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MATHEMATICAL MODELLING IN INFRASTRUCTURE ASSET MANAGEMENT:

Increased decision intelligence and automated processes for more effective asset management.

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How modelling enables asset managers to predict asset degradation, orchestrate maintenance, and safeguard against failures.

Asset Managers face a daunting task.

From factory machinery to forests, from bridges to space debris. No matter the asset, degradation is unavoidable. Without adequate inspection and maintenance, those assets will fail — at potentially great cost.

Faulty machinery can force production lines to close, landslips often lead to major disruptions to rail services, and fleet failure could bring deliveries to a standstill. Being able to effectively predict degradation and organise inspections or maintenance is critical to operational efficiency.

But several factors make this process challenging:

- Monitoring and inspecting an entire network of assets can be impractical and resource heavy.
- Inspection data is hard to obtain and keep up to date. Even if data is recent, risk of failure can be difficult to predict and track.
- Different assets have different management systems and maintenance processes, each bringing their own unique set of requirements and challenges.
- Degradation patterns are complex and sometimes extremely difficult to predict.
- Budgets force asset managers to prioritise resources, often leading to over-maintenance in some areas while other areas become under-maintained.

Mathematical modelling - the solution?

The field of asset management has greatly benefitted from the technological innovations. Companies are now using drones, satellite imagery, remote sensors, specialised robotic equipment, ultrasonic testing, radiography, wireless sensor networks and more to gather more information to monitor assets - especially assets that have traditionally been hard to inspect and monitor.

Mathematical modelling is a crucial development. By using algorithms to represent real-world systems and predict their behaviour, asset managers can overcome challenges while unlocking valuable insights for informed decision-making.

On the next pages, we will explore some of the key challenges facing asset managers and provide insight into how modelling could be the missing piece of the puzzle.

Three challenges facing asset managers

1. Monitoring complex networks can be impractical

Understanding the state of a network is crucial for knowing when assets need maintaining or replacing. Unfortunately, inspecting an entire network of assets may be impractical for two main reasons:

a. The size of the network
In the UK, there are more than 20,000 miles of railway track. Inspecting each line to understand which locations are most at risk of buckling is almost impossible.

Even if you were to finish the task, the first inspections would be severely outdated by the time you finish. As a result, only limited sections of the network are monitored regularly.

b. The accessibility of the asset(s)
Underground pipes and cables are notoriously difficult to inspect. The condition of pipes usually must be inferred from limited CCTV snapshots, sensors, radar and other inspection processes.

Of course, underground assets are not the only ones with accessibility challenges.

Space debris currently cannot be effectively inspected. It may only be tracked using sensors, with some objects too small to be tracked.

Due to these accessibility issues, some asset managers have adopted a reactive rather than proactive approach, which can lead to huge costs when assets fail. Ad-hoc inspections have also been used, which can waste resources and neglect important information.

2. Managing external pressures and cost of failure

Many asset managers are responsible for assets that perform a critical role in society. While this makes it crucial to effectively maintain the network, it also raises challenges and risks.

a. Industry pressure
There can often be significant industry, regulatory, or public pressure for a network to function and be maintained to specific standards. This is usually the case for environmental assets such as rivers, hospital equipment, and the workforce in the health and social care sector.

b. High cost of failure
Failure to comply with regulations and public opinion could result in fines, reputation damage, and wider societal loss. For example, a sewer pipe break can lead to contaminated waterways and possibly harm to wildlife. Deterioration can also have considerable financial, time, and safety implications. In some cases, such as for nuclear reactors, results could be disastrous.

These two factors underline just how vital it is for asset managers to be able to effectively safeguard against failure.

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3. Balancing cost and consequence

The best way to manage a complex network of assets is to build an accurate map of the condition of each asset in the system. This poses a few challenges:

- The map needs to be updated regularly — instantly, if possible.
- Maintaining this map, and ensuring its effectiveness, is costly.
- Building this map can be impractical and time-consuming.

Asset managers need to strike the right balance. This depends on their organisation's budget, access to assets, risk appetite, and the severity of consequences should an asset fail.

They must also consider the impact of maintenance. Are repairs cheaper than replacements? Will acquiring parts and expertise to manage an emergency repair be expensive, time-consuming, or even possible?

To overcome these challenges, asset managers need to be able to predict asset degradation, schedule inspections and maintenance efficiently, and safeguard against asset failures. All within their budget.

How mathematical modelling can aid asset managers

Modelling real-world assets is a cost-effective way to gain a greater understanding of the state of the network and enable efficient use of resources when planning inspections and maintenance.

Accurate modelling can be complicated by the size, complexity, and lack of inspection data in networks. But, by breaking down asset management into three distinct categories – inspection, prediction, and intervention – the task becomes more straightforward.

Inspecting assets

Instead of random, ad-hoc inspections with no clear strategy, an optimisation algorithm can accurately recommend which asset should be inspected, and when this inspection needs to occur. This recommendation maximises how asset managers can utilise their budget.

Using an algorithm also effectively balances the trade-off between inspecting:

- assets that we know are in poor condition and may have degraded further since the last inspection.
- assets that have not been assessed for a long time but were in good condition at the date of their last inspection.

Over time, the algorithm will become even more effective as it learns from new inspection data. It can prevent resource wastage, provide valuable insights, and significantly minimise the likelihood of asset failure.

Predicting asset condition
Mathematical modelling enables asset managers to accurately predict asset condition and learn more from inspection data. For example, by inspecting one asset we can infer the condition of similar assets. This reduces the frequency and cost of inspection.

The algorithm also makes it possible to forecast asset condition, giving insights into how we can expect assets to degrade over time. This reduces uncertainty in our prediction of asset condition. By removing uncertainty, risks, such as asset failure, can be quantified and addressed.

Intervention to repair or replace assets
Once you have a robust model for asset condition across your network, an optimisation algorithm can be used to recommend which asset will require an intervention next, which could be a repair or replacement, and when this should occur. This proactive approach to interventions, instead of relying on reactive approaches or potentially inefficient inspection schedules, minimises asset failure.

Predict, orchestrate, and safeguard

Through modelling methods, asset managers can automate and optimise their approach to scheduling inspections and orchestrating maintenance. This enables a proactive asset management strategy, reducing number of asset failures, and preventing wasted resources on sub-optimal inspections and maintenance work.

Beyond this, the insight and visibility provided by an algorithmic approach leads to higher decision intelligence, enabling managers to make more informed decisions to safeguard the longevity of critical assets. For example, by quantifying risks, organisations gain clarity over risk exposure. This clarity enables asset managers to address the risk with confidence.

By embracing the potential of mathematical modelling and optimisation, organisations can pave the way to more resilient, efficient, and sustainable asset management practices.

Achieve cutting-edge decision intelligence
Smith Institute empowers organisations to make optimal business choices with for their infrastructure asset management powered by AI and data science.

If you would like to discuss your asset management strategy, or how you can harness the potential of mathematical modelling, get in touch:

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