Instrumented **revenue** vehicles drive track **maintenance** efficiencies

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Continuous monitoring of track condition and vehicle dynamic behaviour using instrumented revenue vehicles provides regular and rapid identification of track and operating problems, which is being used by a growing number of railways to support proactive track maintenance strategies.

Rising demand is posing major challenges for railways around the world. They must invest significant sums to renew and enhance their infrastructure, while at the same time keeping lines open as much as possible to handle the increased traffic. As maintenance windows shrink and renewals budgets tighten, infrastructure managers need to find responsive strategies to drive efficiencies whilst ensuring safe and reliable operations.

Over the past decade, a growing number of railways have adopted Instrumented Revenue Vehicles as an intelligent automated condition monitoring tool which can be integrated into their normal operations. Coupled to sophisticated data processing systems, this offers significant benefits in fine-tuning asset maintenance and operating strategies.

IRVs automatically collect data on the vehicle's dynamic performance, and send it back from remote locations to a central processing facility for real-time analysis. This allows any high-risk track defects to be identified rapidly, along with their precise locations. The system prompts appropriate operational responses, such as the application of temporary speed restrictions and the rescheduling of maintenance activities, in order to limit any risks associated with catastrophic consequences such as derailments and further damage. The technology can also be used to measure the effectiveness of maintenance activities and to identify track deterioration trends as well as any irregular operations. Taken to its logical conclusion, full integration of the condition-monitoring tools into routine operations will enable railways to shift from reactive to proactive maintenance strategies.

Typical Instrumented Revenue Vehicles in use with different operators include coal and iron ore wagons as well as passenger coaches.

Development

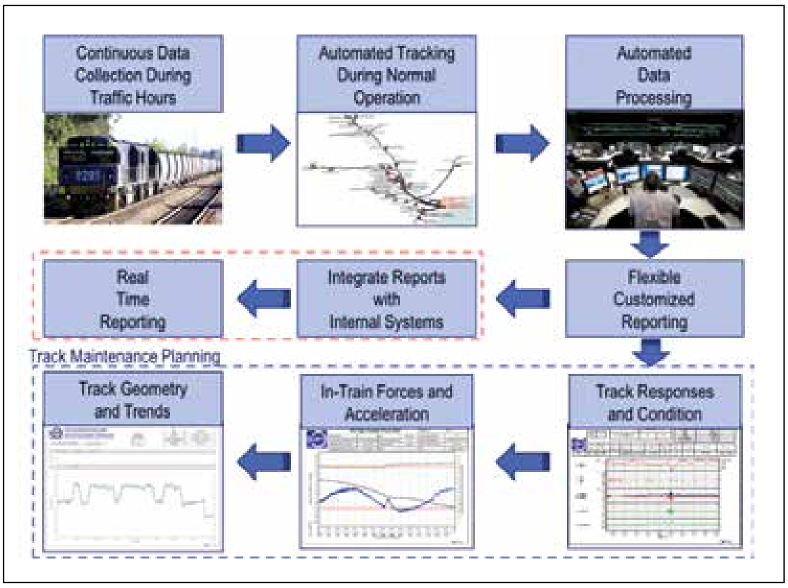
The IRV concept has been developed by Monash University's Institute of Railway Technology, which provides both the measuring systems and the data processing services to a growing number of railway operators including including Hong Kong MTR Corporation, V-Line, Rio Tinto, Australian Rail Track Corp, Fortescue Metals Group, Roy Hill, Aurizon, BHPBIO, Vale and PT Kereta Api in Indonesia. It was initially implemented on several of Australia's heavy haul railways, but has since been rolled out to general mixed-traffic freight and passenger railways around the world[1-3].

Table I: IRV platform measurement capabilities

GPS position
Altitude
Vehicle dynamic response to track
Roll, pitch, bounce and hunting
Vehicle in-train forces
Ride index and ride safety
Vehicle loading and wheel/axle loads
Rail running surface acceleration
Track surface condition
Track superelevation/cant
Track twist
Track curvature

The basic concept is fairly straightforward: rather than using dedicated inspection cars, the measurement platform is mounted on standard vehicles running in revenue service, day-in, day-out. The majority of these are freight wagons, but more recently passenger coaches have also been equipped (left). The platform can support a range of advanced measuring systems, including different types of sensors and logging units (Table I). These provide continuous feedback on track condition, vehicle dynamics and train operation[4, 5].

Using revenue service vehicles brings two important benefits. Firstly, because the IRV is measuring track condition



as part of normal operations there is no need to allocate specific paths or possessions to accommodate the monitoring activities. Secondly, and perhaps more significantly, the equipment is measuring the dynamic response of standard vehicles during their normal operating cycle, both loaded and empty.

Continuous measurement during every loaded and empty run provides a stream of data which can be used for short and long-term trending analysis. Track condition and vehicle responses can be correlated, helping to inform strategies to improve overall system performance. The tools can also be used to assess the effectiveness of maintenance interventions, by comparing the 'before' and 'after' condition.

However, the instrumented measurement platform needs to be very robust, as the vehicles are embedded in the railway's revenue operations. As such, they are treated just like any other wagon or coach operating under harsh conditions, and generally maintained as part of the standard maintenance schedule.

The standard instrumented vehicles are capable of monitoring a broad

Fig 1. The flexibility of reporting systems allows IRV monitoring data to inform a variety of asset management strategies.

range of track conditions, identifying track geometry defects by measuring the bogie suspension displacement and rail surface defects by monitoring the unsprung side frame acceleration. Using GPS and an accurate speed input, the location of any response to an individual track defect can generally be identified to an accuracy of better than ±1 m.

These measurements can be used to calculate vehicle dynamic modes, including roll, pitch, body bounce, body rock and hunting. However, the IRV also monitors in-train coupler/drawbar forces, brake pipe and brake cylinder pressures, providing insights into train handling dynamics as well as the response to track condition.

The basic measuring platform is sufficiently flexible to allow the addition of further sensors to monitor the performance of specific components as required. It can be used in a variety of ways — for example, running multiple IRVs in one train could help to assess any improvement in train performance after the introduction of new components such as ECP braking.

The IRVs communicate directly with the data processing centre using 3G/4G and satellite networks, Field recordings are automatically downloaded to the main logging unit mounted on the vehicle, and the data is then transmitted to the data processing centre for analysis (Fig 1).

Timely Identification and warnings

One of the important features of any continuous monitoring programme is timely feedback in the form of reports and warnings. As well as sending regular trending reports to

PARTNERSHIP

From Australia to China

In July 2017, Monash University's Institute of Railway Technology signed a collaboration agreement with MTR Corp to install its most advanced IRV condition monitoring technologies on the Hong Kong metro network, which is currently carrying around 5·4 million passengers every weekday.

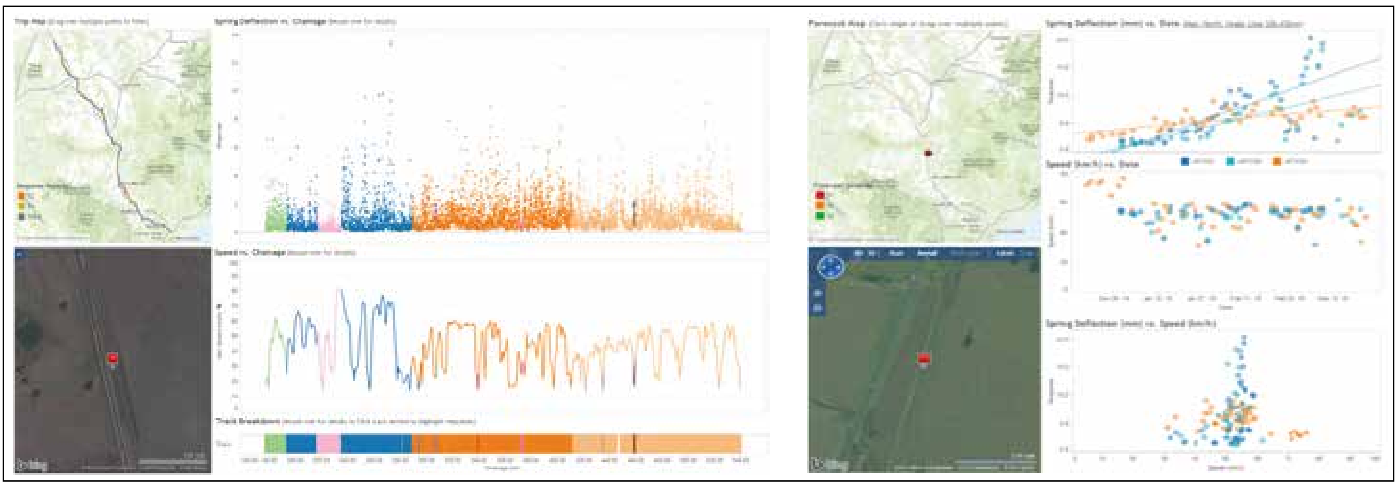
The agreement builds on a long-standing relationship between Monash and MTR Corp, who have been working together for more than three decades. MTR is also a major shareholder in Metro Trains Melbourne.

In September, the Institute was awarded the 2017-18 grant from the Department of Foreign Affairs & Trade's Australia China Council. This is intended to promote the use of 'cutting-edge asset health condition monitoring technologies' to improve the safety of passenger railway operations.

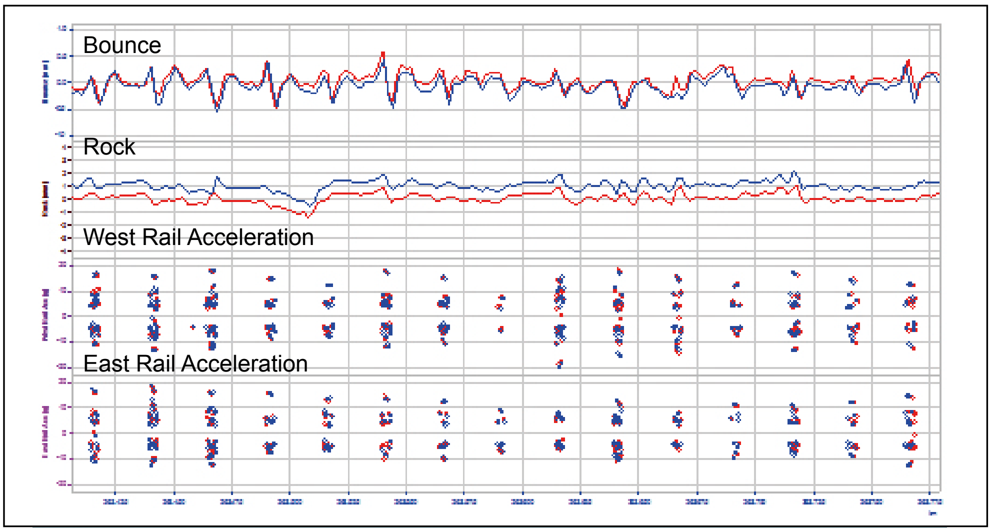
In collaboration with MTR Corp, IRT has delivered a series of workshops on the use of in-service monitoring technologies for passenger railways in Australia and China, including Hong Kong. The workshops considered how the implementation of continuous monitoring can help railways move away from reactive and scheduled maintenance to a more predictive regime which ensures that valuable resources are used more efficiently.

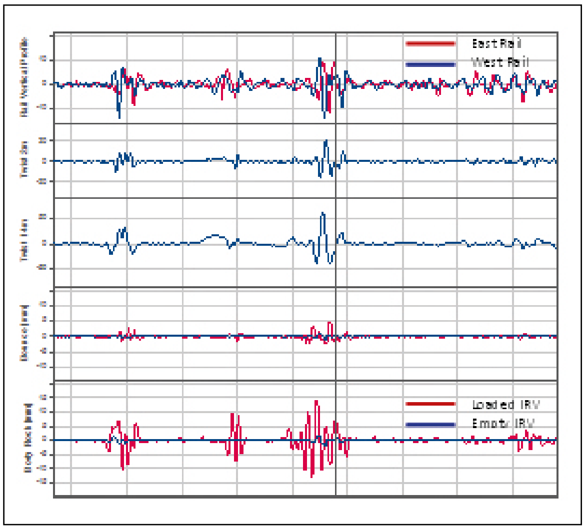
According to Monash University's Deputy Vice-Chancellor Ken Sloan, the ACC grant presented an opportunity to profile both research excellence from Australia and operational expertise from Hong Kong, while raising awareness of new technologies that could support the changing requirements of a modern railway. ■

Fig 2. The IRV package provides users with a customised web dashboard to interrogate the processed data.



MONITORING Australia





Top: **Fig 3. Elevated dynamic responses detected by an IRV.**

Above: **Fig 4. Track geometry and vehicle dynamic responses as measured using an IRV.**

Right: **Fig 5. The condition of rail welds can be identified from the recorded data.**

the railway companies, the data processing centre can issue urgent warnings and supporting data to operational personnel in the event that any individual response exceeds an agreed threshold. Recipients could typically include track inspectors, maintenance engineers, train control centres and traffic planners. Reports and messages are sent by email and SMS text message, as well as via customised web dashboards (Fig 2).

While the data for each individual railway is kept confidential to that operator, the Monash team aggregates all of the information using machine learning and deep learning techniques to look at broader trends across the entire data set to predict future performance of the railway networks. This has proved particularly valuable in addressing emerging issues that are common to many different railways.

Track condition

The basic IRV technology is used to identify rail weld, surface and other track related defects in a timely manner. Because the IRV is monitoring dynamic vehicle performance under loaded conditions, this significantly improves the probability of detecting any deterioration of track quality before it is too late, helping to avoid potentially catastrophic consequences.

Elevated vehicle dynamic responses, such as side frame acceleration on each side of the bogie, which indicates bounce or rocking of the vehicle (Fig 3), can be directly correlated to accurate track location(s). This in turn can be attributed to specific track features such as welded rail joints, insulated rail joints, corrugation or turnouts, so that such assets are adequately maintained to ensure an appropriate level of ride quality.

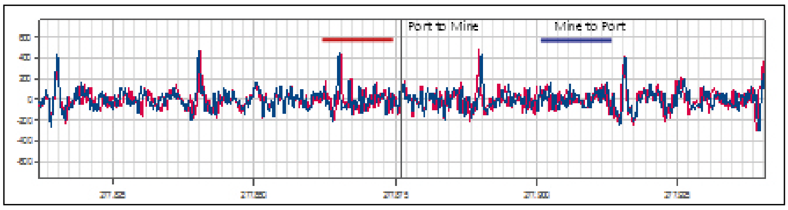
Similarly, vehicle dynamic responses including passenger ride comfort or ride safety can be associated with track geometry measurements (Fig 4).

The ability of an IRV to accurately locate track features means that the system can even be used to investigate the condition of each individual weld on the track, and whether they are peaked or dipped (Fig 5). Furthermore, the shape of each weld, including the heat-affected zone, can be correlated with accurate monitoring of the vehicle side-frame accelerations over the weld in both directions of traffic (Fig 6).

Speed restrictions

Poor track condition is usually mitigated by the application of temporary speed restrictions until the necessary maintenance intervention can be scheduled. The reduced speeds are often pre-defined within each railway's engineering standards, and are generally quite conservative, as there is no measured relationship between the poor track condition, its influence on vehicle ride and the consequent derailment risk. But whilst erring on the side of caution, an overly conservative restriction could disrupt operations unnecessarily.

Because the IRVs continuously measure both track condition and the related vehicle dynamics, railway operators and engineers are starting to gain a better understanding of the relationship between the two. This means that individual speed restrictions can be set at a level sufficient to minimise the risk of derailment whilst trying to maintain operational efficiency at the best possible level. Regular feedback from the IRVs would automatically confirm whether the speed restrictions are having the required effect, or need to be adjusted further (Fig 7 a-c).



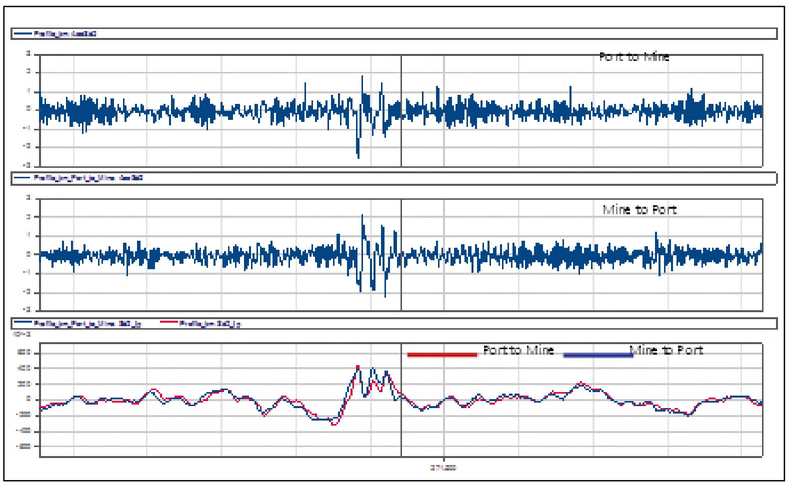
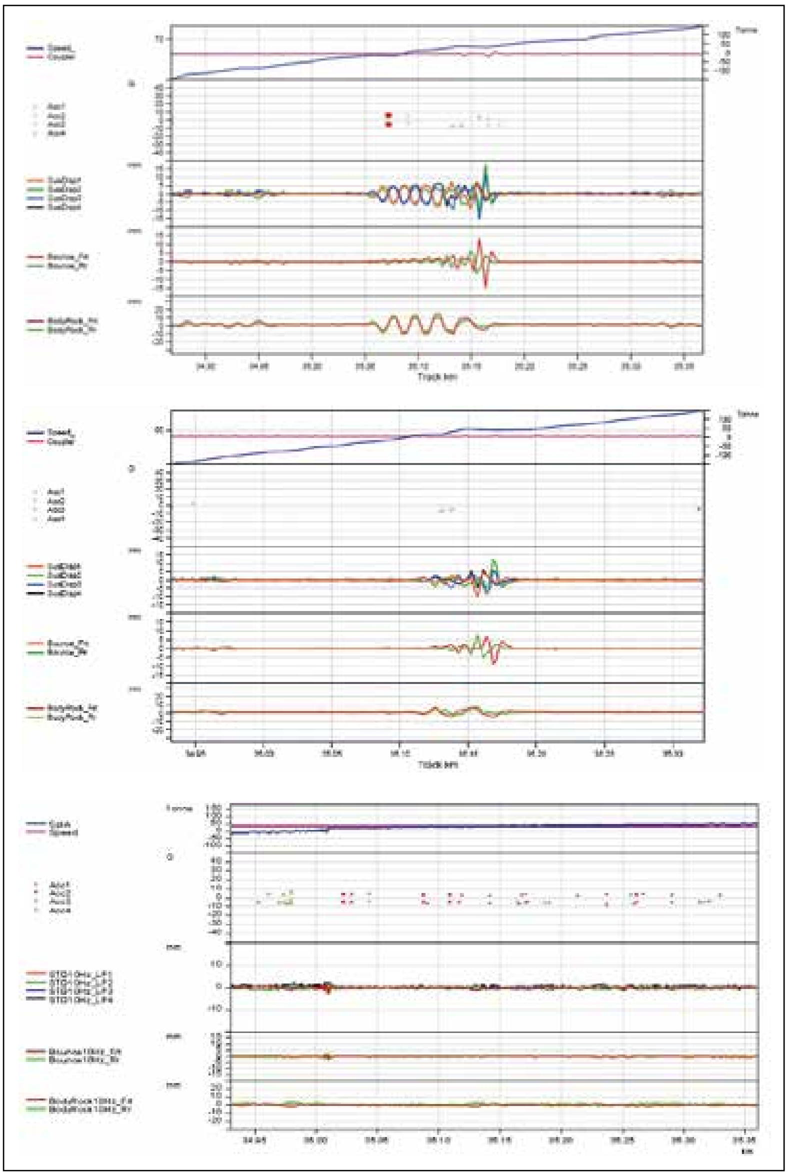
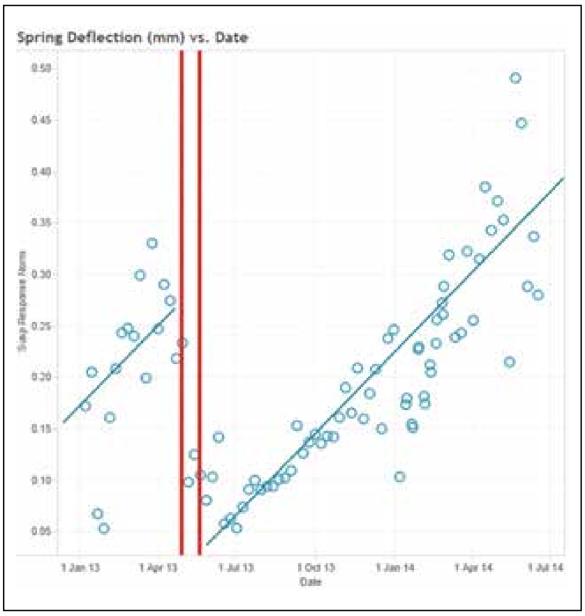


Fig 6. There is a clear correlation between weld shape and the corresponding vehicle dynamics.





Left: Fig 7. IRVs can be used to tailor temporary speed restrictions; this plot shows an elevated bounce response at 72 km/h (top) and the reduced bounce at 56 km/h under a 60 km/h speed restriction (middle); the bounce is removed at 37 km/h after the speed restriction is lowered to 40 km/h (bottom).[5]

Above: Fig 8. The effectiveness of tamping can be assessed by considering the suspension response before and after the work.

Evidence-based track maintenance

Continuous monitoring of track condition and vehicle dynamics in a normal operating environment offers the prospect of a paradigm shift in the planning and management of track maintenance.

Routine maintenance strategies on most railways are based on track condition reports and the experience of their staff. Having a greater understanding of the vehicle-track system as a whole would help them to determine more proactively what maintenance is required, when it is required, and what the outcomes should be.

As a core principle, track maintenance should seek to minimise undesirable vehicle dynamic responses. These increase the track loading forces, which reduces the life of infrastructure assets and increases the risk of derailment.

Because the IRVs are continuously measuring a range of track geometry parameters and vehicle dynamic responses, this information can be used to assess the effectiveness of individual maintenance interventions (Fig 8). This in turn helps to inform decisions about the optimum maintenance frequencies.

Properly implemented, continuous monitoring should enable railways to move away from overly prescriptive track maintenance regimes and adopt a more effective predictive maintenance approach.

A reactive ‘firefighting’ approach to dealing with problems as they emerge can be costly, and unscheduled interventions are disruptive. While routine maintenance is less costly, it can also be inefficient, because the cyclic nature of the process means that maintenance activities are done which may not be essential at that time. Meanwhile, other locations may require maintenance on a shorter cycle, but that work is not being undertaken because of scheduling and/or lack of resources.

Continuous monitoring collects up-to-date dynamic responses, which together with historical data can assist in predicting future deterioration for each section of track[7]. Based on the IRV feedback, scheduled maintenance activities could be prioritised at locations exhibiting rapid deterioration rates. ■

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