The “go with what you know” approach to forecasting future asset replacement expenditure

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Abstract A reliable predictive model for the deterioration of water mains and sewers has been the quest of water industry asset managers for several decades. No doubt driven by finance managers, asset managers have been searching for that mythical formula that will tell them exactly when an asset will fail and allow them to accurately forecast replacement and renewal expenditure into the future.

Although it is imperative that water authorities act to avoid and prevent the catastrophic failure of major infrastructure assets where the consequence of failure is high, for most authorities these assets form a relatively small part of the asset base. Therefore, the detailed predictive modelling and analysis of pipe material properties employed to plan the replacement of these critical assets is not appropriate or practical to apply to reticulation assets that represent over 95% of the total infrastructure for most Authorities.

The application of predictive models based upon pipe material performance to develop replacement programs for extensive reticulation systems, does not adequately take into consideration the variations in construction methods, ground conditions, consumption patterns, topography and climatic conditions that exist in many networks. These variations are, however, implicit in historical performance data which also provides information of the rate of failure of assets which is the main driver for the replacement of reticulation assets. It is only when the rate of failure of an asset becomes unacceptable that replacement is necessary and this adopted level of service will have a greater influence on future asset replacement expenditure than the assessment of the deterioration of pipe materials. All the more reason to base asset replacement programs around historical data and go with what you know.

Keywords Asset management; asset replacement; historical data; predictive modelling

Introduction
Water supply and sewerage systems are formed mainly of a network of small reticulation pipes consisting of different materials, constructed at different times by different contractors in differing ground conditions and servicing different needs, with all of these variables influencing the longevity of the system. So predicting the life expectancy of a pipe, is not dissimilar to predicting the life expectancy of a human being. Whether we live until 90 or 19 depends upon our heritage, living conditions and lifestyle and while we know that on average most of us will live on into our seventies, it is difficult for anyone to predict how long an individual person is likely to survive.

The collection of historical performance data provides a mortality rate for pipe systems. Although the life expectancy of an individual pipe cannot be accurately derived from this data, the information can be used to predict the expenditure required to replace groups of assets with the same or similar attributes. Modern asset management systems have simplified the process of capturing field data and the accuracy and reliability of the data collected by most authorities operating such systems is improving.

Historical performance data can be used to directly predict replacement expenditure for reticulation assets because the failure of these assets can be tolerated to some degree. It is only when the frequency of failure threatens to compromise agreed levels of service, that the pipes are considered for replacement.

All water authorities have critical assets which are not permitted to fail. For these assets a more detailed individual assessment of their condition and life expectancy is justified.
The historical performance of less critical assets of similar age and material can however be used to prioritise such assessments or to feed into asset augmentation programs which will provide redundancy to critical assets and optimise their life expectancy.

**The human analogy**

The factors that determine the longevity of a water or sewer pipe are many and varied. Many predictive models for asset replacement by default, focus on factors that are readily assessable such as pipe age and material, only to find that the replacement volumes predicted do not correlate with actual volumes.

Human beings also all have basically the same makeup, but some of us will live to ripe old age while others will die in a midlife crisis inspired attempt to run their first marathon. Although we are aware of many of the factors that determine our longevity, it is still not possible to accurately predict the life expectancy of any individual. However, by examining mortality statistics we can assess the probability of individuals in various demographic groups of surviving to a particular age.

Historical performance data for water supply and sewerage systems basically provides the mortality statistics for pipelines. Although the data collected cannot predict the longevity of individual assets, the performance of assets with similar characteristics can be assessed and extrapolated to forecast the life expectancy of younger assets in the same asset group.

There are, however, some differences in the ways that humans behave in relation to pipe systems. Despite the blatantly obvious ones like being living animals rather than inanimate objects, humans tend to reduce their workload as they approach the end of their life. The opposite is often the case with pipe assets where loads are often increased due to system growth requiring the aging asset to work harder. In these cases, system augmentation can be used to shed some of the load, reducing the dependency on the ageing system but avoiding the need to replace pipes prematurely. The use of historical performance data in conjunction with forward growth projections to direct system augmentation around pipes that are approaching the end of their useful life, is discussed later in this report.

**Data collection**

Of course the reliability placed on historical performance data depends of the quality and accuracy of data collection. Whereas most authorities have collected statistics on asset failures for many years, these have often been referenced against street addresses rather than to the assets themselves. It has only been in recent times with the advent of modern asset management systems, that data has been collected against individual assets. The use of historical data has also benefited by a continual improvement in the performance of personal computers which has streamlined the process of analysing large volumes of data.

Nevertheless, the process of gathering information from the field remains a challenging one. People who choose an occupation that relies on their manual labour, generally have an aversion to paperwork in any way, shape or form. So it is important that asset managers keep this in mind when designing forms for data collection. The volume and quality of data collected is inversely proportional to the complexity of the paperwork required to be completed.

For authorities who have contracted out their maintenance and operation activities, making accurate data collection a contractual obligation and/or the basis for payment, will ensure that good quality data is collected. For other authorities, it is essential that data collection forms are kept as simple as possible and that field staff are informed about what the data is being used for and understand why the accuracy of the information captured is so important.
GIS systems also assist greatly with the identification of assets in the field. Operators who would have difficulty in identifying an asset ID from a database list can at least point to it on a plan and obtain its attributes that way. Field workers are also becoming more highly skilled and with the prevalence of computers in everyday life, they are less daunted by new technology than they would have been ten years ago.

Using historical data
A limited amount of historical data can go a long way if you know how to use it. Obviously the more data you have the better your asset replacement forecasts will be, but when you’re projecting replacement volumes twenty to fifty years out it doesn’t pay to be too fussy.

Looking back to the human analogy, we know that as we age, the probability that we will survive another year lessens. The analysis of historical performance data for pipe systems will reveal a similar trend and a probability of failure for pipes with different attributes can be produced. This data can then be extrapolated out to derive future failure probabilities. Such analysis does not directly produce a life expectancy but produces a probability of failure for each asset that in conjunction with service level considerations are used to develop replacement projections.

The actual asset replacements performed are driven directly by the level of service adopted by the authority. In this instance the performance data collected is analysed to identify individual assets with a high frequency of failure. Assets that are found to have compromised agreed service levels are scheduled for replacement.

Service levels
For most assets operated by a water authority, one failure does not mean that the asset has reached the end of its useful life. In many cases, a failed asset can, once repaired, continue to remain in service for many years. It is only when the frequency of failure of an individual asset, or the frequency of interruption to customers becomes unacceptable that replacement is considered.

The level of service adopted has a significant influence on replacement expenditure. Figure 1 depicts the long-term water main replacement expenditure projection for Goulburn Valley Water. This graph shows that an incremental reduction of the water main replacement criteria from three failures per annum to two failures per annum, results in an immediate fourfold increase in replacement expenditure. It also shows that peak expenditure for asset replacement will occur twenty-five years sooner if a two failure per annum
replacement criterion is adopted over a three failure per annum criterion. It is clear therefore that the level of service adopted has a far greater influence on long-term replacement expenditure than any of the pipe attributes.

**Application of historical data to the replacement of critical assets**

Critical assets can generally be defined as assets that must remain in service at all times. Whereas most assets maintained by water authorities are allowed to fail and the frequency of failure is used to drive asset replacement, critical assets must be replaced or relieved before a failure occurs. These assets generally represent less than 5% of an authority's overall system. As they are relatively few in number, a detailed assessment of each individual asset is justified.

Historical performance data for reticulation assets will provide and indicative assessment of life expectancy and can therefore be used to identify the optimum time to begin such assessments. By identifying reticulation assets with similar attributes to critical assets, an assessment of the minimum life expectancy of the critical asset can be made. Detailed condition assessments including physical inspection of the asset can therefore be scheduled some time before this minimum life expectancy is reached allowing the derivation of a more precise estimate of asset life.

An alternative approach for critical assets is to take the historical performance data into consideration in forward planning for system augmentation to accommodate growth. System augmentation can then be planned to relieve critical mains that are nearing the end of their useful life thereby providing redundancy in the system. Having introduced this redundancy, the relieved asset can now be treated as the same manner as a reticulation asset and replaced when the frequency of failure becomes unacceptable.

**Conclusions**

Like people, the longevity of pipe systems is influenced by many variables. The use historical performance data allows and assessment to be made on the mortality rate for various classes of assets and this mortality rate by default takes into consideration all of the variables that influence asset life.

However, to rely upon historical performance data, protocols for the data capture need to be developed to ensure primarily, that data is collected against the correct asset and that all field activities are captured in the asset management system. To achieve this asset managers must take into consideration the difficulties involved with capturing data in the field and develop data collection systems that are conducive to collecting reliable information.

Once the asset manager is confident of the reliability of the information on system performance that has been captured by the asset management system, failure rates for various classes of assets can be determined. These failure rates when assessed against service level requirements will provide replacement forecasts. It is the level of service adopted by an authority that has the most significant influence on replacement expenditure.

The historical performance data will also allow minimum life expectancies to be determined for critical assets which are typically not permitted to fail. Detailed asset inspection programs can then be programmed to occur well before the minimum life expectancy is reached permitting more precise estimates of residual life to be made. Alternatively, the consideration of historical performance when planning system augmentations will allow critical assets to be placed into semi retirement by introducing system redundancies. In this manner the return for investment in the asset is optimised and the pipes are permitted to provide a useful service until they expire by natural means.