TOWARDS A CLASSIFICATION METHOD FOR GRAVITY PIPELINE FAILURES

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ABSTRACT

Asset management planning for wastewater pipe networks typically uses an estimate of pipe life and scheduled replacement dates. Uncertainty in the process leads to large financial implications for local government. The use of currently collected data in decision-making is hampered by the difficulty in separating correlation from causation between pipe condition/failure, and pipe parameters (eg, material, size, construction method, soil condition). Pipeline renewal investments can arise from a wide variety of causes, some of which are unrelated to pipe age, and some of which are random events that no amount of monitoring could predict. To help further discussion, it could be useful to develop an agreed upon pipeline failure classification system.

Failures would seem to need classification based on: (1) the management path (i.e., who pays), (2) the system component that fails, (3) whether the pipe failure is because of a factor intrinsic (e.g., corrosion) or extrinsic (e.g. local settlement) to the pipe's properties, and (4) factor(s) that contribute to the failure. The extensive experience of industry professionals would be needed to develop a classification system, and a sample is provided here to stimulate discussion.

KEYWORDS

Pipe repair, wastewater system failures, asset management planning, data analysis

1 INTRODUCTION

Asset management planning for wastewater pipe networks requires an estimate of remaining pipe life and scheduled replacement dates. This approach fits well with the commonly accepted business practice of depreciation of an asset and an estimated remaining life of an asset.

Uncertainty in the estimation of remaining asset life leads to large financial implications for local government. A number of efforts are underway to better support the decision-making including a Wastewater Renewals Framework (WRF) (McFarlane, 2018) and a revision to the New Zealand Pipe Inspection Manual.

Issues related to the cost of data collection, and the value of data in decision-making remain. The use of currently collected data in decision-making is hampered by the difficulty in separating correlation from causation between pipe condition/failure, and pipe parameters (eg, material, size, construction method, soil condition). That in turn makes it difficult to assess the amount and method of monitoring that is needed to reduce uncertainty in asset management planning most efficiently. Failures leading to a need for renewal investments can arise from a wide variety of causes, some of which are unrelated to pipe age, and some of which are random events that no amount of monitoring could predict.

There could arise a situation where pipe inspections estimate an average remaining life for a pipe of 100 years and yet the average time to replacement is 50 years because so many pipes are replaced for reasons independent of the age and wear of the pipe. Because of this, it could be critical to collect data related to the cause of pipe replacement.

Amortisation of computers provide an analogy that could be useful to consider. To plan for replacement of computers, one does not use the remaining life of a computer, which could run for 30 years or more without a serious component failure. The “useful life” of a computer is a function of its estimated time to technical obsolescence more than it is a function of the durability of its components. Inspection of computers to identify wear and better predict the time to component failure is often not worth the monitoring cost.

The WRF provides a starting point for such a failure classification. As “Modes of service failure” it lists: operational, strength, containment, and capacity. These modes describe the failure, but they do not distinguish clearly between failures caused by properties intrinsic to the pipe and those that are not. The use of these modes without further clarification would run the risk of confounding correlation and causation in terms of pipe failures and so lead to weak estimations of “useful life”. To further the discussion of the “useful life” of an asset, it would be useful to develop methods to assess the reason for various pipeline replacements. To allow nation-wide comparison of data would need an agreed upon failure classification system.

2 FAILURE CLASSIFICATION

Failure must be clearly defined and estimated costs associated with major interventions must be distinguished from operating costs resulting from minor interventions. A demarcation line for the two types of interventions might not be clear considering the spectrum of options available to address service problems. For example, installation of a pipe sleeve or application of a pipe coating would cost more than a removal of a blockage, but less than the cost of a new pipe installation. Should the estimated costs for those interventions be classed as annual operating costs or as part of a budgeted renewals programme? The definition of a “failure” must match with the definition of costs estimated under an asset replacement programme and not as part of an estimate of future costs of normal operation.

With an agreement on the definition of failure, there would then seem to be a need for a clear classification based on

- The management path
- The system component that fails
- Separation of failure modes based on factors intrinsic or extrinsic to the pipe’s age

- Failure modes defined considering ease of identification and potential for use in future decision-making

Some preliminary thoughts on these classification steps are provided to promote discussion. Figure 1 provides a summary of these preliminary thoughts.

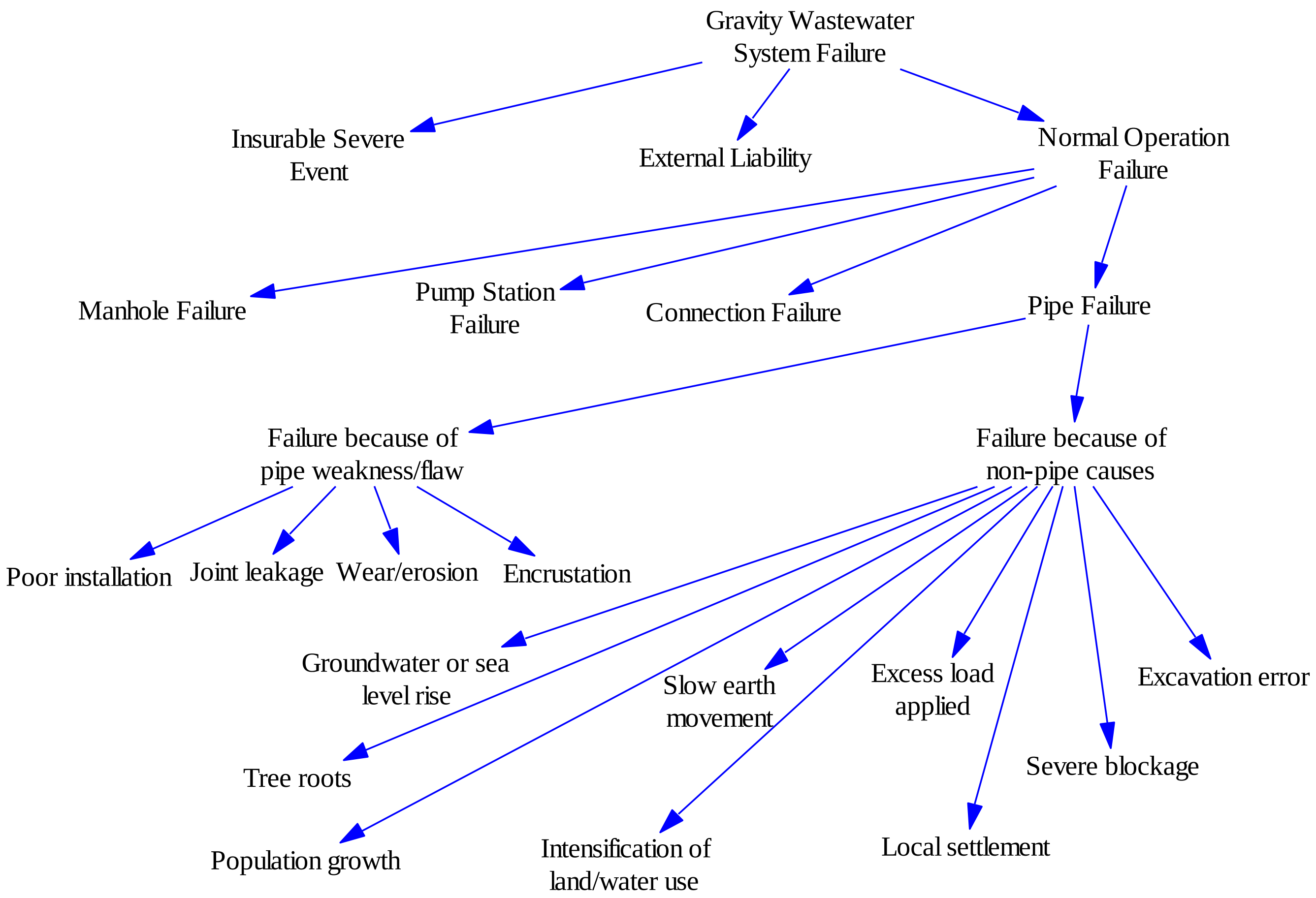

Figure 1: Hypothetical Pipe Failure Tree

2.1 CLASSIFICATION BY MANAGEMENT PATH

Pipes that are replaced are not just those prepared for with an asset management plan in a 30 year infrastructure strategy. Some pipes are replaced soon after installation and can be tied closely enough to installation to be the financial responsibility of the organisation that conducted the installation or supplied the materials. Others are replaced due to negligence independent of the local government body, for example, a contractor on a private site breaking a sewer pipe; the responsibility for the cost of replacing those pipes would seem to be covered by the contractor (or their insurer).

In addition, some severe events can damage pipes that would otherwise have not needed renewal for many years. Most local authorities would have some type of insurance cover to make up for the financial shortfall associated with early renewal of assets.

Local governments need, for asset management planning, to estimate the costs they can expect to be responsible for, separate from the costs for insurance or the costs associated with improper installation, material defects, and third party error. To avoid mixing of failures and costs, it would seem important to distinguish failures based on their management path.

It would still be valuable to keep records of those pipe failures where the costs are covered by extreme event insurance and by payment by external parties. Long-term management of those pipe failures would benefit from clear data. But they need to be classified separately; assessing the useful life of a pipe from a database of pipe failures should not be confounded by having to consider how many of those pipe failures were from an extreme liquefaction event or from provision of faulty materials. The exact definitions of the various management paths would need serious consideration prior to developing a robust database on pipe failures to aid in asset management planning.

2.2 CLASSIFICATION BY SYSTEM COMPONENT

Development of a pipe failure database would seem to present an opportunity to look at the broader issue of failure—failure to maintain a desired level of service in a wastewater system. Looked at from that context, the definition of a system failure is needed. That also implies a classification system so that all failures are classified as one type or another type and that no failure is classified twice. This might not be as easy as it seems in wastewater networks. A wastewater system could be seen as a series of components-- manholes, pump stations, pipes—but then there are also failure modes that involve an interaction of these (say, a manhole sinking and a pipe rising), or at an interface. Is the failure of the connection of a customer lateral to a pipe a pipe failure? a connection failure? a failure on private property? If a pipe fails at a joint between sections, is that a pipe failure or a connection failure? Clear definitions of a set of failures would need to be considered together in order to provide a good dataset of pipe failures to use in improving pipe renewal strategies.

2.3 SEPARATING FAILURE FACTORS INTRINSIC AND EXTRINSIC TO PIPE AGE

If wastewater renewal planning is to be based on the concept of "remaining asset life", then it would seem important that failures (and past renewals in general) can distinguish between those that are due to a pipe's age and those that are not. If hydrogen sulphide can attack concrete over time, and there are data on the ages of concrete pipes were when they failed from hydrogen sulphide attack, then we can make better estimates of the remaining life of existing concrete pipes. To do so requires a database that distinguishes between the concrete pipe failures due to hydrogen sulphide attack from other causes.

Pipe failure modes can be strongly related to specific pipe materials and pipe characteristics such as diameter. But they can also be related to ground conditions, issues associated with use (hazardous chemicals, fat), ground conditions, and many other matters. Trying to infer failure rates for specific pipe types will be challenging when failures are not classified by those that are intrinsic and extrinsic to the pipe. After separating out the failures that are not related to pipe type, one can reach more certain conclusions on how likely failure is for a given pipe type.

Similarly, it could be useful to distinguish between failures that could have been detected by a monitoring system and those that could not. This type of classification would need definitions dependent on a specific monitoring method, which would make it vulnerable to a need for frequent updating and the confusion that could result. Still, such a classification could help greatly to evaluate the value of monitoring programmes.

2.4 CLASSIFICATION BY FAILURE CAUSES

A very long list could exist of causes of failure, and any failure classification system would need to be only as detailed as is needed. Any classification system should be developed with a view to keeping the costs of data collection reasonable. PoA difficulty is that we do not know how the database might be used in the future, and so cannot be sure what set of failure causes will be needed 20 years or 50 years from now.

There is an additional issue that those assessing failure will not be sure what the cause was. Care would be needed not to have a failure classification system where a significant number of entries are classed as "other" or "unknown". Some guidance, training, and judgement should be able to narrow the likely causes to a small number, with one potential cause seen as more likely than others. A classification database should be able to capture that judgement. That might mean a classification system where a most likely cause is given along with likely contributory causes.

A pipeline failure classification system will be of greater value when the causes of failure are aligned with potential decisions that can be later made to reduce that specific type of failure. For example, when a joint between two pipe sections is compromised leading to “failure”, it is important to classify this as either a failure because of tree root intrusion or poor installation procedures eventually leading to failure. Similarly, instead of defining a failure because of “lack of capacity”, a more specific cause should be given such as “population growth” or “intensification of land/water use”.

3 DISCUSSION

The focus of this effort is on gravity pipelines, principally for wastewater networks, though with implications for other water system assets. When developing data systems to support asset management of gravity wastewater pipes, one must be careful not to push the analogy to road systems too far. The issue of road wear leads naturally to estimation of useful remaining life, and directs monitoring of wear as well. With wastewater pipes, the image of wear occurring until failure is much less applicable. Failure can occur for a wider variety of reasons, many of which are only weakly related to age.

Because of the wide variety of causes of pipe failure, there could be merit in a shift from an asset management system focused on estimating remaining life to one that focuses on changes in probability of failure. Analogues to pipe condition factors could be used to evaluate a diverse range of failure modes. This might include a ground condition factor, a technology obsolescence factor, and a factor representing the potential for a change in land use to necessitate pipeline renewal.

Classification of failures for pipes can lean on efforts in other disciplines. Road accidents have a long history of classification. Classifying these failures has been difficult but, over time, clear guidance and training have led to a valuable and robust database that has helped greatly to support decision making on methods to reduce accidents. There could much to learn from a closer look at how accidents are classified.

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