As time goes by…

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Abstract

Since privatisation, the water industry has invested £150b on its physical assets. Over half this spend is on replacing existing assets though the exact proportion is hard to pin down. The industry has a fascination with building high profile new assets but the less glamorous activity of replacing old assets is sometimes neglected. With many physical assets, for example dams or pipe infrastructure, it is notoriously difficult to find the right balance between spending on replacement and the risk arising from not replacing. This is often because assessing them effectively is difficult or, to be precise, the relationship between our inspection results and the actual likelihood of failure is not always strong.

The science of optimal asset management as developed by Barlow et al in the 1960s and made more applicable by Penny Burns in the early days of asset management development is not often applied, perhaps due to the relatively low confidence in deterioration models. Improvements to asset management could be made and the key decisions must hinge on good informative inspection, meaning inspection its widest sense, including monitoring of any kind. Using that data to make good judgements about our capital maintenance spending is as important as the more exciting spending on new types of asset.

Keywords: Asset Management, Deterioration, Capital Maintenance

Introduction

Time crumbles things; everything grows old under the power of time and is forgotten through the lapse of time. (Aristotle, Physics Book IV, 4th century BC)

July 2019 was the 30th anniversary of the privatisation of the water and sewerage industry in England and Wales. Over £150 billion of capital has been invested in assets in these three decades[1], building new assets and replacing old ones.

As we enter our fourth decade since privatisation, embarking on another hectic 5-year plan, perhaps it is time to take a step back to a more distant vantage point to appreciate the bigger picture. In the context of the slow and relentless cycle of asset deterioration and replacement, has the industry's asset base reached some semblance of stability? We certainly haven't replaced everything yet, and are still expanding by building new assets, so many assets have clearly not completed their first cycle. Or are we careering towards a cliff-edge?

The national body charged with thinking about these things, the National Infrastructure Commission, did not mention deterioration at all in its 5-yearly assessment[2] instead entirely focussing on the need for new infrastructure across communications, transport, power and water sectors. It is a characteristic of most future planning exercises to focus entirely on the modest investment in shiny new assets achieving new objectives and overlook the critical investment on replacing worn-out old assets. Whilst having the approach is understandable, it is not necessarily the best position to take.

Our Assets

The partial collapse of the Toddbook Dam in Derbyshire in August 2019 has focussed attention on the state of the UK's major water assets[3]. This particular dam was not used for water supply, but many others are. How long can we assume a dam lasts before we have to replace it? The trouble with dams is that when they fail, it's not just the interruption to supply that we have to worry about.

UKWIR's latest research to answer the same question for the UK's enormous pipe networks, Long-term Investment in Infrastructure[4] (Servelec, Atkins and Frontier Economics, not publicly available) calculated that we're renewing about 0.6% of the water pipes and 0.2% of the sewers per year. Much is made of the "implied lifetime" which, if you imagine a homogeneous pile of assets being turned over in age order at this rate, implies you'll get 170 years from a main and 500 years from a sewer.

Now 500 years may sound a lot, but the "Cloaca Maxima" sewer in Rome is apparently still going strong at about 2600 years old (see Fig 1). Constructed in about 600 BC by Etruscan engineers, it continues to drain rainwater and debris from the centre of the city. In 33 BC, when a mere 600 years old, it did get inspected and rehabilitated by Agrippa, the Roman Consul and great civil engineer, many of whose greatest contributions to the city were sadly burnt down by his grandson Nero. But the big sewer's still there and it's still functional.

The UKWIR report concludes, after modelling the deterioration of mains and sewers, that every year we need to replace 1.2% of mains (rising to 1.3% after 2030) and 0.8% of sewers (rising to 1.2% after 2030). This is a four-fold increase in sewer replacement and a two-fold increase in mains replacement.

Other types of assets present their own tricky decisions. Mechanical and electrical equipment has a shorter turnover time in principle, but in practice it is not so easy to monitor the ages and conditions as reduced labour forces become less familiar with the equipment and plant.

Treatment works and pumping stations vary widely. Some are very old. The Abbey Mills Pumping Station in London is so old that it has become a tourist attraction, despite still pumping 200 Ml of wastewater a day. It was constructed in 1865 by the great engineer Bazalgette in an extravagant Moorish style (Figure 3). Because such a lot of new equipment has been built in the last 20 years, there is some uneasiness about whether it will all need replacing at the same time, at significant expenditure.

Fig 1: Toddbrook Dam. Image from "Toddbrook Reservoir Independent Review Report" Balmforth (2020), DEFRA Report

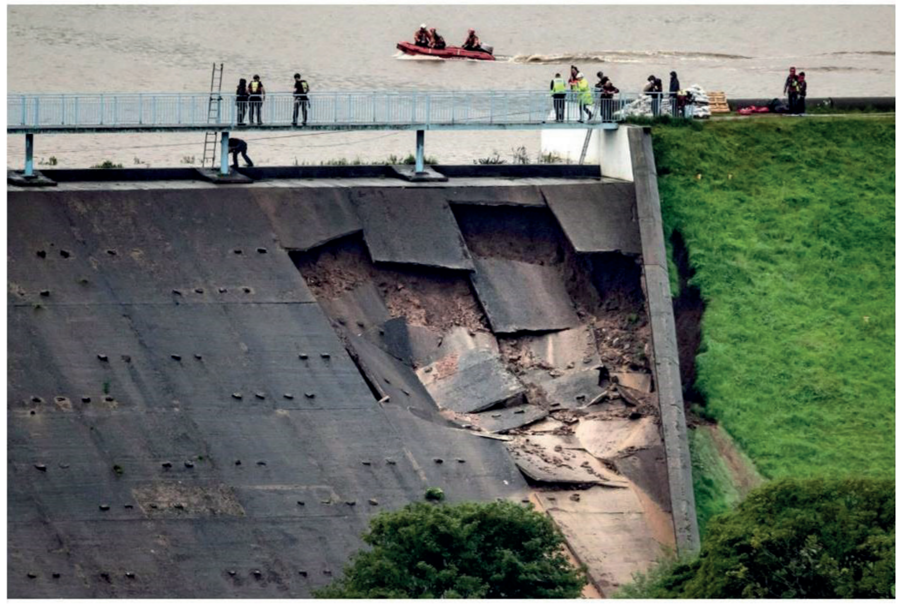


Fig 2: Cloaca Maxima in Rome. Copyright: 1968 George W. Houston (used with permission)

Fig 3: Abbey Mills Pumping Station. Image source: Chris Sharman

The Building of New Assets

The figure overleaf shows the industry measure RCV (Regulatory Capital Value, the value of our physical assets) since 1993, shortly after privatisation.

It shows that the value of our assets has risen from £18bn to £51bn (in 2010 prices) in 24 years, well over double. That's about £23bn to £64bn in today's money (or £1.7bn per year). Whilst the number of properties supplied has gone up a little (about 5%), this still shows that our industry is not yet in "steady state" but still building fast. However, the trend is clearly levelling, and it may be that with water and environmental standards now high the industry valuation will peak at around £60bn, with an acceptable balance between performance and cost. The idea that there will ever be a utopian time when steady state is reached and we are serenely cycling through our assets as they wear out, is perhaps unrealistic – there will always be disruptors of some sort.

There are many potential sources of a disruptive change - climate change, nationalisation and the predicted digital revolution for example. In this AMP, many companies are making bold claims on reducing leakage and internal flooding that will be extremely challenging without serious infrastructure investment. However, let us focus on the impact of ageing assets.

According to Water UK, we will be investing £8bn per year over the next regulatory period[6]. That sounds like a high level of spend although typically only 50-70% of that is capital maintenance. £4.8bn on capital maintenance on an asset valuation of £64bn is 7.5% per year which implies an average asset lifetime of 13 years. Is that enough?

There is a case however that we actually build too many assets. Water UK's Briefing Note 3 (December 2018)[1] pointed out that the water industry spends 42% of its turnover on capital and this is very large compared to other industries (see table below). The comparison with National Grid is striking, especially given the sizeable operational costs our industry bears for pumping heavy water. The RCV financial framework imposed by Ofwat set up artificial incentives to push money towards Capex, and this has not helped. Ofwat recognized the problem (see for example the discussion document on the topic[7]) and has tried to move us all towards Totex which may pull us back to a more equitable balance with Opex, but it raises the question of whether we might even be spending too much money replacing assets and not enough operating, inspecting and maintaining them.

There is certainly anecdotal evidence that the Operations departments in some UK water companies are spread very thinly. Research by Global Water Intelligence, see figure below, suggests that England and Wales spend significantly less per capita than other European countries. It could be that England and Wales achieve their operation with more efficiency, but it could also be that we should be spending more.

There must be an optimal balance between Opex and Capex and this could be radically different for different types of asset. For each asset, we have to understand the risks and age deteriorations associated with that asset type.

Understanding the Deterioration of Assets

Below is a simple time series model of burst rate in a UK water company. The number of bursts that happened for each month is plotted against time. The count has been

Fig 4: Water Industry RCV 1993-2017 in 2010 prices (from "Productivity Improvement in the Water and Sewerage Industry in England Since Privatisation", Frontier Economics, Sept 2017)[5]

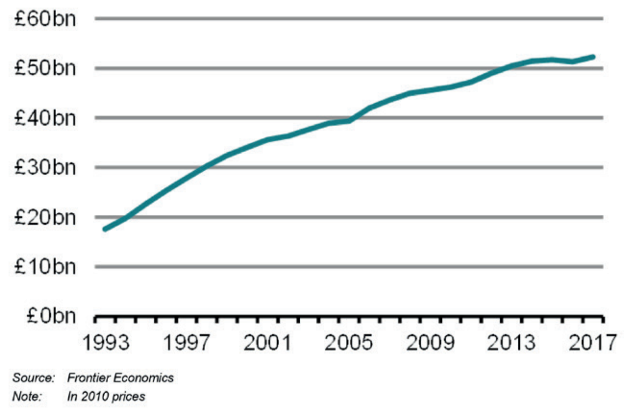


Table 1. Relative Scale of Capital Expenditure in different sectors, from Water UK (2018)[1]

	Turnover (b)	Capex (b)	Capex/Turnover
BP	US $ 245	US $ 17.8	7%
Tesco	£57.5	£1.1	2%
National Grid	£15.2	£4.3	28%
England & Wales water industry	£11.7	£4.9	42%

Fig 5: Opex per Capita in 2017 Euros (from "International Comparisons of Water Sector Performance," Global Water Intelligence (2018)[8]

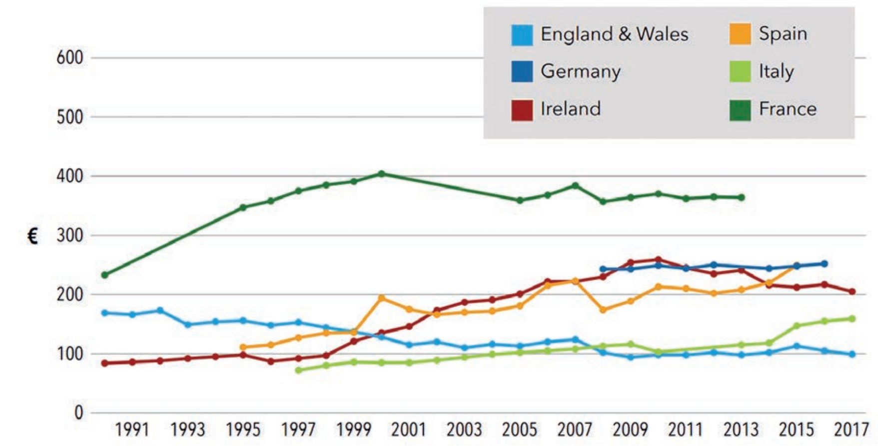
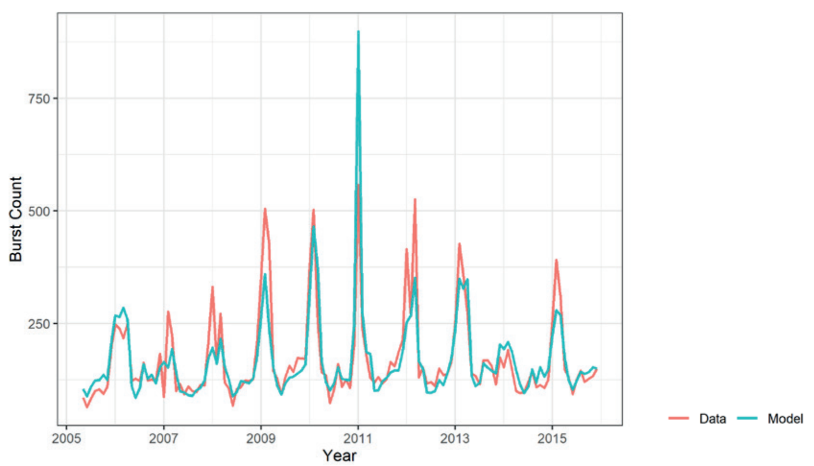


Fig 6: Burst Rate in subset of CI pipes at a UK water company



restricted to cast iron pipes and further restricted to the subset of pipes that were present throughout the whole period.

It seems to be quite a good model capturing not only the month-to-month variation but the different shapes of different years. The predictors used for the model included average temperature together with soil moisture deficit, potential evaporation and an indicator for weekends and bank holidays.

But the most interesting fact was that after all these influencing factors were allowed for, the underlying pattern underneath was a steady increase in burst rate of about 1.2% per year (too small to be visible in the graph). The standard error on this increase was significant at 0.6%. It is important that there were no changes in the pipe population in the graph through the 10-year period, neither decommissioning nor commissioning of pipes, just one group present throughout.

So, does that mean we have to replace 1.2% of pipes per year? Absolutely not – that would be muddling our model of deterioration with our strategy. Certainly, if brand new pipes had a very low failure rate and we picked pipes out at random, then 1.2% replacement would hold the burst rate steady. But we should be able to do better than random by using age and other clues as to condition. Also, brand new pipes are not failure-free so this needs to be allowed for. Simple example calculations using exponential deterioration show that a random strategy might need 2% replacement to hold steady, but an age-based model might reduce this to 1.1% and by using observed performance (e.g. burst rate) we should be able to get this down to a fair bit less.

If the bursts are coming from a smaller subset of the pipes and we can find these, then a much more efficient strategy might be possible. Suppose the 1.2% was caused by 10% of the pipes which were increasing at 12% a year and the rest not deteriorating. Then we'd only need to replace 0.12% a year (if new pipes were perfect).

Perhaps it is better to think in terms of getting rid of our cast iron and uPVC networks and replacing with polyethylene pipes (PE). Most companies are about halfway there, so if replacing at 1%, we would be totally replaced in 50 years. Good international comparisons are hard to find, partly because many networks are newer than the UK's. According to a survey in the USA and Canada presented in a Utah University study[9], the average replacement rate in the USA is 0.8% per year.

This is the sort of issue that our infrastructure asset managers have to wrestle with. Deteriorating infrastructure is not easy because so much of it is, to quote the title of a key National Audit Office report on water industry infrastructure from 2004[10], "out of sight not out of mind."

Our above ground assets, on the other hand, are at least susceptible to a visual inspection. Visual assessments are a cheap and easy way of getting some level of understanding of the ageing, but they can sometimes mislead us. Much work is done in the UK on deterioration, attacking the issue both from the engineering side and from the statistical side. The bringing together of a good understanding of the physics together with good quality empirical data should lead us to the best approaches. In many ways the UK, with its older asset stock for research, should aspire to lead the world in developing techniques and models (e.g. numerous UKWIR projects such as "Deterioration Rates of Long-Life Low Probability of Failure Assets," 2011[11]).

Asset Management

It was probably the Australian Dr Penny Burns who brought the arcane study of optimising when to replace assets into the limelight. Till then, it was the territory of dry academic research by people like Barlow & Hunter (1960)[12] and Fox (1966)[13] with research only appearing in publications like the Journal of Operational Research. Burns's work in the mid-1980's for the South Australian Public Accounts Committees alerted the world to, in her phrase, the "true costs of services" and in 1993 she wrote the Total Asset Management Manual[14] for the NSW government cementing the term "asset management" for physical assets.

Since then we have realised that the old concept of "remaining lifetime" is not so simple. Remaining lifetime is used in several completely different ways including:

- the time till expected fatal failure,
- the time till expected next repairable failure,
- the time till risk of failure becomes too high for us to leave it in place,
- the optimal time till we should replace it to minimise our costs (also called remaining economic life).

We have realised that the optimal replacement time of even the simplest asset depends on many things:

- the cost of replacement
- the cost of the failure, including all consequence to us, whether that be financial or indirect (monetised as necessary)
- the exact condition it is in now
- our estimate of the asset's condition profile in the future (i.e. our model of deterioration).

Sometimes the overall budget situation and how much money we can spend is allowed to affect our judgement. For more complicated assets, this simple model needs to be combined with performance (how well the asset is doing its job).

And we have realized that all these numbers and graphs are very hard to pin down. The measure known as "Condition" in its most useful form needs to be an indicator of probability of failure. Sadly, the condition by this definition is not always obvious from the asset's appearance or any of the measurements we can take.

The Solution

So, is £8bn a year enough to cover both building new assets and replacing existing assets for the UK water industry? And if it is, how can we be sure that we are spending in the right places?

When the replacement time arrives, it is an opportunity to rethink. This is the time for innovation by thinking flexibly and imaginatively about whether there are alternatives to a simple like-for-like replacement. The emphasis on the environment and our carbon footprint are accelerating and yesterday's solutions are not always sustainable enough. However it is still important to get the replacement timing right – too late and we are loading our risks, too early and we are needlessly wasting money (and carbon costs).

The solution is better condition monitoring both in terms of the systems used to capture the data and the technology used to measure condition. The word "condition" in this context represents a measure of how likely the asset is to fail, which is not always well defined by the cheaper measures available (such as looking at it). Such monitoring must be used alongside deterioration modelling, helping to improve the modelling and where available superseding the models.

Every asset group has its own characteristics and it is difficult to generalize, but a few specific comments may be made:

- Our subsurface sewers have a reasonably cost-efficient method of condition monitoring: CCTV inspection. There has been a tendency to reduce the amount of CCTV in recent decades but its relative ease, perhaps augmented by automated image recognition software, gives us a good method of ensuring we are replacing the right pipes. Using machine learning to correlate specific defects with blockages or collapses could improve our somewhat arbitrary SRM grading system.
- Our subsurface pipes do not currently have equivalent methods (dig-down pipe external inspection is expensive) although new methods are constantly being attempted. Technology may improve the success rates and the drive for leakage reduction may foster innovation.
- Pumps and treatment works may benefit from vibration, sound and temperature monitoring now appearing and certainly the increase in pressure and flow monitoring will help. Analytical techniques such as machine learning may help us interpret the data.
- Service reservoirs and concrete structures should benefit from better understanding of deterioration and more measurements of compressive strength, chloride profiles and so on.
- Dams require specialist inspection using all the tools available including drilling concrete cores and geotechnical measurements. The Toddbrook report[3] written by David Balmforth provides over 20 recommendations on improving our inspection and maintenance practices.

Companies need to systematically and proactively collect condition data for water infrastructure assets. Most companies already have a condition grade for their civil, mechanical and electrical non-infrastructure assets, and the use of a computerised maintenance management system to compare planned maintenance against reactive maintenance is common. But efforts in this area need to be stepped up.

Only by understanding the condition of our assets and therefore how likely they are to fail can we make the difficult tactical judgements about what we need to replace now, and the difficult strategic judgements about what we need to budget for the future.

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