More and more railways are looking to introduce predictive maintenance regimes for their rolling stock, based on the continuous monitoring of asset condition to identify potential component and system failures. It is relatively straightforward to incorporate such concepts in new trains which are being built with communication platforms, but not so easy to apply them retrospectively to legacy rolling stock built before the widespread use of sensors and integrated train management systems.

Over the past three years, UK rolling stock leasing company Angel Trains and engineering and commercial consultancy Fishbone Solutions have been studying the possibility of extracting useful engineering information from operational data that was already being collected. A key factor behind this project was the desire to avoid installing extra hardware to extract this data, which could require significant capital expenditure.

The use of ‘black box’ data recorders is now legally mandated in many countries. They are referred to in the European TSIs as the Juridical Recording Unit and known in the UK as the On-Train Monitoring Recorder. OTMR records various channels of operational data, such as speed, acceleration, throttle position, brake setting and brake cylinder pressure, at time intervals typically down to 0.1 sec.

With support from operator Merseyrail, the research is using data from the Angel-owned fleet of Class 507 and 508 EMUs, which date from 1978-80. The work has demonstrated that recorded OTMR data can be interrogated to create Key Performance Indicators for individual trainsets, helping to inform more efficient use of maintenance resources.

Research objectives
The initial aim was to develop a computer system into which data from each unit’s OTMR could be uploaded...
at regular intervals, typically at the end of each operating day. This would allow the system to spot any deviations from expected KPI patterns as early as possible.

Project development to date has identified a robust method of creating user-generated performance indicators, which is limited only by the extent to which the data is recorded by the OTMR. Trending and threshold analysis has been performed using the channels that are available and correlated with data from other sources to verify the accuracy of the results.

The project has already provided stakeholders with some valuable information about the Merseyrail fleet. As a specific example, a system has been developed to rank the performance of air compressors, giving data capable of providing the justification for reliability improvement initiatives.

Merseyrail has played a key role in the project, providing access to ongoing OTMR downloads and helping Fishbone Solutions to develop the algorithms that create performance reports for specific components and systems on the two EMU fleets. These algorithms can be adapted to work with whatever data sets are available, facilitating their integration with other remote condition monitoring systems using an Ethernet backbone.

In terms of data analytics, the key outputs are graphs and tables, which are not always easy to interpret when looking for a simple fix to a problem. Fishbone Solutions is working with Vector Informatik GmbH, a German specialist for the development and testing of automotive electronics, which has already developed a robust diagnostics software tool that is well-regarded in its industry. Vector’s software can be integrated with the statistical algorithms to create a more ‘visual’ display of the results, that will facilitate local analysis and alerting of significant data events at rolling stock maintenance depots.

**Interpreting the KPIs**

Many OTMR devices on legacy fleets do not have GPS capability, and integrating with other GPS-enabled train systems has proven to be complex and time-consuming.

Among the OTMR data channels recorded is the ‘door closing’ function, which allows time-stamped data to be correlated with station calling patterns on each Merseyrail route. This means that train performance and driving data can be assessed geographically, without the need for a GPS signal. Without performing this key baselining exercise, the data is too variable to be compared fairly.

In terms of equipment condition, two KPIs developed in the pilot project are activations of the Wheel Slip Protection system and the operation of the brake compressor, which together provide insights into the condition and performance of the train braking system.

Fig 1 shows three plots of the WSP activations on one EMU performing three trips over the same route in a single day. The green lines mark the station stops, while the blue dots show the activation of the WSP relay. A cluster of dots indicates an area of repeated wheel slip, which seems to be independent of train performance. This could be indicative of a track condition problem, which the train operator would need to discuss with the infrastructure manager. Conversely, if a single unit experiences persistently high or unexpectedly low WSP activation at a particular location but other units do not, that would suggest that the unit in question might require a maintenance intervention. Any unit reporting low WSP activation on a regular basis might suggest that the brake system has been poorly set up or may be failing.

An alternative approach now being explored is to generate a KPI that is largely independent of track location. The frequency of WSP activation can be logged over a set time period, and a trending algorithm would look for deviations from the normal pattern as an indicator of an unhealthy unit.

An increase in activations over time might indicate an emerging failure. Catching this early would help to reduce the frequency of tyre turning to deal with flat spots, extending wheel life and improving availability.

Fig 2 provides a plot of compressor performance. The top left quadrant (fast pump and slow consumption) is where the most efficient systems would be expected to lie, while the band running from bottom left to top right represents a region where the pump is
not working optimally, possibly due to a leaky cylinder. Even at this developmental stage, the algorithms are helping to inform optimisation of train maintenance regimes by trending historic data on component performance. The algorithms rank the Merseyrail trainsets which take the longest to charge the air reservoir and the vehicles that need to recharge the reservoir most often. This ranking, and any relative change from month to month, provides an advanced warning of a potential compressor failure.

The ability to extract acceleration curves from the OTMR data has identified potentially failing units, even where they may be operating in multiple with better-performing sets.

**Progress**

With all of these derived KPIs, it is not so much the actual figures but more the change in ranking and performance over time that can be explicitly reported to give advance warning of impending failures.

The next stage of the project now under development is therefore to look at ‘near real-time’ transmission of OTMR data from rolling stock in service for analysis on an external data server.

This type of analysis is mainly intended to determine longer-term operational trends for each unit, as opposed to generating short-term failure alerts. So, an intermittent download would be adequate for this purpose. One option being considered is to use the wi-fi networks at stations and depots to transmit the raw data.

The data collection techniques and algorithmic processing routines that have been developed have clearly demonstrated that it is possible to utilise the hardware which is already fitted by law to every train using Network Rail tracks, facilitating an efficient and commercially attractive approach to rolling stock fault analysis. This is especially appropriate for older trains which are not equipped with modern telemetry systems, but it is not limited to such trains.

While the algorithms have been designed to work with data captured from existing monitoring systems, the routines have been structured in a way that they could be expanded to make use of any future updates, such as the introduction of additional data logging channels to the OTMR. They could also be used without modification to assess the performance of rolling stock that has already been fitted with remote condition monitoring equipment (Fig 3), demonstrating the versatility of the concept.

The research has established that it is possible to bring innovative monitoring concepts to legacy rolling stock fleets without the need for additional hardware. When carefully considered, there is a business case for utilising existing equipment in new ways to facilitate better performance. It can also optimise the use of maintenance resources and assist engineers with fault finding.

The system is only limited by the data available to work with, and as such the concept is equally applicable to any railway around the world where the rolling stock is fitted with some type of event recorder.

The research was presented at the 2016 IET Railway Condition Monitoring Conference in Birmingham, and at the IMechE’s Stephenson Conference earlier this year.

Fishbone Solutions is actively developing the tools and techniques, and hopes to see the concept rolled out across a number of rolling stock maintenance depots in the UK during 2018.