INTUITION, INFRASTRUCTURE AND OVERCOMING BIAS

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Abstract:
Who can we trust to make the strategic infrastructure decisions that our communities desperately need? Wisdom tells us to first look to the industry experts. But how well are we cultivating this intuitive expert knowledge? Does the decision-making process hold up to scrutiny and is it conducted in a framework of continuous improvement?

This article is adapted from the 2019 winning IPWEA NZ Hynds Paper of the Year and showcases the results of James’s master’s thesis research examining “Intuitive Decision-making for Wastewater Pipe Networks”.

1 Introduction
The principles of integrated asset management are well understood and implemented in our region. New Zealand and Australian local governments have led the way through the development and publication of the International Infrastructure Management Manual (IIMM) which promotes a Total Asset Management Process. The IIMM forms an important benchmark for integrated asset management systems around the world and is regularly referenced in academic papers. The strength of the IIMM is the focus on developing integrated organisational strategies and having a decision-making process that is aligned with the overall plan and takes into account all of the various stakeholders.

There are numerous standards, guidelines, computational models and support tools that assist the development of integrated asset management frameworks by describing the decision-making process from a rational perspective. For example, capital expenditure strategies may focus on the “hard” network data such as pipe size, age, material, and perhaps camera footage from inside the pipes. Reliance on this “hard” data for decision-making is problematic due to the complexity of wastewater networks and uncertainty regarding the relationships between data, performance and causality. Poor data quality is another reason to be wary of deterministic decisions based on “hard” data.

In contrast to the numerous support tools using “hard” data, little formal guidance is available on how to appropriate operational deficiencies into the decision process. And potentially more significant, is the omission of formal methods of including intangible factors such as political, economic, environmental and social influences. It is often these intangible influences that have the greatest bearing on capital expenditure for wastewater networks.

A next step in wastewater asset management, perhaps, is to provide decision-makers guidance for practically implementing a process of weighing up intangible and often competing influences to make transparent and robust decisions.

Investment decisions for wastewater networks are complex and take into account a broad
system of influences. The wide range of influences supports the idea that wastewater networks are complex and deterministic decisions based on “hard” data alone are not appropriate. Instead, decisions require the use of “intuition” to weigh up the various factors in order to make a best fit decision so that investment and construction actions can proceed. Good intuitive decisions rely on the relevant knowledge and experience of the decision-maker(s) and also on processes that reflect the complexity of the system. Current research and guidance for intuitive decision-making is not well developed, thereby leaving local governments potentially exposed to risks of bad decisions.

This study addresses the problem by investigating intuitive decision-making processes and develops a new methodology to quantify and document decision data.

2 Intuitive decision-making

2.1 What’s so complex about wastewater networks?

The complex nature of wastewater networks comprises the following categories:

**Socio technical**
The influences are a mix of the technical (pipe attributes, hydraulics, loading demands etc.) and social (financial impacts, stakeholders, public safety, environmental protection, political interests and regulation).

**Network complexity**
There is an important connectedness where each individual element is part of the wider system and there is an inherent interdependence. As pipe networks grow in size and number, the complexity of the connectedness also grows.

**Unknown causality**
Causation is the “cause and effect” relationship where a network performance state can be shown to be the result of a particular characteristic. Due to the complexity of the network there is a high degree of uncertainty as to what characteristics caused a particular issue of failure.

**Missing data**
Local Governments struggle with asset data that is either altogether missing, incomplete or unreliable. This issue is confounded by the nature of wastewater networks being buried underground assets, effectively invisible. This data issue is a barrier to the prediction of outcomes using calculative models.

2.2 Why intuition?

Psychologist Daniel Kahneman describes two distinct modes of thinking: System 1 and System 2.

**System 1** operates automatically and quickly, with little effort and without the requirement of voluntary concentration. This mode draws on relevant experience, knowledge and “gut”, and is fundamentally important for intuitive decision-making.

**System 2** allocates attention to effortful mental activities, tracing mathematical and logical solutions to the task at hand. This mode is relied upon heavily when adopting rational decision-making processes.
2.3 Intuitive pitfalls

There are however some associated pitfalls to understand when using expert intuition.

Transparency

There is a transparency issue as decision-makers use their own expert knowledge to jump from A to E in a decision without necessarily being able to articulate or document the skipped calculations of B, C and D.

Bias

Unconscious bias is present when using intuition and undermines decisions accuracy. Bias can appear in; anchoring, confirmation bias, groupthink, information bias, and loss aversion.

Institutional knowledge

Knowledge is gained through experience and our senior expert staff have accumulated great insight. However, our aging society presents a risk of losing intuitive expertise and institutional knowledge of retiring staff.

One way of overcoming pitfalls and bias is by documenting the intuitive decision-making process. This gives a reference point; a chance to audit and challenge assumptions, and provides an opportunity for learning so that intuitive decisions can be improved over time.

3 Industry survey to document intuition

3.1 The decision system model

The developed method focuses on relevant factors and their levels
of importance. This importance weighting or “significance” of factors comes from an industry survey of wastewater network experts.

The context question for the decision model is: “which pipe should I replace/repair?”

The decision tree used to answer this question considers how each factor contributes to the overall network performance. The tree branches down into the five main network failure categories and includes factors that contribute to the likelihood or consequence of each failure risk.

### 3.2 Quantitative assessment

For each factor the various factor scores and significance weightings can be used to quantify the impact to network performance.

**Factor score**
A factor score of 5 is bad and a factor score of 1 is good. “Bad” is also synonymous with high risk and “good” with low risk.

**Significance weighting**
The significance of each factor is determined from the industry survey. The survey frames the questions from the perspective of a wastewater network asset manager tasked with having to determine which pipes in their network to repair or replace. The weightings are quantified using a 1-5 Likert-type scale.

**Survey participation**
The survey was distributed online and circulated to Water New Zealand and the Institute of Public Works Engineers of Australasia, with some direct requests to Council and engineering consultant contacts. Participants who were experienced in wastewater network renewal decisions or investigations were asked to self-select. The survey was taken by 43 participants between 7 February 2017 and 27 February 2017.

### 4 Results

Typically the significance scores from the experts were in the 3 – 4 range. A “Top 2 Box” calculation is useful for Likert scale survey methods. Top 2 Box results are the percentage of all results on the 1 – 5 scale that were reported as 4 or 5, that is, **Very Significant** or **Extremely Significant**.

These results provide the input for the significance weighting for each of the factors. Further analysis was done to determine how much of an influence each factor has on the overall network performance score. This was conducted by creating a model where each factor score is combined with its significance weighting and connected together using the format of the overarching decision tree.
Unsurprisingly, those factors appearing near the top of the decision tree had more of an impact on the overall network performance compared with those that appear as sub factors at lower levels of the tree. The impact of each factor and the ranking is provided in the full paper.

5 Conclusions
The industry survey and overall method of documenting intuition provides insight into several benefits:

5.2 Benefits
Provides prioritisation scores
The method provides prioritisation scores once the significance weights are combined with the factor scores. The method is adapted from existing techniques and theories and provides a workable solution. Documenting the prioritisation scores allows improvement of intuitive decision-making over time.

Identification of the factors to include or not include in decision-making
The Top 2 Box results provide clear indication of which factors are significant or not for the renewal prioritisation decision. These observations can be used to refine and simplify the decision tree model to only use the highest scoring factors.

Targeted data collection
The significance weightings also show the most important factors to concentrate on for data collection.

Targeted effort for setting 1 to 5 factor score categories and thresholds
Similar logic also applies to the task of setting the 1 to 5 factor score thresholds. The knowledge of which factors are most significant can help to hone the effort applied when coming up with the 1 to 5 factor score categories and thresholds.

Qualitative decision-making and prioritisation
Numeric representation of a decision tree may be beyond what an asset manager is capable of at a given point in time but nevertheless the significance weightings could still be referred to. Using a qualitative high/med/low significance would provide useful prioritisation.

Testing the decision tree structure and hierarchy
The process of completing the survey and applying the method provides a chance to analyse the results and then go back and challenge what was originally assumed as the appropriate decision tree.

Can be applied across a network
Once set up, the method can be applied at scale allowing the computational benefit of process repetition to apply scoring across the network.

Provides a documentation trail
The documentation allows auditing of the decision quality and also gives a starting point for refining the method over time to facilitate continuous improvement.

Links individual factors with ultimate decision outcome
For each factor it is possible to see which other factors are influenced by it and also to see how those factors ultimately affect the decision outcome.

Used as a shortlist
It may be that the asset manager wishes to retain the autonomy of the ultimate decision-making, and even in this case the method provides assistance. This method could be used to shortlist pipes as candidates for action still allowing room for the asset manager to apply their own expert intuition at the end of the process.