Asset health in the water sector

Proposal for a framework

United Utilities

Water for the North West

Asset health in the water sector

Proposal for a framework

The overall health of water company assets is of interest to customers, companies, regulators and other stakeholders. We all want confidence that the health of our assets is adequate to ensure service and environmental performance can be sustained and enhanced, that our systems are resilient to the increasing frequency and severity of external shocks and stresses (such as climate change) and that the costs of maintaining our assets are being fairly split between current and future generations.

Asset health has been in and out of focus over the years since privatisation and most would acknowledge that its complexity and lack of a simple consistent metric makes collaboration and benchmarking across the sector difficult. As performance targets get tougher and bills get lower, the likelihood that companies are tempted to take more risk with asset health, jeopardising long-term resilience and sustainability, must be increasing.

It is in all our long-term interests that a mechanism is found to enable better understanding of the true and consistent asset health position of all water companies. This would help to stimulate debate on questions including:

- What is an appropriate level of risk to take with asset health?
- Do companies need to improve asset health due to future stresses such as from climate change?

In this document, we present our view on how an asset health framework could be developed to capture a range of concepts that are required to cover all the elements of health.

Why is asset health important?

Water companies need to ensure that their assets are being maintained appropriately for the benefit of current and future generations. Ofwat has described asset health as a key factor supporting network and service resilience. It is therefore clear that asset health is a useful indicator of a company's ability to continue to perform its functions for the benefit of customers and the environment, now and in the future.

Climate change means that our assets are going to have to cope in future with more extreme conditions and wider fluctuations in the operating environment. It is likely that companies will, in some contexts, need to enhance asset health to maintain the same level of overall risk to service. A coherent asset health framework would be invaluable in enabling a mature conversation between companies, customers and regulators about the concept of risk.

What is asset health?

Poor asset health occurs when assets are allowed to deteriorate to a point where the risk of failures, which will impact on customers and the environment, becomes unacceptably high (accepting that not all failures are due to poor asset health). By this definition, asset health therefore deteriorates as the reliability decreases. However, using probability of failure alone to define unacceptable risk is too simplistic.

This is because what constitutes an unacceptable risk is different for more critical assets than for the other assets, where poor asset condition may be based more on comparing the cost of failure versus the cost of replacement in purely economic terms. Different assets may need different measures of asset health but they could be indexed to provide a consistent overall view.

Asset health in the water sector

Defining asset health

Through interviews with water companies in England and Wales held in 2017, CH2M (on behalf of Ofwat) found no consistent definition of asset health. Several companies considered that asset health was a richer concept than asset condition, taking into account not only the physical state of the asset but also the role and importance of the asset in ensuring that service performance targets and customer expectations can be met.

These companies combined likelihood of failure (asset condition) and severity (importance) to present a view on risk (likelihood x severity); we believe that this detracts from the clarity of the concept of asset health and therefore prefer to present asset health as the state of the assets (focusing on the likelihood side of the risk equation only) as this is easier to understand, define and measure.

If we assume that deteriorating asset health can be measured through probability of failure, now (under normal and abnormal operating conditions) and in the future, we will need to understand:

- The probability of asset failure in each of these contexts (lead indicators and forward forecasting will be essential); and
- How best to balance asset health against other forms of resilience in order to achieve an economic level of service, now and in the future (system models may help with this).

The link to resilience

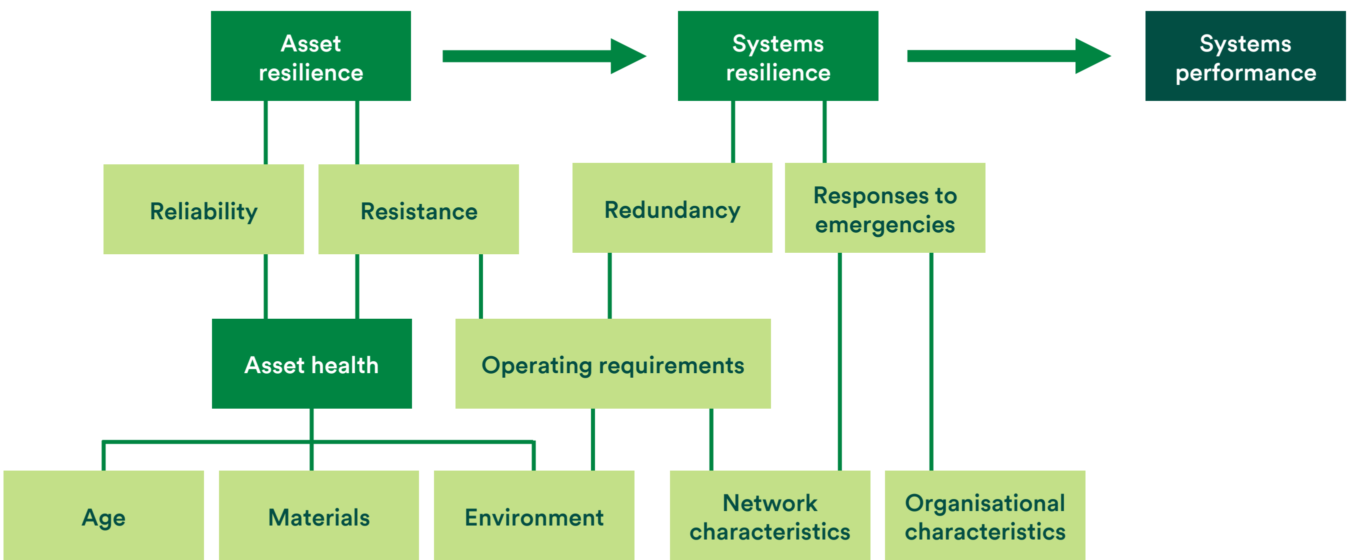
Asset health also contributes significantly to resilience, the ability to cope with, and recover from, disruption and anticipate trends and variability in order to maintain services for people and protect the natural environment now and in the future (Ofwat 2017).

In particular, asset health supports the **Reliability** and **Resistance** elements of the 4 R's of infrastructure resilience as outlined by the Cabinet Office in 2011. Figure 1 illustrates this relationship and shows how asset health supports asset resilience, which in turn supports systems resilience and systems performance.

The importance of this diagram is that it shows how systems performance (based on our measures of success) in a reasonably healthy system of assets can be maintained, and even improved, by improving operational response and increasing system redundancy through, for example, increasing capacity and network integration.

Whilst these options are important for achieving a balanced approach to resilience overall, it is our contention that eventually a net decline in asset health (particularly for the more critical assets) will result in increases in asset failure, the effects of which will exceed the compensational ability of our operational and system resilience. It is inevitable that service failure would be the ultimate result.

Figure 1: The relationship between asset health and resilience (CH2M, 2017)



Asset health in the water sector

The weakness of serviceability measures

In the 2017 Targeted Review of Asset Health, CH2M found widespread use of the original 1990's Ofwat serviceability indicators (and variants of these) as proxy indicators of asset health. Many companies were satisfied with the use of these measures as broad indicators of asset health, although several had refined these measures to, for example, improve consistency and eliminate double counting.

Some companies were concerned that using serviceability-derived measures had conflated the issues of asset health and the ability of their systems to provide a good service to customers. Although asset health and systems performance can be strongly related (see Figure 1), it is possible, within limits, to provide an adequate level of service to customers even if individual assets are in poor health, since redundancy and spare capacity within networks and systems can compensate for the poor health of individual assets. However, allowing asset health to decline cannot continue in perpetuity. Eventually, declining asset health will result in asset failure and potentially, service impact. The value that good asset health provides may not be fully appreciated by some until the unforeseen event actually occurs.

Over the last five years, an emerging concept of asset health considers the physical condition of the asset taking into account the (dynamic) environmental conditions to which the asset is exposed, and the operating conditions within which the asset is expected to function. To develop a more rounded definition of asset health, analogies can be drawn to human health concepts such as 'fitness' and 'tired' or expanded to include an ability to react effectively or 'sprint' in response to a shock. Considering this analogy over the lifecycle is also useful.

Human health problems are detected and treated through different types of intervention based on their criticality and changes over our lifetimes. The same can be true when dealing with physical assets. For example, the best of different resilience interventions might be weighted in favour of a particular factor or factors from the 4R's of resilience which is appropriate to the particular point in the asset lifecycle.

Asset health in the water sector

Systems Thinking: measuring health

Asset health, along with other concepts used in the UK water sector, such as resilience, can be challenging to explain. We believe that there is value in applying a human health analogy. Not only does this help create a common language and understanding, it will also support our dialogue with customers and other important stakeholders.

A human body is a complex system, like a water and sewerage system, formed of many separate but symbiotic organs and systems working together. The function of which can be impacted by the external environment.

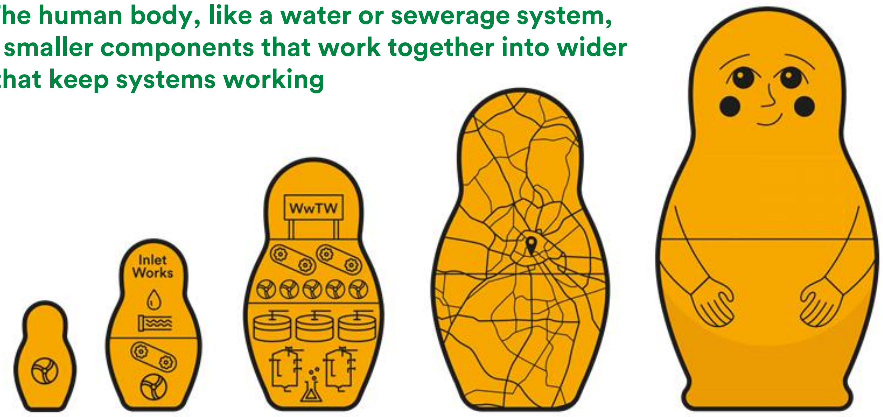
When assessing an individual's remaining life expectancy, you could take the easiest approach and just look at their age. Without knowing anything else about a person, their age is enough to give you an idea of whether they are at the beginning, middle or towards the end of their lives.

However, doctors don't just rely on age, they also measure a number of 'performance' metrics including weight, blood pressure and pulse rate. They may also take into account other factors like health history, lifestyle, diet or even genetics to improve the accuracy of their assessment of remaining life.

Many of the concepts that apply to assessing human health can also be applied to assets and systems. A key consideration is that age alone cannot always tell you everything you need to know about the health of a complex system.

The same principles hold for water and sewerage systems, where a single metric is not always adequate for assessing asset health. Further, the metrics for assessing asset health may differ by asset type.

Figure 2: The human body, like a water or sewerage system, comprises smaller components that work together into wider networks that keep systems working



When considering asset health we look at many different factors such as age, material, operating environment, maintenance history, etc. Just as a doctor seeks a broad range of information to understand the health of their patient.

Systems Thinking delivering resilience

Systems Thinking is a key business strategy for United Utilities to improve customer service and efficiency. It also provides resilience in the face of a changing climate, a growing population and changes to asset health. Systems Thinking means looking at the bigger picture, understanding how everything is connected, and being able to start to predict performance.

It is enabling us to work smarter. Our systems thinking capability brings together people, processes, tools and technology, and data and information to ensure our business is characterised by the following Systems Thinking traits:

- A strong customer service and systems thinking culture throughout the organisation
- Clear line of sight, vertical through levels in each system and horizontal between systems, across different capitals and between operational, corporate and financial factors
- Effective data and information management, a foundational trait for systems-based ways of working
- A whole of life approach to managing all assets, not only physical ones
- A risk-based approach which accounts for uncertainty

This is supporting our delivery of resilience in the round, built upon the concept of interdependencies between related systems with customers at the heart of it all. Understanding asset health will help us understand the vulnerabilities within our systems and manage them better.

Asset health in the water sector

An asset health framework

Our proposal is for a framework for asset health, applicable at multiple levels, using a human health analogy, consisting of three primary components:

- **Wellness** – we can measure how fit a system is today by observing how well it is performing. Whilst this information is useful as supporting information, in and of itself it will not tell us how long that system might continue to perform at such a level. This is the concept that the common, lagging “asset health” metrics for AMP7 tend to measure.

- **Fitness** – how fit a system is governs how effectively it can cope with changes in activity levels and how resilient it is to shocks and stresses. In the human system, if your fitness levels are poor either due to age, illness, lifestyle or genetics you are less able to bounce back from shock events. This is a key concern for water systems health; that as the average age of components increases it will be harder to cope with and take longer to recover from incidents. If the environment becomes more challenging an increased level of fitness will be required.

- **Life expectancy** – this is the third dimension of asset health. This is not a novel concept and practitioners are already familiar with the concept of short, medium and long-life assets. The life expectancy is the timeframe over which the asset can be expected to operate

Wellness

The ability of an asset to deliver its function under normal conditions

Fitness

The ability of an asset to deliver its function outside normal conditions, considering external pressures and forcing factors from its environment

Life expectancy

The period of time over which an asset can deliver its function under and outside of normal conditions

An example of how this framework could be applied to our assets is presented on page 9.

Asset health in the water sector

Short and long-life assets

When looking at water and wastewater systems, for many assets, a simplistic measure of age is not enough to determine health. However, there are exceptions where aging processes are very well understood and impact on performance and cost of ownership are obvious. We also have a growing cohort of relatively short-life assets such as IT where obsolescence and manufacturers support factors tend to be most significant to end of life determination.

However for longer-life assets such as civil assets, condition is much more important than age. In some cases, where the links are well defined, performance trends are more useful for determining health than either age or condition.

Different metrics would be required for different asset types.

Levels of diagnosis

It is also the case that the tests of human asset health can be 'hierarchical' from a diagnostic point of view, focusing down from general screening for increased depth of understanding – albeit for increasing cost (for example, measuring blood pressure, to undertaking an ECG, to a cardiac MRI scan).

This is an analogy that can also hold for measuring and understanding asset health, but we need to understand what the right high-level indicators and triggers are and what are the needs and options in terms of getting a more sophisticated and detailed understanding of patient health/asset 'condition'. We need to determine the optimum balance between the cost of diagnosis versus the risk to the system performance.

Criticality

Criticality is a measure of the importance of an asset. Within a system of assets, and continuing with our human health analogy, criticality can be defined:

- Criticality – with the human body, whilst every organ has a purpose there are several that we can live without due to a combination of evolution and medical advances including the gallbladder, spleen and much of the digestive system. Whilst losing any organ might be less than ideal for long term health or quality of life, it highlights that some components of any system are more critical to its performance than others and that criticality isn't fixed, for example technology can play a role in changing levels of criticality.

Health is a measure of likelihood of failure of the asset, now or in the future and criticality will determine the potential consequences of the failure. Combined, this provides an indication of risk.

It is important to measure health and criticality separately as this informs causality of potential problems and how to target mitigations. Criticality is also used as a stand-alone parameter to inform prudent levels of investment in inspection, maintenance activity and data needs.

Definition of asset health

The 2017 Ofwat Targeted Review of Asset Health and Resilience in the Water Industry revealed that there was no consistent definition or measure of asset health being used in the UK. Furthermore, the international review undertaken by CH2M indicated that this was also the case internationally. A definition for asset health is an important starting point for creating a common language and understanding, to enable more objectivity and insight into the role of asset health in asset management.

Without a common agreed working definition, it is difficult to provide insight into the role of asset health and the value of measuring and managing asset health.

An understanding of asset health should provide a basis for helping to understand how likely our assets are to perform well; how this may change in future and when they may need to be replaced.

Our proposed definition is:

Health: defined by a condition of wellness, fitness and life expectancy. The ability of an asset to deliver its function under and outside of normal conditions, over an extended period of time.

Asset health in the water sector

Common measures in a consistent framework

The concept of asset health is nuanced and there is not a single measure of asset health. Before we can optimally manage asset health, we need to work out exactly what it means and how it is best measured.

We are proposing that there is value in developing a suite of measures (sub-measures) reflecting the various aspects of asset health (wellness, fitness and life expectancy) and from these a single index measure can be created. This could ultimately be at a company level but could initially be applied at a smaller scale to a group of assets. An example of the framework being applied to water distribution mains is provided overleaf (on page 9) as an illustration.

We need to think about how a baseline can be set for each company and how tracking should be incentivised. Any theoretical asset health optimum will depend on context; existing balance of resilience and the associated criticality of assets and the systems they are part of.

However, an important starting point would be a comparative measure that can be tracked and trended with time and which will increase in value as our wider approach to managing our assets becomes more sophisticated.

We would like to work with the sector and with regulators to develop and agree common metrics that cover the three key components of asset health:

- Wellness
- Fitness
- Life expectancy

Water companies and regulators use a variety of typical data that they regard as being informative regarding asset health. It is striking that these are largely lag performance, mostly reflecting current health in terms of 'is the asset performing OK' or 'Wellness' to use the analogy introduced on page 7.

The common asset health outcome metrics in use in AMP7 are lagging, wellness type measures such as:

- Mains bursts
- Sewer collapses
- Unplanned outage

These can be informative but they do not tell the whole story. A richer picture can be revealed by expanding the framework to include measures of fitness and life expectancy.

Examples of existing asset health metrics in use in the water sector and other sectors, in the UK and internationally, are provided in the Appendix.

Asset health in the water sector

Applying the framework

The framework could be applied at multiple levels, from a whole company level down to individual asset groups. This, for illustration, is one way that the framework could be used to measure the health of a group of assets.

Water distribution mains example

The water distribution networks across England and Wales have received significant investment since privatisation, particularly through quality drivers in AMPs 1-4 leading to substantial replacement and refurbishment. However, in the last ten years the industry has been replacing and refurbishing less as investment is directed at more innovative interventions to manage and improve service.

The overall age of the water mains network in some companies is now increasing, however the average life expectancy of these assets has also increased through interventions such as pressure management and localised rehabilitation.

Current asset health metrics

Since privatisation the key asset health performance metric for water mains has been burst repair rate. This is a suboptimal measure of asset health as it includes for company activity in finding and fixing leaks. Proactive leakage detection leads to a short-term seemingly worsening health indicator. Other measures that have been suggested as health measures, such as properties at risk of low pressure, are rarely to do with network health as more often they are inherent design issues.

The following are examples of potential measures for wellness, fitness and life expectancy that could be used for water distribution mains.

Wellness measure

As an alternative to remaining life, customer reported leaks (associated with network asset failures) could be reported. This has a number of advantages over the legacy ‘mains repair’ metric as:

- It is a commonly held metric across the industry already
- It is not adversely influenced by company leakage detection activity
- Surfaced leaks are a true indication of the health of company assets
- It should correlate strongly with the remaining life of the network

It is not just the pipes that fail, the fittings on the pipes also fail. It would be recommended that reported leaks associated with the failure of distribution mains, fittings and company owned service pipes should be included as a water infrastructure asset health measure.

Fitness measure

A good fitness measure is the existing “customer minutes lost” supply interruption measure. This gives an overall view of the ability of the network, including the operational management, to sustain service, despite localised failures or constraints. This measure is significantly affected by management operational decisions, however it is underpinned by the resilience of the network to failures through the provision of operational rezones and appropriate response and recovery contingency plans.

A second potential type of fitness measure would involve an assessment of changes in service such as; low pressure, interruptions or taste and appearance contacts, during periods of high demand due to extremes of heat or cold. Such a measure would require temperature or demand thresholds to be defined.

Life expectancy measure

An ideal life expectancy asset health measure for water mains would be the average remaining life of the network. This metric could be influenced;

- Either by increasing the lives of existing assets through interventions such as pressure management, calm networks, or relining.
- Or by replacing or rehabilitating pipes, effectively giving complete new lives

For this to work there would need to be agreed;

1. Mains cohorts, by material groups and diameter bands
2. Asset lives for cohorts, operating under different pressures

There would be work to do to ensure reliable, accurate and complete data from such a measure but a rules based approach to assessing extended asset life could be developed in collaboration.

Any one of these metrics alone gives an incomplete view, but taken together they provide a **richer picture** of asset health. Asset health metrics that fit this framework could be applied at many levels, from whole company down to groups of assets.

Asset health in the water sector

An optimal, sustainable level of asset health

Asset health is one of the balancing elements of resilience. Whilst a temporary deficiency in asset health can be compensated for by other aspects of resilience, there will be a point where the asset health component will become critical. This will be situation specific and at the present time, water companies do not fully understand the trade-offs and the point of criticality.

This means that there are situations where the current level of asset health is not at an efficient level, either from a positive or negative perspective.

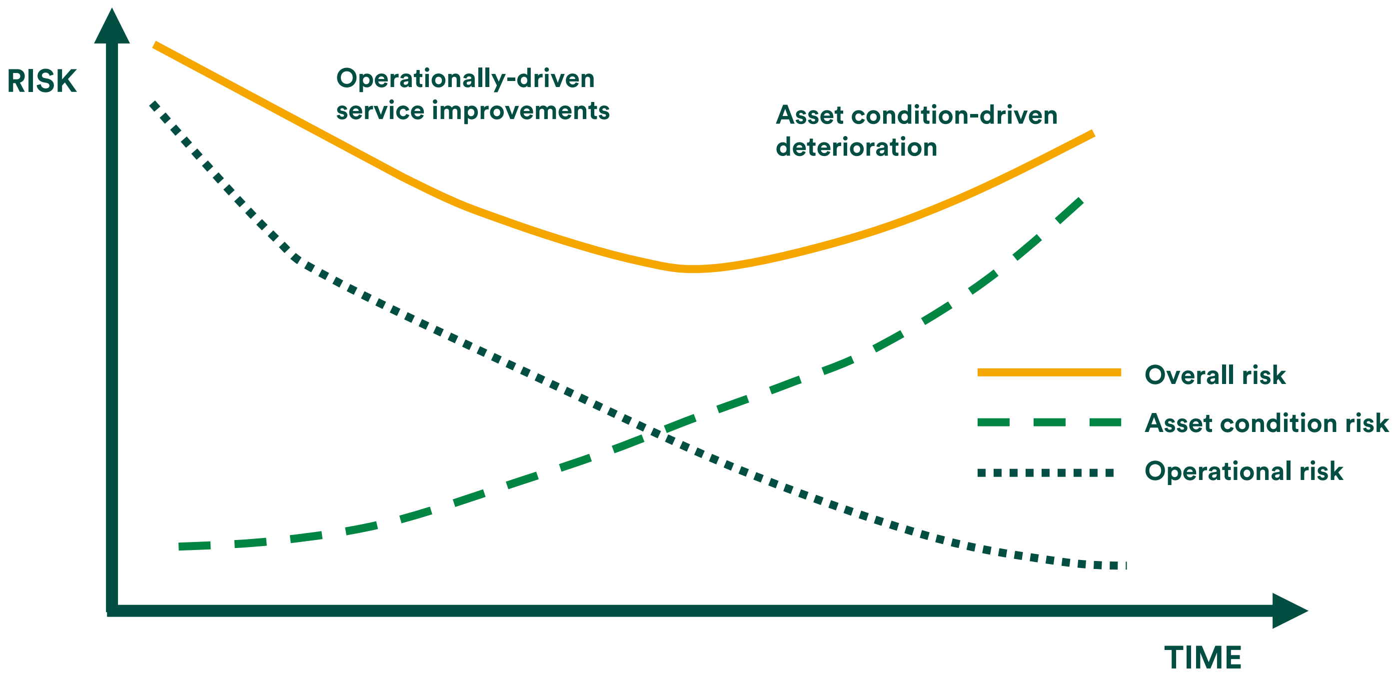
It is not fully understood how asset health contributes to long-term resilience and the ability to compensate for unexpected system shocks; however, we know from experience in our sector (the high number of bursts and discolouration events occurring in the 1980s caused by iron pipe deterioration) and other sectors (Network Rail and its predecessors' experience with catastrophic failure of civil infrastructure in more recent decades) that if asset health is allowed to deteriorate past a critical point, that operational resilience cannot compensate for the impact.

The concept is described in Figure 3 where, over time, operational service improvements mask deteriorating asset condition. When the most straightforward operational enhancements have been exploited, the rate of improvement from operating strategy starts to decline and asset condition starts to dominate as the overall risk position worsens.

This raises the possibility that it may be feasible to define a sustainable level of asset health where, taking all costs and benefits in balance, the most optimal level of asset health is, based on customer expectations. This would need to take account of how future innovations may affect this as for the water sector the improvement in service from operational changes and the implementation of new and newly adopted technologies still has further to go.

There are other stresses that have an adverse impact on these risks including climate change that would also need to be taken into account. Climate change would have the effect of shifting the point of sustainability as operational interventions become less effective at mitigating the more extreme conditions.

Figure 3: Operational improvements and innovation can mask underlying asset condition deterioration – for a time



Asset health in the water sector

In conclusion

A single metric can't tell us everything we need to know about asset health, just as we wouldn't expect a doctor to be able to know everything about a patient's health just by looking at their date of birth or taking their pulse. A framework based around the three concepts of **wellness**, **fitness** and **life expectancy** would provide a deep and insightful view of the real asset health of companies. By framing the language around these well recognised "health" terms, it will also be helpful for opening up the debate with stakeholders and customers about water sector performance on asset health.

There are challenges for companies and regulators alike. Which measures are the most appropriate to use for each component of the framework to deliver a robust assessment of asset health without creating undue burden for data collection? How do we get convergence in data definition and standards to ensure adequate consistency between companies? How do we all gain confidence that such a framework can provide an accurate assessment of future efficient maintenance requirements with all the appropriate customer safeguards?

We don't have the answers to all of these questions, but we believe that the concept of a framework based on the relatively simple concepts we have described can resonate as a useful model to consider. We hope that this is a constructive contribution to sector thinking on asset health and helps stimulate collaboration between companies, regulators and other stakeholders to pursue a more future looking, risk based approach to the consideration of asset health at Price Review 2024 and beyond.

Key references

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Appendix

This appendix illustrates how different industries and different geographies use a range of metrics, indexes and other tools to characterise and understand asset health, and traits related to asset health. It has shown that:

- Age and condition models exist at various levels of maturity and United Utilities' Base Asset Health Index is one approach the industry could explore further.
- Performance and service metrics can be aggregated and reported in a number of different ways. Care needs to be taken to ensure comparability when looking for trends. The approaches are focused on what we would have previously described as serviceability. These are mostly lag measures and contain a mix of asset performance and service measures. These would tend to be focused on current wellness, but further analysis on trends could generate leading indicators that would help start to support awareness of declining asset health. For example, some water companies use trends in asset performance, such as burst rates or sewer collapse rates to forecast the optimum time to replace the asset based on consideration of the whole of life economic models. Cohort models can be used for this purpose.
- Risk models often include components of asset health (asset failure probability component) but conflate this with criticality to infer risk. Clearly understanding what asset health is (and is not) is important if it is to be used effectively within the industry.
- State of the Assets reports could help to improve awareness of the importance of asset health among stakeholders.
- Maintenance metrics are not so directly relevant to asset health and without forecasting and extrapolation the information they provide is limited; however, the information is complementary.

Categorisation of asset health metrics

The list below summarises some of the general categories of approach that are used to measure asset health. It should be noted that the risk and service categories in this list are conflated, going beyond the definition of asset health to include consequence and therefore risk. As such they are of limited value in understanding asset health.

Age

- focused on life expectancy
- simplistic and potentially inaccurate
- easy to apply and can be refined using statistical techniques

Condition

- focused on life expectancy, but can also indicate wellness and fitness
- potentially more accurate and forward looking (than approaches focused on age)
- asset-specific, and can be misleading if relationship to failure probability is not understood. Potentially valuable for low failure probability, critical assets

Performance

- focused on wellness, but can be developed to provide a life expectancy indication
- tend to be lag indicators
- can be enhanced by trend analysis and deterioration modelling

Service

- focused on wellness. Provides a comparatively detailed view of customer and environmental impact
- tend to be lag indicators
- conflated measure, losing sight of asset health contribution

Risk

- can cover wellness, fitness and life expectancy
- can combine lead and lag indicators
- useful for investment prioritisation but a conflated measure, losing sight of asset health contribution

Appendix

Age and condition models

Age and remaining life models

A variety of sophistication exists. Some use a simple 'book life' estimate and knowledge of asset age to estimate renewals. Others such as the KANEW survival models (developed by Raimund Herz, TU Dresden) apply statistical models to cohorts (assets grouped by type and age band) to estimate the future renewals need. The Herz survival model has three stages: defining asset cohorts by type/material and age band; developing the survival curves and forecasting future renewal needs.[1]

Simple condition models

These models are based on inspection of assets (often visual) and use of condition grading; in the UK water sector a 1 to 5 (good to poor) integer scale for condition grading of assets is typical. Condition models are often simple 'static' approaches and use grading for identifying renewals backlogs, for example, 'replace all condition grade 5 (life expired) assets'.

Condition deterioration models

A more sophisticated condition-based approach involves making a more precise assessment of the physical condition of the asset, potentially using more sophisticated inspection technology, and using knowledge of asset age and deterioration mechanisms to forecast remaining life based on the observed and modelled rate of deterioration.

The rate of aging of a population of assets is an indication of the rate of renewal activity required to maintain the overall state of the asset. However, unless the relationship between condition and performance is known, it is difficult to determine the appropriate overall target for the state of the assets. These models are also constrained in their applicability because of the range of rates of deterioration in the asset population. This is particularly problematic in the case of specific, very critical assets, because extrapolation from a model introduces significant uncertainty at the individual asset level and it can be difficult and costly to estimate with precision, what the actual condition and hence failure probability of the asset is. Understanding the criticality of individual assets can help to prioritise resources and investment for determining the condition and likelihood of failure for these assets.

These models are also constrained in their applicability because of the range of rates of deterioration in the asset population. This is particularly problematic in the case of specific, very critical assets, because extrapolation from a model introduces significant uncertainty at the individual asset level and it can be difficult and costly to estimate with precision, what the actual condition and hence failure probability of the asset is. Understanding the criticality of individual assets can help to prioritise resources and investment for determining the condition and likelihood of failure for these assets.

An example of condition deterioration models are those developed for UK Water Industry Research Ltd (11/WM/13/2 Deterioration rates of long -life, low-probability of failure assets), and the toolkit developed by the project which provided condition deterioration models for ferrous and cementitious asset types.

Base asset health model

United Utilities has developed a standard index of asset health based on remaining residual life that has been applied across the whole asset base whilst taking account of the various existing asset health data streams well embedded across the business. It is an example of an aggregate asset health index (supported by a number of individual metrics) which could be considered as an approach for the industry as a whole.

Base Asset Health (BAH) indicator metrics are predictions of remaining economic life of assets as informed by the age, condition and performance of the assets coupled with our asset deterioration models. They can be aggregated together at any level of the Wholesale business. The flexibility of the index means that it can represent the health of a wastewater treatment works, all pumps of a particular type, all water mains of a given size and material, or even the company as a whole. This gives the ability to use the index for both operational and strategic purposes.

[1] For more, see Report 10, WP4 – Strategic planning and investment, of the CARE-W project funded by the European Community: https://www.sintef.no/contentassets/9e221cde66604461b90b4aa74dd62ca7/d10-care-w-rehab-strategy-manager.pdf

Appendix

The Base Asset Health index enables:

- A clear view of asset health at any level from organisation, price control, facility, process or individual asset
- Useful comparisons across different assets and groups of assets in a consistent and simple manner
- Better investment decisions through a clear indication of the relative asset health of specific assets
- Risk based proactive operational maintenance, in conjunction with criticality assessments
- Access to good quality, standard data about the asset base

The BAH index is determined using the following information:

1. Asset identification: date installed, replacement cost of asset, location and other data – base information for assessing life expectancy
2. Condition of asset (for civil assets and sewers) – an indication of fitness
3. Reactive maintenance (for mechanical assets, sewers and mains) – an indication of wellness
4. Failure analysis: Analysis of the most common reasons for failure, as well as failure trends – used to forecast life expectancy

This data forms the asset deterioration curves, which are then used to determine a typical economic asset life for each type of asset, such as a screw pump or a certain size and material of sewer. Data (such as performance, condition or failure rate) specific to an individual asset is used to determine its effective asset age.

These data are used to calculate the BAH index. The effect of differing operation and maintenance regimes upon asset health can be to improve or degrade the asset health. Effective maintenance may mean that a relatively old asset may have an increased life expectancy, and hence a reduced BAH index value.

Performance and service metrics

Basket of measures

Metrics are typically visualised in dashboards that monitor levels and trends in performance and service indicators. Some of the UK water companies see a sub-set of the former serviceability measures as being potential asset health metrics, though others think that lead indicators such as asset condition need to be part of this basket.

An example of using typical performance metrics and creating a weighted index is that used by South Staffordshire Water during AMP6, using a selection of sub-metrics to make them more asset focused. Their index recognises that some individual metrics carry more weight than others in contributing to the monitoring of asset health and were not represented in other ODIs (metrics represented in other ODIs are given a lower weighting).

South Staffordshire Water calculated a composite asset health index using the five sub indicators defined for each component using the following process:

1. Apply scores to the metrics depending on performance relative to the reference level and upper control limit
2. Multiply the scores by the indicator weighting
3. Total the weighted scores to determine the asset health index score for that year.

Turning a basket of metrics into a health index has the benefit of enabling comparison and tracking, but care is needed to ensure that negative trends in individual metrics are not being masked by the aggregation and calculation process.

Cohort models

Cohort models have typically been used for determining mains renewals based on burst rate and forecast deterioration to a trigger point. Some companies are still using these models for water pipes. However, the cohort model is really an approach for identifying discrete populations of assets, defined by characteristics that may be expected to influence their level of performance and deterioration. The condition and asset life models previously described also break the assets into cohorts to support forecasting, albeit at a typically simpler level.

Appendix

The cohort models used for water mains and sewers break the asset stock down into discrete statistical groups (e.g. material, diameter, age band, ground type) and use deterioration models to forecast rates of replacement to maintain the stock. Assumptions link the deterioration rates to burst frequency and this enables replacement policies to be appraised in terms of future predicted burst rates. The key indicator in this case is the forecast burst rate by cohort.

It is worthy of note that it is possible to make these tools service and risk based, by incorporating burst location data and estimating the scale of customer impact.

Risk models

SP Energy Networks condition grade model

SP Energy Networks own and maintain the network of overhead lines and underground cables in Central and Southern Scotland, North Wales, Merseyside, Cheshire and North Shropshire. They describe an asset health index that is a measure of asset condition that is applied to a subset of the asset base.

The evaluation methodology varies depending on the asset type; however, at a generic level, health indices will rank assets from: HI1 – new (or as new) to HI5 – end of serviceable life. This model measures asset health in terms of asset condition and also considers how the asset will deteriorate with time. Asset health is determined using a number of factors including: design standards, deterioration, operational issues, vicinity and location, fault rate, critical issues and maintenance spares.

These are combined with criticality (criticality index) in a weighted risk scoring. This is a basic risk assessment using condition categories to indicate asset state[2]. In this example, the asset health index component is based on a fairly simple descriptor. This is similar to the condition and performance gradings used historically by UK water companies for non-infrastructure assets and would potentially not be considered suitably accurate or reliable for justifying future expenditure requirements.

Deloitte condition and criticality model

Referring to an example from the Canadian Electricity Association, Deloitte[3] state that an Asset Health Index can be defined as:

- A way of measuring the overall health of an asset
- A list of data parameters for an asset that feed into a calculated health rating
- A way of comparing different assets and asset classes in a consistent manner
- An input, or building block, to a broader asset management process

They report that a number of Canadian electricity utilities use such an index. In these examples, asset health indexes are comprised of large amounts of specific data parameters for a particular asset, summarised in to a single number, the Asset Health Index rating. This rating typically ranges from 1 to 10 where 1 is an asset in “new” condition, and 10 is an asset that could fail at any moment. Deloitte report that as a rule of thumb, a typical asset health index will consist of five or more elements:

- **Asset identification** – manufacturer name, model number/type, date manufactured, date installed, current age, cost of asset, install location (potentially geographic information system data)
- **Condition** – on-site engineering testing and assessments of: physical attributes, visual inspection results, electronic inspection results
- **Usage** – current usage (i.e. what is a pole holding), loading (i.e. voltage through a transformer compared to maximum rating), stresses
- **Failure modes analysis** – analysis of most common reasons of failure, as well as failure trends and correlations across data sets
- **Criticality/risk information** – criticality of assets relative to one another, and in relation to corporate objectives and risk tolerances (includes location criticality, asset type criticality, etc.)

These elements form the input to a set of calculations that produces the asset health index rating. The simplest form of calculations that can be used applies a weighting factor to each data element and sums the results. Care would need to be taken with such an index as the criticality element conflates measures of health with consequence of failure.

[2] For more, see SP Energy Networks 2015 – 2023 Business Plan. Annex Asset Health and Criticality strategy: https://www.spenergynetworks.co.uk/userfiles/file/201403_SPEN_AssetHealthCriticalityStrategy_GB.pdf

[3] See Asset Health Indices. A utility industry necessity: https://electricity.ca/blog/five-success-factors-in-building-an-asset-health-index/

Appendix

State of the Assets reporting

Whilst not aimed at reporting in terms of a comparative metric or index, a potential example of general asset health reporting for the UK to consider is the State of the Assets Report (SoAR) produced by some of the water companies in Australia and New Zealand. These come in various forms, but tend to provide a high-level overview of key asset metrics such as:

- Average remaining life (% of design life)
- Average condition rating by asset type
- Renewal funding vs demand
- Proportion of planned vs reactive maintenance
- A number of reliability metrics such as actual vs published Mean Time Between Failures (MTBF) and operational hours vs duty hours

Some utilities also report water quality data in their SoARs, although the link to asset condition and performance is more tenuous for these.

SoARs are typically underpinned by regular asset condition assessments and mandated regular asset re-valuations. SCADA historian data and other stored remote sensing data are also interrogated to populate the metrics. The take-up of SoARs in one form or another is increasing across Australia and New Zealand, generally driven by company Boards' requiring greater understanding of how the operational side of the business is tracking.

Currently SoARs are generally discrete and tend to provide more detail on the asset-related areas reported in the Annual Plan. The documents feed into the budget allocation process to varying degrees: sometimes through an asset management plan process, where tracked metrics might support funding need and other times as a reference during budget estimating.

Maintenance metrics

Maintenance specialists do not tend to refer to asset health specifically . They typically use a mix of metrics to help inform maintenance policy and need. A focus is often placed on reducing down-time, minimising repair times and reducing costs. Some typical examples of maintenance metrics are summarised as follows:

- **Equipment Downtime** – there are two basic ways to look at equipment downtime. The first is to consider how often assets are unavailable due to emergency breakdowns. The second is to measure how often an asset is actually available to do the work it is intended to do.
- **Mean Time Between Failures (MTBF)** – this metric looks at a particular asset, records the time between each equipment failure, and averages those measurements. Each company should evaluate a critical asset independently and determine a reasonable goal for increasing its MTBF.
- **Mean Time to Repair (MTR)** – similar to the MTBF, this KPI evaluates the time from the moment of failure through to the actual repair. It takes into account diagnosis, planning, scheduling and the actual work required. By using this metric, a company may be able to identify inefficiencies in the process.
- **Overall Equipment Effectiveness (OEE)** – this metric looks at a facility's overall performance. OEE is based on the availability of equipment, the efficiency of its overall performance, and the level of quality in final products.
- **Planned Maintenance Percentage (PMP)** – planned maintenance is always less expensive and less disruptive than emergency maintenance. This metric measures how much of the total maintenance are planned tasks.
- **Schedule Compliance** – this KPI looks at the percentage of time that an organisation successfully completes a scheduled work order.
- **Maintenance Cost as Percent of replacement asset value (RAV)** – this metric illustrates how cost-effectively the maintenance program operates. World-class companies can keep this value at around 1%.
- **Average Days to Complete Work Orders** – at a basic level, the faster a maintenance crew can complete work orders, the more efficient it may seem. Note that there is a balance with doing things thoroughly.
- **Percentage of Work Covered by Work Order** – this metric helps a maintenance team determine how much maintenance work is getting entered into the computer system. This is critical as the collected data can provide the basis for future important decision-making efforts.
- **Maintenance Overtime** – similar to measuring maintenance backlog, a metric that looks at overtime can help you set the right level of labour for the organisation.

Whilst interesting and of value, most of the above metrics are not asset health indictors and none are lead indicators. Equipment downtime and MTBF are relevant to asset health but without forecasting and extrapolation they only tell part of the asset health story.

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