RISSB
RAIL INDUSTRY SAFETY AND STANDARDS BOARD

FASTTRACK

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INSIDE THIS ISSUE – WHAT IS SHAPING THE RAIL INDUSTRY TODAY AND INTO THE FUTURE

P1 Machine Learning for Conditioned Based Maintenance – Jake Vanderlinde

P2 Data-driven insights for reliable assets – Scott Hukins

P3 Integrating Multiple Projects into Centralised SCADA systems – Tony Tran

P5 Obstacle Detection Systems for Safety and Efficiency of Rail Transportation – Kanashya Thivagarupan

P6 AR & VR: taking the leap from lab to track?– Frank Scheurich

P7 Transformative Rail – Damian Hong

Machine Learning for Conditioned Based Maintenance

When performing maintenance on any asset, whether it be a personal vehicle or a rolling stock fleet, the aim is to minimise the total cost associated with maintaining and operating the asset. If the asset is not maintained frequently enough there will be a higher number of failures and higher repair (reactive maintenance) costs. If the asset is maintained too often, there will be higher prevention (preventative maintenance) costs. In an ideal world maintenance would be performed at the point that produces the lowest **total** cost for maintaining/operating the asset. This point would be the moment before the asset is about to fail. However, knowing the exact moment a failure will occur is difficult, thus strategies to predict or model when this moment is 'likely' to occur are important.

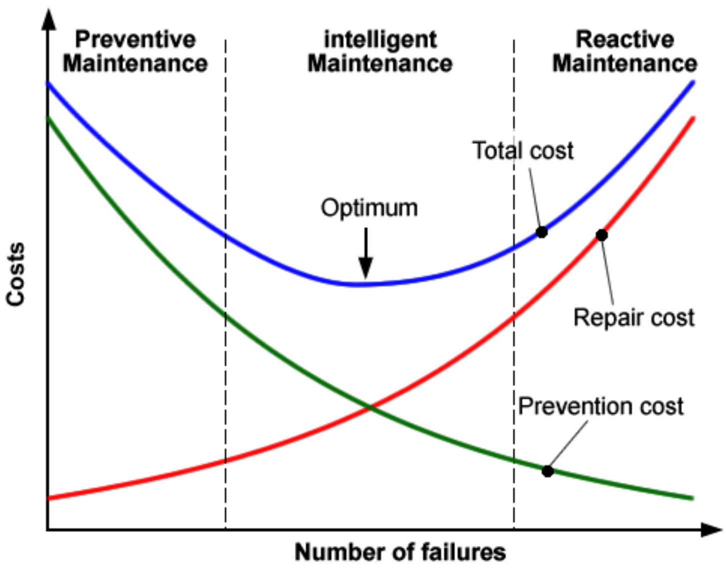

Figure 1 Preventative vs Reactive Maintenance (image source)

Conditioned based monitoring (CBM) is a technique used to predict when this moment will occur. It involves monitoring data or health indictors from an asset and using changes, or trends, in these to predict failures. For some failure modes, such as bearing failures, these changes/trends are relatively simple such as looking for increases in vibrations. However, this is certainly not the case for all failure modes and thus traditional conditioned based monitoring proved to be ineffective. What if there were health indicators that could be used to predict these more complex failure modes. These indicators may not be as intuitive as the vibration example or may involve a complex set of indicators that react in a particular way to cause the failure. This is where machine learning (ML) can be utilised to support CBM to provide more accurate failure predictions.

ML involves a set of algorithms analysing and learning from data sets to improve the accuracy of a prediction or model. This can be applied to CBM by using ML to analyse health indicators from when an asset is performing normally, immediately prior to and at the moment of failure. The ML can find patterns or trends in the data that were previously undiscovered by traditional techniques. This will lead to far more accurate failure models and subsequently a reduction in the **total** cost for maintaining/operating assets. Examples of this can already be seen with non-safety critical assets such as HVAC units on rolling stock. However, as both eh accuracy and confidence in these ML algorithms improves, we will see ML enabled conditioned based maintenance utilised on more assets both in the rail industry and beyond.

Data-driven insights for reliable assets

Traditionally rail operators have used time-based maintenance to ensure their assets are operating reliably, aiming for a more efficient and safer network. The major issue with time-based maintenance is that there is no recent quantifiable data to assess whether the asset requires maintenance, maintenance is just conducted on an arbitrary or recommended maintenance schedule. This would be like regularly taking your car to a mechanic for a service every 6 months without having any idea whether it needs an oil change, new oil filter and air in the tyres. Unfortunately, that is what most of us do. We either do that or wait for the check engine light to start flashing, by that stage, the damage has already been done and you have been driving around in a dangerous vehicle. Wouldn't it be nice if your car had a system to say, "Hey mate, my wheels aren't spinning quite as fast as they used to when you put your foot on my accelerator. It's time I went in for a service." That way you would know that you're not wasting your time and money taking your car to the mechanic for an unwarranted service (not to mention the mechanic trying to upsell you an inflated set of windscreen wipers).

There are now products in the rail industry that can help provide that voice for your asset. Conditioned-based and predictive maintenance aim to increase asset reliability by proactively scheduling maintenance before it is are breaking down. Saving the rail operator maintenance costs and reducing asset downtime.

Both types of maintenance use data captured from trackside devices to assess whether your asset requires attention from the maintenance team. Where they differ is how they process the captured data to determine when maintenance is required.

Conditioned-based maintenance (CBM) uses the real-time data captured from the asset and once a data point reaches a predefined threshold, the maintainer receives an alert to inform them that maintenance is required on the asset. Therefore, CBM systems perform a maintenance assessment at that snapshot in time.

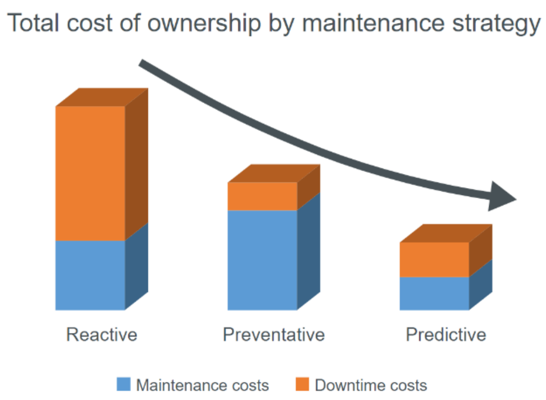

Figure 2 - Cost of Maintenance per Strategy (image source)

On the other hand, predictive maintenance (PM) utilises real-time along with historical data and advanced analytics to provide an evaluation of an asset's health. This provides a customised approach to each asset opposed to applying universal thresholds to each piece of equipment in an asset class.

PM aims to inform a rail maintainer that an asset requires maintenance before the deterioration of an asset's performance. A product like Downer's DNA solution is the first step in the journey to predictive maintenance. Combining data and a smart analytics platform, it enables data-driven decision making to improve efficiencies in asset maintenance.

TrackDNA intelligently integrates historical datasets and information from multiple asset classes to enable faster and better decision making. This provides a structured output of information based on business rules, allowing users to easily generate reports and view alerts on demand from a simple and intuitive interface. By proactively monitoring assets and establishing trends, the solution is designed to:

- Reduce unscheduled asset downtimes
- Increase availability by proactively predicting failures
- Minimise maintenance costs through improved efficiencies.

Integrating Multiple Projects into Centralised SCADA systems

Many railway operators utilise centralised SCADA systems in order to consolidate control room functions such as integrated day-to-day operational and security management of railway and bus operations as well as unified response to network-wide fault and incidents. With the recent boom in railway infrastructure projects, a new challenge has emerged, that is, concurrent integration of multiple projects back to these centralised SCADA systems.

There are important considerations required in both the client organisation and industry suppliers to ensure the success of these integration activities and the accelerated schedule of these projects can be accommodated into a cohesive SCADA system.

Some of the core success criteria in management of these integration activities are:

- Effective business risk mitigation and gaining control of integration activities in scope and timing – While it's common, and often simpler, for project boundaries to be drawn up geographically, it is challenging to determine project boundaries within software-based systems. Strategic management of both: software core dependencies and individual project branches within SCADA systems is vital to ensure unified integration between these projects and effectively managing the risk of the changes to an operational system by providing the coordination between the projects. A common mistake is to assume a rail line wide closure is all that is necessary to 'isolate' a project from other parallel projects. Integrated SCADA systems makes this no longer the case!

- Supporting the supply chain – It is true that there are only a few Industry-leading Industrial control systems available and an even smaller subset of these systems suitable for the railway application; and as such it's common for these SCADA packages to be highly user-configurable and hence heavily tailored towards the organisational needs of the operator. As such, railway operators play a crucial role in driving project-enabling processes due to a better understanding of the software's internal structure. This will accelerate the development process by not relying on the supply chain to reverse-engineer many obscure software intricacies that may exist in the operational systems. With the organisation acting as a centralised coordination body, this should also drive consistency between look-and-feel operation of SCADA systems and consistent approach to data collection for better business decision making through common standards and data formatting

- Ensuring no gaps within Integration activities such as integration activities to other indirect 'Enabling' systems. Common challenges with railway systems include poorly documented technical interfaces on legacy systems (e.g. obscure asset condition monitoring systems) and integration back to systems required to enable business systems which are not directly part of an operational SCADA system.

A possible method to drive successful SCADA integration can be driven by the railway operator itself by applying the concept of *Organisational project-enabling processes* from ISO 15288. The intention of this is to provide the resources needed to enable projects to meet the needs and expectations of the organisation.

What this can look like in the context of a railway SCADA system, is conducting an independent, pre-project assessment and to conduct any resultant forward works necessary on any identified system limitations. Limitations can include spatial provisioning on common HMI pages, estimating additional computation load, impact of any system-wide interlocks or any impact of the coexistence of new technology with legacy technology.

Another key concept as part of the *Organisational project-enabling* process is to establish the environment from which the projects are conducted in. From the perspective of a railway operator, this may include activities such as:

- Creation of a system development roadmap in order to coordinate cross-project integration activities and enable software code branching

- Style-guide and control philosophy development to establish typical user functional requirements, design standards and guidelines for conceptual designs of console page layouts, screen navigation, etc. with sufficient underlying technical principles as a basis of design

- Requirements for specific testing in addition to any software integration tests identified by general methods in established standards (e.g. EN 50128) some examples are system benchmarking prior to and after integration and proof of concept requirements for novel interfaces

- Specification review and gap identification for continuous improvement.

Obstacle Detection Systems for Safety and Efficiency of Rail Transportation

There are multiple injuries and fatalities on the railway network across Australia every year. CCTV cameras work as a physical deterrent and a real time warning to control room operators of obstructions on track and railway premises. However, CCTV cameras have limitations in that weather conditions such as sunlight, fog/smoke, tunnels and night time may obscure views. Furthermore, there is the added requirement of an operator constantly viewing video output to become aware of obstructions and intrusions, which also introduces human error and reaction times.

However, thermal imaging cameras with automatic incident detection (AID), such as FLIR can be used to overcome the limitations of normal CCTV as the thermal imaging technology produces images of invisible infrared or 'heat' radiation. This assists to send an alert when detecting people entering a train tunnel, walking on a track falling from platforms or stopped cars on tracks. This technology can then warn the operator with details of position of the obstruction. There is also the added opportunity to detect obstacles at level crossings which would otherwise harm passengers and damage rail infrastructure. An alert is sent to the operator who can then review the situation.

In Belgium, it was found in 2018 that there were 768 intruder incidents with a total of 139,000 minutes of delay. 30 FLIR thermal imaging cameras were then employed to detect intruders on the network. The system is configured to be highly efficient in ignoring small animals or passing trains. The FLIR cameras have been achieving a 99% accuracy of detection.
Thermal imaging can be extended to an emerging technology known as SMART (Smart Automation of Rail Transport) stereo-vision system. This contains 3 cameras, a laser scanner, thermal camera and a night vision camera. The prototype is designed to be mounted on the train itself and have obstacle detection up to 1000m in a rail-specific framework. With the programmed algorithms, real-time detection of objects and obstacles on tracks can be flagged and the distance between the obstacle and rolling stock can be determined. A concept solution of SMART ODS is shown below in Figure 1.

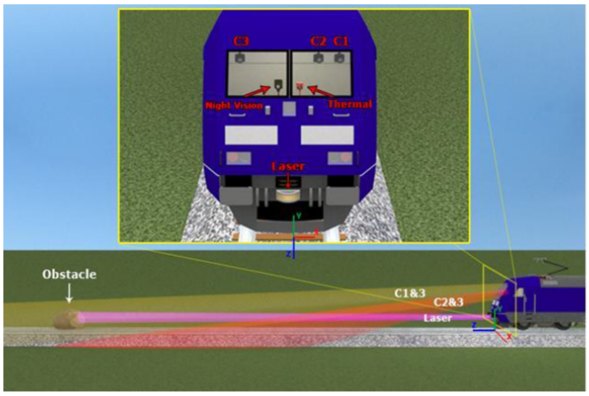

Figure 3: Concept of SAMRT multi-sensor obstacle detection system. (Top) Front view of sensors mounted on locomotive, (Bottom) Side view of range sensors and obstacle detection scene

Overall, obstacle detection systems using thermal imaging are proven to be more reliable and enable increased safety on the rail network. With future technology of rolling stock mounted thermal cameras, there will be increased safety and reduced damage to rail infrastructure, with enormous cost savings.

AR & VR: taking the leap from lab to track?

Figure 4: Virtual Reality in Practice. Credit: HS2

For many years the self-concluded Virtual Reality and its interconnected sibling Augmented Reality have been mostly applied in the safeguarded environment of design offices and training centres. While exploring digital mock-ups and training personnel in a virtual world is nowhere new and an established practice, application outside those spaces is yet to make a bigger impact.

It is therefore very exciting, that a closer look at the program of the RISSB Rail Safety Conference in Sydney (11-12/05) and the Virtual Forum of the Horizon 3.0 Program reveals Tech Talks and Speaker Presentations on topics, that offer the possibility to either enable (Digital Twins, Digital Engineering Innovation) or expand (AI Vision Systems, Suicide Prevention) the application into the world of rail.

While thrilling innovations are on the horizon and there is little to no doubt about the positive influence on Rail Safety across all areas, entering the mainstream will surely face challenges with regards to its impact on the users health, the protection of sensible and personal data and of course the acceptance of wearables by the end-user.

Still, it seems foundations are made, and with enabling high throughput mobile network infrastructure on the advance, time has finally come that we see immersive technologies emerge from their niche existence.

Transformative Rail

As the importance of sustainable development within the built environment have become more apparent in recent years, the way that we think and create as contributors in the rail space have challenged us to think more broadly and adopt a holistic perspective.
As part of the United Nations' Sustainable Development Goals (SDG's), Arup have embraced its sustainability principles into the wider strategy for rail and about the importance it plays for the industry's future.

In March 2020, Arup have published their collaborative literature "Transformative Rail". The literature explores emerging trends facing the rail industry, such as customer experience, sustainable development, and the digital evolution. It aims to focus on relevant solutions for railway systems that are fit for today's demand and tomorrow's opportunities.

Find out more here:
https://www.arup.com/perspectives/publications/research/section/transformative-rail-the-issues-shaping-the-future-of-the-industry

Figure 5: Arup's Transformative Rail Publication
(image source)

Thanks for reading

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