needs can be sustainably financed in the future.

1 Introduction

1.1 Purpose of the project

This document summarises the output from a series of interviews carried out for the Water Industry Commission for Scotland (WICS) to explore how well the ongoing investment needs of regulated industries are understood. WICS is continuing to develop its regulatory framework so that the water industry in Scotland serves the best interests of customers today and in the future. In its preparations for the next Strategic Review of Charges for 2021-27 (SRC21), WICS has identified issues that will require changes in the way it regulates Scottish Water.

Understanding the long-term requirement for maintenance expenditure, to ensure that assets are fit for long term service, is one of the areas of focus. A recent WICS Board paper described the challenge in the following terms:

- "Assessing the correct level of expenditure on maintenance of assets is very difficult. This is because of the uncertainty that exists in the timing of required maintenance expenditure – with many long-life assets - and because of the regulatory focus on establishing a 'hard budget constraint'. It can also be difficult to demonstrate a material impact on the levels of service experienced by customers of additional spending on maintenance. The approach of the regulator has defaulted to a 'pay as you go' approach; investing based on the short-term needs of the assets, often to the detriment of the long-term performance.
- *"A fair price for the service provided:* The 'pay as you go' approach shifts the liability for future maintenance onto future generations. Potentially, this means that today's customer is not paying the full cost of the service that is being provided to them. They benefit both from the legacy asset base and current borrowing. Given that we have also spread the costs of new assets over time through borrowing, there is a question of inter-generational equity. There is also a question whether it is politically acceptable to see the increases in customers' charges that may come about from this 'pay as you go' approach. What would be the response, for example, if Scottish Water were to face an unplanned and urgent need for maintenance expenditure?"

WICS asked Indepen to obtain the views of knowledgeable and experienced people, across a broad range of companies in asset intensive sectors, on factors that affect maintenance decisions and outcomes.

Respondents described a wide range of challenges which we have categorised under the following headings

- language and objectives
- political uncertainty
- techniques and data
- regulation, risk and company governance
- culture and business processes, and
- delivery, trends and events.

Each challenge is relevant to the situation in the Scottish water sector. WICS intends to use the information in this report to inform the work it is undertaking with Scottish Water to develop an approach that addresses the need to maintain service levels over the long term.

WICS believes that addressing the information asymmetries that exist between regulator and regulated company is a necessary first step and it intends to work with Scottish Water and other industry stakeholders in a joint approach that is consistent with Ethical Business Regulation (EBR).

EBR is an approach to regulation, in a multi-agency context, that has been researched and developed by Professor Chris Hodges[2]. Hodges work has been extensively discussed in policy and regulatory circles and forms part of the policy of the Scottish Government towards consumers and competition[3]. Some thinking about how EBR might apply to the regulation of network utilities in Scotland is set out in a briefing paper prepared for a roundtable on this topic[4].

WICS intends to use this document in its discussions in two ways; in the formulation of their methodology and approach for the next Strategic Review of Charges for the 2021-27 period and in discussion with Scottish Water and stakeholders to explore where views coincide and where they differ.

1.2 Approach

The fact finding had two phases.

- Phase 1 - Indepen conducted informal discussions with key industry experts with experience in the infrastructure supply chain; as executives in utilities and other capital intensive businesses; and as investors in network businesses.
- Phase 2 - The results of these discussions were summarised to inform the agenda for a series of in-depth interviews with senior people across a range of asset intensive sectors.

The interviews were on the basis that replies would not be attributed.

1.3 Structure of report

The structure of the report is as follows.

Section 2 gives a summary of the findings and our take on what they mean
Section 3 provides background on the issues affecting capital maintenance
Section 4 contains a structure for the results of the interviews
Section 5 uses the structure to summarise the points made by respondents

[2] Hodges research and the principles of EBR are summarised in a paper he wrote for BEIS. https://www.gov.uk/government/uploads/.../16-113-ethical-business-regulation.pdf

[3] Delivering better outcomes for consumers and businesses in Scotland www.gov.scot/Publications/2016/12/5688

[4] Issues about the application of EBR to network utilities in Scotland are discussed in paper produced by Indepen for a workshop with stakeholders in Scotland. Briefing paper for roundtable on January 17th 2017

2 Background to capital maintenance

2.1 What is capital maintenance?

Asset management is central to capital-intensive sectors such as water and waste water. By asset management, we mean the process for managing asset interventions.

In utility networks, the term capital maintenance refers to the investment required to maintain existing levels of service to customers either through replacing worn-out plant and equipment at the end of its useful life or by intervening to ensure that the asset does not deteriorate to the point where it needs to be replaced.

2.2 Why is it important in water?

If we measure capital intensity as the ratio of a sector's capital stock to its output (GVA), we see that network utilities are the most capital intensive industries in the UK. In 2015, this ratio for selected sectors and the UK average were as follows[5].

Water supply, sewerage and waste	6.8
Electricity, gas steam and air conditioning	4.7
UK average	2.6
Manufacturing	1.5
Professional, scientific and technical activities	0.5

Water is the most capital intensive of the sectors identified and this means that it is a sector for which capital maintenance has great significance.

2.3 How does regulation deal with capital maintenance?

In regulated utilities, the topic of capital maintenance has been an issue of debate for many years. Regulators have responded variously, but there is no consensus on what is needed.

It is important to be clear about which outcomes are affected by capital maintenance:

- It affects the resilience of networks in respect of their ability to perform their functions, including when the demands placed on them change or fluctuate. In practice, it may be better to sustain reliability in other ways than asset maintenance and renewal.
- Maintenance is critical for other measures targeted by regulators, such as leakage, pressure maintenance and sewer flooding. This may result in a higher focus on maintenance activities in some areas than others. For example, setting a leakage outcome and publishing performance against it has undoubtedly influenced the behaviour

[5] http://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/bulletins/capitalstocksconsumptionoffixedcapital/2016#analysis-by-industry. These ONS data are based on "market value", which in the case of water is a function of regulation. It is acknowledged that in water MEAV is a poor proxy for market value – no one would replace Victorian networks in their existing form unless remunerated for doing so by monopoly obligations and price limits – so these numbers should be interpreted with caution.

of company managers. Customers have expressed willingness to pay for leakage reduction and regulators have provided for this.

- Short term outcomes and incentives of the type that water companies have generally faced from their regulators and shareholders will not optimise asset management over the longer term. One driver of the short-term nature of water regulation in England & Wales has been the absence of any appetite among investors to take long term regulatory risk. The reason for this is that private equity will always value future benefits less than society will. This situation does not apply in Scotland, where investment in water is via the Scottish Government. Even so, a focus on short term performance has been observed in the past.

In a recent paper on capital maintenance[6], WICS summarised the current position on regulation and capital maintenance in the following terms.

> The regulation of capital maintenance and improving resilience has been a challenging issue for many years. Ofwat produced a helpful note, MD161[7], which sought to set out the evidence that a water company should be able to produce in order to allow a regulator to respond positively to the funding need identified through customer charges. MD161 was based on sound economic and business principles. Some 15 years have passed since the issue of MD161, but a robust economic case remains elusive.

There have been developments since MD161 was written, and different sectors have gone down different routes. PR14, in England and Wales, was the first time that Ofwat had the information it needed to extract substantial shortfalls from some of the regulated companies because of inadequate capital maintenance.

[6] WICS Advisory panel discussion paper 2: Capital Maintenance
[7] Letter to the Managing Directors of all water companies from the Director General (MD 161, Ofwat April 2000)

3 Summary of findings

The objective of asset management is to optimise the performance and cost of an asset or group of assets. This is done by managing various asset interventions including operational performance, maintenance activities and network renewal throughout the lifetime of the assets.

None of the interviewees said that infrastructure companies' approaches to asset management would meet this objective, still less the more exacting standard of providing asset stewardship. The key feature of asset stewardship is that it elevates the scope of the optimisation to the whole of the company's assets and systems and considers evidence about the interests of its owners and those it serves in evaluating and optimising asset interventions.

Respondents revealed divergent views as to whether the overall level of maintenance expenditure in the water sector (and probably in other utility sectors) was adequate or not.

They took one of three positions.

They said the amount spent on capital maintenance was insufficient.

- A conventional view, expressed by many, is that for a range of cultural and incentive reasons, companies tend to underspend on capital maintenance.
- An example, which may be representative, is that we would need to double maintenance expenditure on the sewer network to stop its condition continuing to deteriorate.

They said the amount spent on capital maintenance was excessive.

- A counter view is that companies do not get good value for their expenditure on maintenance: expenditure is ineffective and inefficient and the same results could have been achieved for less – so relative to the outcome of the investment expenditure is excessive.
- Another take on this is that because of inadequate data and approaches and the risk averse nature of decision making in monopoly utilities; companies are more likely to spend too much on capital maintenance than too little.

They said they did not know whether the amount spent was insufficient, excessive or just right.

- The adequacy of capital maintenance should be assessed in the broader context of asset management which should have regard either to the baseline operating expenditure and capital maintenance costs (known as botex) or to total expenditure for the asset (referred to as totex, defined as botex plus enhancement), which it was not.
- The absence of well-defined and measurable outcomes that were to be delivered by capital maintenance, asset management and asset stewardship.
- Failings in the objectives, scope, data, techniques, analysis and application of asset management, meant we could not know whether maintenance expenditure was adequate or not.

There was no general agreement about the nature of these factors or their prevalence, or about what should be done to improve the situation. Some significant failings identified by respondents, and their possible consequences were as follows:

- Key concepts and variables are not well measured or assessed so the evidence that should inform decisions could be biased or unreliable or both. Areas include: asset valuation, lifetime measures, the effects of asset interventions on costs and performance; and the risk and value of failures.

- In a system context, the effect of the failings is likely to be compounded relative to the position with respect to individual assets, for example via a knock-on effect of failure due to a lack of maintenance. In the extreme, this compounding could lead to major asset failure with serious or catastrophic consequences.
- The approaches to valuing, maintaining and regulating assets and systems are not invariant in outcomes or technology[8] or to the nature of the regulatory control framework. An increase in the pace of technological change, in the form of new materials, smart applications, more data and better analysis, would make the position worse. The new technologies would change the economics of infrastructure and existing approaches would become less appropriate and lead to worse decisions. Similarly, it is hoped that changes in regulation, such as the shift from using poorly defined distinctions between opex and capex to the use of totex (or botex) evaluation, will change the nature of efficient asset management interventions.
- Benchmarking relative to history is incremental, and if customers want a different level of serviceability in future, it will be wrong. A zero-based approach is needed, which would mean some clear long term outcomes and a botex optimisation approach.
- There is a presumption that the status quo represents the right or at least an appropriate level of serviceability but with little compelling evidence that this is what customers want and are prepared to pay for and that investors are prepared to provide. In the absence of evidence, there is a risk that any standard imposed by regulators either provides protection for the maintenance of a level of service that is below what customers require and does not provide the improvements customer want over time. This would be consistent with the view that maintenance expenditure tends to be too low. The alternative outcome is that a standard determined by regulators protects gold-plating and excessive capital expenditure. In either case, mobilising evidence and pressure from customers about what levels of service they want will prove beneficial.

In addition to these fundamental issues, numerous inadequacies were identified. Many of these are more readily controllable by company management and other parties in the sector (including customers) and might respond to effective incentives or other initiatives:

- Poor level of data and information about assets and systems including at a basic level – location and condition - as well as more complex matters of serviceability and resilience.
- Ineffective modelling approaches.
- Organisation and associated business processes.
- Cultures and attitudes to risk.

Economic regulation and changes in its application had led to different approaches being adopted by the companies in England and Wales from time to time but measurement issues and changes in circumstances meant that the outcomes of these experiments were not known. As far as respondents were aware, there were no counterfactuals against which the effects of the changes could be evaluated[9].

There may be lessons to be learned from other sectors. The interviews covered several

[8] This is a major issue for between sector comparisons, although many respondents thought there would be useful lessons to be learned from these.

[9] The documentation for PR14 contained justification for the totex and outcome approaches – unfortunately this seems not to have been well communicated to those respondents who commented.

asset intensive sectors and there are differences in their approaches to capital maintenance. A key difference appears to be the degree of risk aversion but contextual differences between the sectors make it difficult to daw conclusions that would apply across the piece.

For example, experience in rail and aviation was said by some to be noteworthy. It is, however, in a context where directors and managers can face jail for maintenance mistakes and where economic and safety regulation is combined in a single entity. If, as many observed, maintenance in water is perceived to be optional in the short run with available cash paid out as dividends, it may be because few believe there will be severe repercussions should safety levels be breached. While the economic regulator can, in some cases, add penalties of its own, it is not clear how effective this is ex ante. For PR19, Ofwat is asking for indicative outcomes out to 2030, which would give the opportunity to show how long term optimisation might work.

Emerging from the results of the interviews is the following view of the current position.

- There is much room for improvement, but this is not widely acknowledged in the sector.
- Companies do not make full use of the information they have. In future, there will be even more information.
- There are examples of good practice where companies demonstrate that collecting asset information systematically over time results in better decisions on asset strategy, including maintenance, and provides companies with the evidence they need to evaluate decisions.
- Efforts to spread the good practice seem ineffective and regulatory incentives have not encouraged the widespread adoption of better asset management approaches. One reason for this may be companies' unwillingness to accept incentives and the associated risks of optimising expenditure and outcome decisions over more than a five-year period.

Neither current customers nor the intergenerational issue were mentioned by many. Some observed that customers believe that they have paid already for the assets to be well and efficiently maintained and would consider they had been treated unfairly if they found out that they were not in such a condition. This might not be surprising but no evidence was adduced.

The position described above suggests that approaches under the banner of EBR and starting from shared customer outcomes would create considerable traction to improve matters. Any improvement will take a decade or two to show and for their value to be evaluated. This is not a reason not to start.

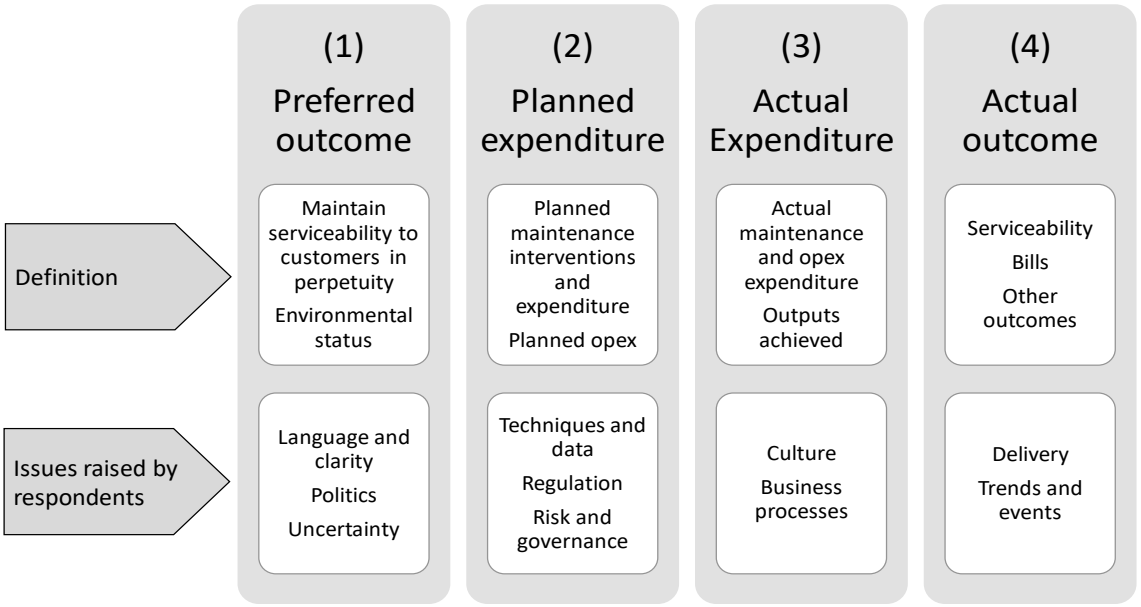
4 Structure for the results of the interviews

MD161 said that water companies should demonstrate how their planned expenditure would maintain serviceability at least cost. It said each company would need appraisals of capital maintenance and operating expenditure[10] (a combination now referred to as Botex) relative to a counterfactual[11]. This would feed into an asset management plan for maintaining serviceability and to arrangements for implementing the plan.

From this, the structure for our findings is illustrated in the diagram.

- Column 1 - preferred outcome
- Column 2 - expenditure planned to achieve the preferred outcome
- Column 3 - expenditure actually incurred
- Column 4 - outcome achieved.

The second row in the diagram shows definitions of each of the stages and the third row the headings we have used to summarise the issues raised by respondents. The topics in row three are reasons for weaknesses in the link between the preferred and the actual outcome.



This assumes that the preferred outcome from maintenance is to maintain serviceability but there is no expectation that this will be the right level in future. The preferred level of serviceability will change with innovation – e. g. distributed storage, SUDS - and changes in the demands on the system – e.g. use of flushable wipes, interruptible or off peak only use.

[10] MD161 said that the appraisals should have regard to: cost of any loss of serviceability, including of risks and their probabilities and illustrations of how serviceability would decline if the activity was not undertaken; impact on operating costs of capital maintenance, before and after assets are renewed; the timing of asset replacement; and the impact of obsolescence and new technology

[11] MD161 did not specify what the counterfactual should be. The CMA struggled to define a counterfactual in the Bristol inquiry, as there had been no consistent capture of botex data over investment lifecycles, after the end of the July Return.

5 Issues raised by respondents

5.1 Preferred outcome

5.1.1 Capital maintenance: language and objectives

Language	Different parties with roles in asset management decisions and implementation have different backgrounds, knowledge and priorities. The language of asset management is technical and presents a barrier to shared understanding. Different practitioners use the same words and phrases to mean different things, for example, the terms asset management and asset stewardship were sometimes not distinguished.
Objectives	There are divergent views about the scope and the objectives of capital maintenance. In terms of scope • Does it make sense to consider capital maintenance as such? Should it not be botex or totex? • Are we talking about maintenance management, asset management or asset stewardship and what do these mean? Contenders for the role of objective. • Compliance • Asset focus - physical condition • Service focus - capacity of the asset to deliver services, in the case of a water company to customers and the environment • Financial focus – capacity of the asset to generate cash from operations or a sale value in the resale market or as scrap • Resilience focus Each of these has various dimensions each of which could drive some form of maintenance expenditure. For example, resilience might be • Short term or operational resilience - the ability of the system to deal with the failure of an individual asset - a concern of the DWI • Longer term or strategic resilience to support sustainable outcomes in future • A grey area in the middle, where the fragility of the system's ability to cope with substantial shocks can be eroded Each of the contenders has its own definition, measurement and data issues and that there will be inconsistencies across companies and sectors. • Condition can be defined and measured but condition data is expensive to collect and condition does not correlate with serviceability. The sets of models in the CMA's reset of Bristol Water's price limits demonstrated the lack of any robust relationship. • Serviceability is relative to the recipient of the service. It is definable in principle but it is complex and difficult to specify relevant measures on which consistent data can be obtained. PR19 Working Groups have confirmed that searching for single outcome definitions that will span multiple customer categories is likely to be futile. • Financial capacity can be defined and evaluated but it does not translate into decisions about the productive assets. The notion of shared outcomes has not been at the forefront of thinking about investment in the water sector. Asset management has been driven by EU directives, the basis for which is not clear to those involved in decisions about what to do and how much to pay. We might speculate about how this will develop with Brexit. The course of EU directives might then provide a useful counterfactual to UK policy. As a result of the above • there is no consensus on conclusions about the quality of maintenance decisions or the adequacy of maintenance expenditure. • we do not know if the existing level of expenditure is too little, too much or just right. • if the parties involved are to move towards a better understanding of this area and to know whether the substantial sums are being well spent, then they should attach clear and common meanings to the concepts and the terms they use. • there are no shared outcomes in EBR terms. • these factors add to the difficulties of explaining the issues to government customers and stakeholders.

5.1.2 Politics

Motivations	The attraction to politicians and others of shiny new projects means there is a risk of under spending on maintenance. Politicians, including ministers, like something new to announce and are unlikely to counter any bias against capital maintenance. Some decisions with implications for asset expenditure taken by politicians, typically in response to events, are not soundly based. Policy makers, senior civil servants and advisers have not explained the risks of inadequate maintenance - major asset failures, long term outages etc - in terms that customers and politicians can understand. Information on customer preferences and risk appetites is not sufficient to establish the value of resilience and sustainability. Historically, civil servants have been desperate to avoid infraction from the EC and willing to sanction major investment to avoid it – e.g. TTWT. They do not advise ministers adequately on the evidence, options and consequences of decisions. There is reluctance to airing the issue even though all parties - politicians, regulators, customers and investors - have skin in the game.
Priorities	In the water sector, the political priorities – water and water resilience – are partial and leave the waste side underinvested. Waste water and water assets are allocated roughly the same expenditure and priority by companies, which is not proportionate, even though the public good aspects are probably greater in waste. The excess of investment in water quality (disputed by some, who say that water failures are much more material than sewer failures) means that some of the expenditure achieves little or no incremental benefit. This could be rectified by service separation and incentives that recognised different valuations, underpinned by more transparent dialogue with customers and other stakeholders over the specific values of wastewater outcomes. Traditional capex solutions to water quality issues can be disproportionately expensive if there is a low proportion of pollution in a catchment that they can address but alternative solutions which recognise this are not favoured by some companies or by regulators. In England & Wales undertakers have statutory duties to spend efficiently in water but no equivalent duties in wastewater. There are different regulatory regimes for the services– with the water business being more tightly controlled including mandatory inspection.
Fines	Public policy on fines (i.e. to relate them to ability to pay) means that company decisions on maintenance are driven by compliance. This is a flawed approach in terms of asset management as the indicators are lagging. The threat of higher fines following court judgements is likely to push expenditure on discharge compliance to uneconomic levels.

5.1.3 Uncertainty

Unknown unknowns	The presence of unknown unknowns may make what decision makers think is the preferred outcome irrelevant. Known unknowns are unknown in their extent: by definition, decision makers are not sighted and there will be unexpected developments. Examples given were unexpected changes in: technology; asset lives; demographics; farming practices; climate; and customers use of the assets – e.g. "flushable" wipes, increased surface run-off. An effective process under EBR or a CCG process as practised in England & Wales could be effective in exposing and reconciling preferences using assured information. In PR19, the intention is to strengthen CCGs' ability to benchmark performance by using nationally defined outcomes.
Effect on modelling approaches	Statistical models forecast the future based on what has happened in the past, by taking account of past trends and variability and assuming that the averages of the underlying probability distributions do not alter. If things change the forecasts will be unreliable. When things change, model forecasts are based on information that the change has rendered redundant. The "law of iterated expectations", which uses probability distributions based on previous experience to predict future outcomes, breaks down. This means that models cannot cope with unknown unknowns or what econometricians refer to as "extrinsic unpredictability". An example of how increased modelling capability does not necessarily yield benefits, is that many sewer collapses are caused by third party disturbance and as such, cannot be predicted easily by the owner of the asset.

6 Expenditure plan

6.1 Techniques and data

6.1.1 Techniques

Approaches to making asset management decisions	Approaches mentioned. • Investment appraisal methods as envisaged in MD161. • Risk based approaches such as the Common Framework. • Statistical modelling of serviceability and asset deterioration. • Comparative approaches, including benchmarking, cross section econometric modelling, asset health index. • Bottom up assessments, based on professional judgement and supplier specifications. • PFI contracts. • Increased role for customers – how do you want your money spent?
Frameworks	Plethora of frameworks bearing on asset management. Are they consistent and do they deal adequately with the maintenance element? • Green Book • Strategic direction statements • Common Framework • AMA, ISIL, ISO, PASS 55, AMCL, etc – including behavioural elements • Asset Condition and Asset Heath indices • Incentives set by the economic regulators • Implications of the requirements of the quality regulators, incl WRMPs These frameworks are good if they are deeply embedded and affect behaviour, training, recruitment, etc as well as strategies and standards, but not otherwise – a management issue. They could in principle apply across sectors but in practice need considerable tailoring for each. AMA was widely regarded as successful in its application in PR09 – its effectiveness stemmed from the combination of data, analysis and a system to measure and report asset performance.
Investment appraisal	Investment appraisal is a high-level approach within which other techniques can sit. Respondents said that historically IA approaches had been only rarely applied to maintenance expenditure and opex. Evidently, this situation was changing with the adoption of totex in PR14.
Risk based	The Common Framework is a black box and as such is prone to the risks associated with poor data. It is also the case that the fundamentals of the approach cannot be validated.
Statistical modelling	The use of deterioration models to allocate expenditure is positive but the data requirements are substantial. • The models technically sound: this does not mean they can predict which asset will fail. • The models are not based on data of the necessary quality. Data from the whole life cycle of assets is needed before the modelling becomes useful. If this is available, it allows inspection and maintenance to be focused to good effect. • Without such data maintenance expenditure is likely to represent poor value for money.

	• Modelling has improved; a big step was the introduction of deterioration modelling and further advances are likely to be minimal. • Asset managers rely on deterioration and risk models more than initial estimates of asset life. • It is important to allow for circumstances and without detailed adequate data the average results are too aggregated and not useful. • Integrated models, such as those promoted by SEAMS, are useful but not widely used in the UK, being more widely adopted in the rest of Europe and the US. • Some respondents were sceptical about models that are calibrated to historical data and then used for forecasting. This is not evidence based and will lead to problems of the type that contributed to the financial crisis. • The standard models do not help managers to deal with uncertainty.
Benchmarking processes, procurement and performance	Various standards are used to benchmark asset management processes – AMPAP, ISO 5000, PAS 55 and AMCL were mentioned. Most companies have not looked to benchmark their asset management performance. Comparatively, the air transport sector scores high on benchmarking, driven by compliance and complete transparency, as does oil. Achieving ISO 5000 or PAS 55 is equivalent to being merely competent (45%) on the AMCL asset management excellence scale. To achieve excellence, a company must exceed the competent standard and must embed the maintenance process in its management. Having achieved competence, excellence will be achieved through continual improvement. In the water industry in England and Wales, Yorkshire used to lead on benchmarking. More recently leaders are Anglian, Northumbrian and Severn Trent. An economic regulator can exert influence over the standards adopted by a regulated business – one example was the ORR requirement that NWR should adopt the AMCL benchmark. Asset management teams do not think holistically nor do they think in terms of the link between performance and serviceability or other outcomes. Sometimes this was said to reflect the fact that the organisation does not regard itself as an asset management business. Would it be worth it to increase the amount spent on asset management in utility companies? Yes, if there was a pay off in the form of lower risk, better service and lower capex. The WoCS might provide a comparator here. Management is much closer to the customers and the assets. Similarly, the south-east airports after demerger have a better grip of asset management than they did when part of BAA.
Asset health index	In principle, indices of asset health and performance are attractive but they are contentious, data intensive and take a long time to stabilise. A health index was introduced in rail before the Hatfield crash. NWR has had 15 years of experience and there are lessons to be learned. Ofgem has recently required the use of an asset health index by energy network businesses but the data input is not yet good enough for comparisons to be reliable.
Econometric modelling	The model spec, i.e. the relevant dependent and independent variables and the formulation of the relationships, depends on what we are trying to achieve. In Addition, the definition of some of the concepts we need to measure, for example, serviceability is controversial. The comparative approach inherent in benchmarking and econometric modelling requires the data to be comparable - defined, measured, cleansed, collated, normalised and analysed in a consistent manner - across businesses and in some cases across sectors and internationally. Any deviation from this limits the comparisons that can validly be made. Modellers should spend time interacting with people running the assets – model says this, what do you think?

PFI model	There may be lessons to be learned from the more commercial approach deployed in PFI contracts – cf regulatory contract at price review • Less uncertainty about performance measurement • Plan over longer duration – ring fenced to an asset area • Replacement and maintenance explicitly scheduled and funded (maintenance reserve account) • Allows smoothing of asset interventions • Level of application limited to large assets that can be treated as entities – fewer system implications AM in regulated companies tends to be centralised and so the chunks, even major ones, do not get the attention a PFI would bring.
Increased role for customers	How do you want your money spent? Do the people making the decisions and spending the money have any contact with the customers whose money it is? How would an insurance company manage the risk?

6.1.2 Data

Completeness and accuracy	Asset data failings mentioned included • data not available or partial, e.g. too aggregated – averages rather than distributions (important if relationships are non-linear • data not relevant – does not measure the relevant concept – e.g. the SIM score • data inaccurate – e.g. cost attributions, asset lives • data biased – e.g. justifying what we have always done, ignores important aspects • data not comparable over time – e.g. changes in definitions and methods • data not comparable between businesses – e.g. common definitions and methods absent, different business models and structures Inadequate asset, performance and cost data (any or all of these) mean that asset management models are not soundly based. Areas of relative weakness are underground assets and civils. Smart infrastructure will improve data (quantity and quality) and developments are due in next few years. Some would say this is overdue and that the utilities are slow to in reap the benefits of technology – hardware, software and processes. One example was a parallel with jet engines. Engine manufacturers now collect data continuously on the performance of engines in use and analyse it using the latest techniques. This could happen with major items of plant in water companies. It would avoid the need to develop the necessary skills in numerous companies. Ofwat has made it more difficult to make comparisons by ceasing to publish disaggregated econometric models and cancelling the June return. Comparison was made with NHH market opening where companies have done little to validate customer data. This will not be rectified until the market opens. Similarly, the main way in which companies will improve their asset data and know what needs to be done is when they need to make an intervention. Even then, some very major interventions, e.g. VMR, were not based on good data. The information is poor (i.e. insufficient to support optimal asset interventions on a lifetime, system basis) for the great majority of the water sector in England & Wales' assets. This means that the risk of unpredicted failures is high. The evidence for this is that for PR14, companies (unspecified) assessed the need for intervention on a small proportion of their assets – mainly large assets and those on which the delivery of ODIs depended. Significant parts of the system were not considered. When assets are evaluated there is often a need for strategic replacement investment.

Definitions	Issues mentioned by respondents about basic asset management variables were as follows. • Capital expenditure and maintenance – depends on accounting treatment, which can vary by company. • Accounting information is a poor representation of information about long lived capital assets. • Asset valuation – how many answers do you want? Depends on what question you are asking? There are no widely accepted and consistently applied valuation approaches even within sectors. What is the appropriate valuation concept for maintenance? • Asset condition – not related to performance or failure. • Asset serviceability – the measures are partial. • Asset resilience – who knows how to define it or how to measure it? • Asset lives – a moveable feast.
Consistency	Issues of consistency • the sources of data • methods of collation, for example sampling approaches • methods of analysis applied in the units to be compared. This can take time (years) and effort and any significant lack of consistency can lead to results that are inaccurate or biased or both. Example - it took Glaister (Imperial College) 10 years to assemble a data set to compare the performance of EU metro systems.
Cost of failure	A key failing of asset management models is the poor quality of information about the cost of asset failure. There is a trade-off between reliability (affected by downtime from maintenance) and availability of plant. The effects of asset failures on system performance are not properly valued – biased and based on a one-sided assessment of consequences of not maintaining. Customers want the right balance between bills and resilience and a prime consideration in striking the right balance is the cost of failure, including that part of the cost that is borne by customers. The cost of failure (value of avoiding failure) is hard to quantify, poorly understood and poorly reflected in decisions, so it is likely that we do not strike the right balance, including in asset management decisions. Example, train crash at Hatfield in 2000 • Railtrack knew about the nature of the problem and that replacement was overdue. • The rail did not get replaced (role of contractors, who controlled the maintenance schedule). • The consequences were wide ranging – Speed restrictions and track replacement led to significant disruption the whole national network for more than a year – The disruption and spiralling costs were part of the reason for Railtrack entering administration – TOCs suffered serious disruption – substantial revenue reduction for passenger TOCs in the year after the crash
Linking expenditure and performance	If we are to ensure that all asset interventions are effective and efficient, we need better understanding of the link between asset expenditure, including maintenance, and performance. All forms of asset intervention should show a clear cause and effect but the link between capital maintenance expenditure and performance is not well researched or understood.

	As technology develops the nature of this relationship changes. Technology is not the only factor that would affect the right level of maintenance that is subject to substantial change. Demand side issues are also changing rapidly, an important example being the growth in the use by customers of flushable wipes. This is having major effect on the serviceability and cost of running sewer networks.
Use of the available data	The quantity of asset data that is available is increasing and will increase faster as technology is applied to monitoring and control systems. The date now available to asset managers is underutilised and unless the ability of the asset managers in the sector to use the increasing quantities of data improves, it will become more so.

6.2 Regulation

Duties	In water, the economic regulator in England and Wales had an explicit objective of increasing the rate of new investment. The RCV model and affordability pressures squeezed out maintenance. The adoption of totex has been too long in coming. Botex presents fewer challenges. The adoption of outcomes in place of outputs makes monitoring of performance harder although the performance that is being monitored is more relevant. The move (by Ofwat) to ODIs presents a massive challenge. If, as some believe it will, it results in outcomes for which customers are not prepared to pay, and they are maintained in future, with implications for capital maintenance, then this will be a major inefficiency. When there is a big Q programme, maintenance is included with enhancement. Much of it is incremental and so this is not necessarily wrong. There will be a problem if it leads to a maintenance holiday with proceeds appropriated by shareholders – analogous to pensions holidays. There is a similar boundary issue with maintenance and opex. Are these border issues significant enough to mislead us? Both lead to an understatement of the actual level of maintenance.
Incentives	Incentives that were tough on opex and maintenance and lenient towards enhancement capex meant that the former were crowded out. "No matter how sophisticated we get, the regulator will not allow more expenditure" - but the example of reliability and DNO networks contradicts this view. Do comparative incentives lead to a race to the bottom? If companies do not spend the amount regulators have allowed, they will need to keep an eye on those assets. There is a degree of gaming, however, the incentive is designed: that is the nature of incentives, different incentive different game. Otherwise with ex ante regulation companies could not outperform on average – which they have done. Whereas totex might remove the capex bias it does not remove the incentive to game the regulatory plan and then underspend it.
Risk aversion	Quality, environment and safety regulators favour new capex over maintenance and opex solutions – possibly on grounds of less risk. • Examples of DWI and EA in E&W. • Catchment based approaches. • Gas distribution/HSE example.

Data	Regulators have insufficient data to know whether money allowed for maintenance in a periodic review has been spent on maintenance. Ofwat has made progress on this in PR14 and logged some companies down by significant amounts.
Challenge from regulation	In 2012, Ofwat dropped its requirement for reporters to scrutinise company submissions. The reporters were qualified engineers and had up to then provided an external view of and where appropriate a challenge to companies' asset management plans. Their departure removed a challenge based on an independent, professional perspective. Ofwat dispensed with a significant proportion of the engineers that until then been on its staff. Other sources have not filled the gap. This was in contrast with rail, where engineers reporting on safety provide on-the-ground intelligence to the economic regulator. An alternative view of the reporters is that they were largely ineffective, often because they did not dig deep enough and they were conflicted in their three-way contract (a logical impossibility) with Ofwat and the company on which they were reporting. Technical expertise among regulatory staff in some sectors – e.g. aviation and rail, where safety and economic regulation are combined in the CAA and ORR – continues to be substantial. By contrast in water environment interest groups have always had a strong influence. The DWI undertakes inspections but less frequently than before and the EA's policy is to prosecute ex post, unlike the NRA which used to deploy experts in waste water and flooding. These changes and comparable changes in the companies meant that the roles of asset custodian and intelligent client were either depleted or missing in the companies. As consequences, asset management plans are not honest or complete, for example some WTW asset management plans cover E&M but not the civils and decisions are based on opinion and not evidence. There is a general issue about the level of expertise and knowledge among those that decide, procure and implement decisions on asset management. Some observed that asset management strategy is not discussed at Boards, still less capital maintenance.
Questions	How can regulators assess how well a network is being looked after? Do regulators know what excellent or good asset management is? How do regulatory approaches incentivise capital maintenance when the quest for outperformance is likely to lead to its deferral? The regulatory regime in England has now been modified (totex) purportedly to remove its bias in favour of capex. Will this result in increased emphasis on capital maintenance? Should totex should be disaggregated into segments that are relevant to how it is actually spent? This would allow companies to demonstrate how they allocate their funding and it would make transparent how much wholesale provision costs. How long will it be until the impact of totex is felt in the E&W companies? In energy, it took several price reviews. Have companies responded to the shift of regulator focus to customer services from assets as before. Is a focus on affordability now, at the expense of future customers? Companies think that it is regulators who see capital maintenance as a balancing amount – is this true?

6.3 Risk and company governance

Risk assessment and management	Risk registers reflect single asset risks rather than the implications for the network or for service provision. Most bottom-up registers use generic risk profiles for asset classes that do not reflect all the factors that will affect risk. Most top-down approaches focus on a single issue, i.e. a resilience risk register, or a risk register for a major project, not consolidated. Companies do not keep risk registers up to date and realistic. There is insufficient review and testing of risk registers. The evidence about the likelihood and materiality of potential major risks is patchy. Responsibility for risk registers is sometimes delegated too far down the organisation. If the people responsible for the registers are moved too often between departments, this limits their effectiveness.
Governance	Given cultural and regulatory biases, Boards may not make the right call when: identifying the risks; evaluating their consequences; making clear and applying the Board's risk appetite; and taking investment decisions. • Budgets are not integrated but allocated to silos and large projects. In some cases, these have separate risk registers with consequences for allocative efficiency. • In some companies, maintenance budgets are divided between alliance members and controlled separately. The data re not assembled in one place so that sensible decisions can be taken and their effects monitored. • Engagement across silos is poor unless a new sort of risk bursts through and gets attention. • Risk registers that reach the board show the most material risks, when risk may be widely distributed across smaller assets. • Top managers struggle to see the whole picture and risks are not brought together for the Board. • The adequacy of the Audit Committee in risk management is questionable. • For excellent asset management, the Board must understand the asset management strategy and the planning process. • Despite the board's key role in this area, few have the requisite understanding. • Without guidance from the board, people at the operational level presume to know the correct solution to an asset problem. They may have good ideas but these may not be optimal from a system or company perspective. • The board should be engaged to check interventions and drive a culture of network-wide excellence. They should scrutinise the ability of all levels to explain asset management plans, convey the risks and their consequences, and explain how the risks might be managed. • For those in the organisation to make the correct decisions the Board must have clearly described its risk-appetite. • Has the focus of Boards shifted away from asset management issues as Boards have become more generalist?
Gearing and capital availability	Maintenance is an equity risk that should not be borne by customers. When gearing is increased, owners withdraw equity in the form of dividends and special dividends as envisaged at privatisation. Will the equity be returned if it is needed, for example for capital maintenance? A cash sweep to maximise the dividend can affect maintenance if it is not well managed. In a state-owned utility, if capital is rationed what happens to maintenance? Do opex solutions become more attractive.
Incentives	The regulatory regime in E&W means that if you invest you will get a reasonable return but it does not require investment to maintain the status of the assets.

7 Actual expenditure

7.1 Cultures

Motivations of relevant parties	Motivations among key groups may engender bias in favour of enhancement expenditure and against maintenance. • Investors – Some financial structures mean that maintenance takes a back seat. – Investors are more informed than they used to be and are beginning to ask important questions about their assets and the connection between financial and physical asset management and maintenance. – Maintenance is moving up the agenda as it increases as a % of cost and can have big reputational outcomes. • Boards – How well has Ofwat's attempt to make Boards take responsibility for important decisions such as investment strategy. Did the Boards do more work, get better data, pick up more issues and risks? – Ofwat has not produced any evidence or said what it thinks. • Senior management – Short tenures, relative to asset lives, mean that maintenance is not high on their agenda. – Asset stewardship is vulnerable to personality changes. – There is little attention to the need for a continuity of approach that would allow asset stewardship to be embedded. – Successful model in DNOs devolves much more responsibility to local people. – Can be helpful for management to reframe the asset management problem. AW's emphasis on carbon reduction (as well as cost) led to substantial win-wins, many of which originated with the supply chain. • Finance executives – Some do not understand the asset businesses they are running. – They are conservative, for example in water some do not acknowledge the concept of totex. – They continue to see maintenance as a balancing item – a slush fund. – This is not always intentional, money switches from planned to reactive as events happen, sometimes building up a significant backlog towards the end of the AMP cycle. – In some water companies, we see the concept of "propex" – minimum expenditure necessary to prevent an asset from falling over. Another possibility is to let an asset, say a pump, run until it fails and then replace rather than maintain it and to keep it going. • Customers and communities – Attempts to engage customers have a long way to go. – How well do customers or their representatives understand asset management and maintenance? • The supply chain linkages between asset management, capital delivery, contractors and operations are variable and sometimes ineffective. – This makes it even harder to ensure that asset interventions are effective never mind optimal.

	– The position is consistent with a water company culture described by some to be more interested in getting the glory for riding to the rescue than for preventing it from happening. • Operations managers – In many infrastructure businesses, the operations function is more powerful than the asset managers. – They live in a world of their own - the only way to communicate with them is via 3D modelling of new build. – The biggest impediment is organisational or cultural - where Asset Management and Capital Development may want to invest or improve, Operations will resist changes. – Someone else's problem – just give me assets that work and are always available. • Contractors – Where contractors have control they may focus on the easier jobs. They have to outperform to make a margin – but this is not easy on capital maintenance work. – If their contracts and their thinking are output not outcome based, over time this leads to resilience issues. – The major part of maintenance in water (possibly between 60 and 80%) is reactive in response to failures – not capable of optimisation. – There are always plans to reduce the proportion of reactive maintenance. Modelling gives estimates that moving from 80% reactive to 80% planned should save 25% of maintenance expenditure. – Lack of good data on the assets also contributes to this. • Asset managers – Impediments come from operating a site based approach to asset management and failing to consider whole network effects. – Totex has not been optimised – opex and capex thinking continues. – They tend not to think in terms of asset classes but in terms of a particular asset – no consideration of how others may fail. – Display bias in favour of new assets rather than adopting opex or capital maintenance solutions. – They like projects they can point at and other ways of delivering an outcome may not get done. Consequence are that maintenance and opex solutions take a back seat and some new assets have become unused or unusable. Examples • New WTWs were not maintained and are not used but continue to be in the RCV. Sludge driers ditto, also water quality examples. • Some companies set up AD but as alternatives appeared (driven by policy changes) these decisions were no longer optimal. • Energy use and procurement across a water company: a whole network approach could have minimised costs and saved a lot. • For resilience, companies realise that there are more efficient ways of maintaining the network service level than big investments, but continue to promote traditional solutions.
Monopoly culture	Lack of innovation - water companies have been slow to adopt new instrumentation technology even though it is getting cheaper. The gap between the available technology and water company practice is widening. Not invented here is prevalent - Anglian has changed and adopted standardised designs for parts, making manufacture of replacements more efficient and replicate of assets only building a new design when necessary. Others have not emulated this. There is normally an internal tussle around enhancement spending with operations and asset management wanting different things. Being monopolies, they can afford that luxury. Individuals don't worry about efficiency and serviceability because there are no short-term consequences of not worrying.

7.2 Business processes

Business cases	It is easier to make the case for expenditure on big, new schemes than on maintenance. For maintenance expenditure, there is no definitive answer to the question of what happens if we defer for a few years. It is difficult to show that it has to be done and easy to defer it. The difficulty is due to a combination of uncertainty about events and the related issue of poor information about the assets. Ideally, we would have measures of asset health and performance but these are contentious and data intensive. They are not widely used in business cases even for new investment. Totex, whole system and whole life concepts also are poorly understood and applied. Usually, capital maintenance expenditure does not require a business case. The counterfactual to new capex might be to maintain but this option is not usually considered. Some cases for new expenditure do not pick up the need for more maintenance of the new assets.
Budgeting	In recent periods, regulated companies have regarded maintenance as a balancing item to keep prices acceptable. In the water industry. this was to offset the effect on bills of investing heavily in new assets to meet new obligations under the EU directives. Maintenance should be seen as an essential and enduring process that is part of asset stewardship. Instead maintenance is a function of the budget rather than the budget being a function of what a company should spend on looking after its assets. For some assets, the effect on performance of slowing the rate of maintenance is not easily or quickly observed. This means that, up to a point, it can be treated as discretionary in the short term without an observable deterioration in the value or performance of the asset. It is not understood that if a maintenance holiday is taken, it will have to be paid back by extra work later. The level of capital maintenance expenditure depends on how budgets are allocated within a company.
Resources	Short term tenures at the top. No continuity or succession planning or long term commitments. Shortage of people with relevant knowledge of technical skills at the top – risky for such unusually asset intensive businesses. Utility companies are short on senior people with the ability to make good use of new technology and the data it generates. As a result, they have little scope to develop asset strategies and those that they do develop are mediocre by modern standards.
Risk assessment	Research by McKinsey shows that biases in decision-making are leading to under-investment. Many executives display a high level of risk aversion when confronted with investment decisions, even relatively small ones, such as those involving capital maintenance. Short tenure, pressure for dividend rather than value creation and weak representation of future customers are among the reasons for this. At the project level, how engineers and operations people make judgement calls depends on the culture of the organisation. A blame culture can lead to bad outcomes: problems being kept hidden; misreporting; overegging expenditure requirements. Avoidance of a blame culture between regulators and regulated is a key element of EBR. This requires professionalism and independence on the part of the regulator as well as the company re-enforcing openness and ethical behaviour. One respondent thought that the explicit adoption of asset excellence standards and continuous learning on both sides would play an important part in this ethical shift.

Internal challenge	Senior executives in water with engineering backgrounds are few. Asset engineers in the companies might blow the whistle, but the culture militates against this. The risks of carrying on under-maintaining are insidious and long term and not necessarily life threatening, whereas reducing the expected dividend is seen as career limiting. The CFO, as custodian of the dividend, is more powerful than the engineers and may abuse this power by pushing for efficiencies that do not exist. Backward looking reviews to test of the effects on serviceability of investment should inform the modelling approaches and decisions. They are undertaken by some companies but the lessons are not often implemented.
External challenge	Customers are insufficiently informed and empowered. Investment managers who should challenge on behalf of the ultimate shareholders are more interested in competing among themselves. Contractors are driven to find the lowest cost interventions, storing up problems and cost for the future.

8 Actual outcome

8.1 Delivery

Positive views	So far, so good, no major failures so far (a water industry person).
Not positive views	In the water context, if the major investments in AMPs 1 to 4 have been under-maintained, based on an historical approach to maintenance expenditure whereas new technology tends to have more bits to go wrong, there will be a big bill for future customers. We do not know whether maintenance has been adequate or not but this has not been a priority for the companies or their regulators. It is a sorry tale of a race to the bottom between companies and the regulator whereby • The company does not have enough information to present a compelling case for maintenance expenditure. • The regulator, seeing this, does not allow as much as the company claimed (rightly or wrongly). • The company is unable to appeal due to its lack of information. • The result is underspending and asset deterioration.
A counter view	Companies should start from the assumption that the current level of serviceability could be maintained and sustained more efficiently. Asset management processes and data that are not excellent, combined with an excess of risk aversion will almost certainly lead to excessive maintenance expenditure. So-called maintenance activity which led to improved serviceability would be excessive if customers did not want to pay for the improvement. The serviceability objective should be stability across all asset classes otherwise some maintenance interventions will not be efficient. A crucial requirement is that each asset intervention should have a clear cause and effect basis, but this test is not applied. Successful capital maintenance programmes are rare: they sometimes pop up in the wake of an incident or disaster but thereafter senior management loses focus and the good fades away. Classic bad examples were the Potters Bar and Hatfield train crashes.

8.2 Trends and events

Factors that have influenced the level of capital maintenance in recent decades were summarised by Ofwat in the context of the level of capital maintenance expenditure in E & W in the 30 years between 1985 and 2005[12].

The following is a list of the factors identified by Ofwat with respondent comments shown as bullets.

Factors listed by Ofwat with respondent comments	Growth in population and consequent growth in services and assets with maintenance growing in line with the stock of assets. • This is reasonable, other things being equal. • The link between growth in demand and maintenance expenditure is not well evidenced. Growth in assets needed to meet stringent standards for water and effluent quality with consequent growth in maintenance. • Reasonable ceteris paribus, but the UKWIR report on which this statement was based was inconclusive. • The link between growth and capex ignores the scope for different ways of working and improved utilisation of the assets. An aging asset base with older assets requiring more maintenance. • There is no evidence for either the ageing or the consequence for maintenance. • Some old assets may require less maintenance than current ones. New assets, having more sophisticated instrumentation, are more likely to fail due to small component failures and will require regular maintenance and monitoring equipment that reports back to a control centre will have to be replaced every 5 years. Changes in construction costs. • No convincing evidence for this. • Relative to other costs, such changes are unlikely to persist in the medium to long term. Changes in asset lives, with a growing proportion of assets with shorter lives, that need replacing more often. • Possibly true, other things being equal, but it would presumably reduce the cost of the replacement assets. • What about the pervasive practice of life extension? • Argument on an UKWIR report that was not soundly based. • M&E assets do not last as long as civils. Civils are usually because of a change in the level of service and not asset performance.

[12] Source: Ofwat – Future water and sewerage charges 2009-10. Final Determinations. Page 2 of 12/RG/06/1

9 Comparisons with other sectors

The following are points that respondents made about asset management and maintenance in other sectors.

Air transport	The regulatory regimes that get the best outcomes are in air transport and petrochemicals. Neither are regulated by economic regulators: both are heavily regulated for health and safety with full transparency of data and incidents. Air is the best example with continual modelling, revision of models, collection of data, identification of missing data and collation of external data. One airline employs four statisticians whose role is to continually monitor the fleet of 80 aircraft to monitor and forecast component failure. This means that the operator can make a compelling case to the regulator to change inspection schedules – i.e. they have built up trust with the regulator. Aircraft in general use have planned capital maintenance but are kept in flight as much as possible with spare parts flown around the world as needed. This is the result of the big financial and reputational incentive to keep the plane in the air.
Petrochemicals	Comparatively, oil scores very high (driven by compliance and complete transparency) To achieve excellence, a company must exceed the competent standard and must embed the maintenance process – some in this sector do so, but not many others. The biggest driver in petrochemicals is the potential commercial loss from asset failure. This has decreased capital maintenance spend in recent years as the oil price has fallen. Petrochemicals is the best example of strategic asset management, and readiness of spare parts and quick repairs. Petrochemical industry is good at this because they throw money at the problem due to the high risk of loss-of-life and the high economic value of the product. The BP Gulf oil spill appeared to result from a poor decision on the type of asset used and an inability to isolate that asset when it failed. In aviation, oil and gas, and power generation the link between maintenance and revenue is direct – not so in utility networks.
Energy distribution	Electricity distribution is well behind the curve in understanding whole asset life approaches. Gas distribution faces issue of 90% being underground (similar to water) and 90% of maintenance expenditure being replacement. In gas the threat to life may not necessarily be the prime motivator, but retribution from the HSE may be. Gas networks are more closely connected to asset failure risk – probably due to direct consequences. Ofgem has promoted the asset health approach but does not believe the results – yet. The stage of development of the measures is such that the companies still have a lot of wiggle room.

Telecoms	Telecoms are commercially driven even though failure can be life threatening - without telecoms health, energy and water would fail. Telecoms assets have shorter lives and asset stranding is prevalent, but maintenance seems to be less of a concern. In telecoms, the single biggest problem is new connections for customers.
Roads	An example of a good approach to capital maintenance comes from the expansion of the M25. Balfour Beatty and Skanska changed from the traditional approach of resurfacing the whole road to only resurfacing those areas which required it. Their offer came in cheaper by £100m than other contractors.
Rail	The ROSCos and HS1 are quite good at life cycle planning and HS2 and Crossrail are expected to be good too. Such an index was introduced in rail before the Hatfield crash. NWR now has had over 15 years of experience with it and there are lessons to be learned. Technical expertise among regulatory staff in rail and aviation and rail, where safety and economic regulation are combined in the ORR and the CAA continues to be substantial.
PFI	Despite being criticised, PFI schemes did much to investigate whole-life cost approaches. They incentivised owners to account for the cost of maintenance so it was more visible in contracts. Risk was collocated with maintenance responsibility. The solution for water regulation will have to be a better link between risk of failure and consequences. Particularly if directors are looking at exit plans post-review and investors want continued dividends.
Other	The institute of Asset Management has good approaches for property and buildings. P3 Canada and P3 Australia have good information on life extension. The TTT whole life cost model is said to be leading edge.