Weather forecasting for the railways: Current & future – tools & analysis

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Brian Douglas Haddock is a visiting Professor within the School of Engineering at Newcastle University and visiting Professor at Loughborough University and holds the position of Head of Weather Resilience at Network Rail. He is also Chair of the Rail Industry Group that manages seasonality. Brian has been Head of Weather Resilience for around two years and started off in the National Weather Team in 2008. Brian has worked within Network Rail Route (Anglia) as a weather specialist and has also worked for train operators, First Capital Connect and Greater Anglia where he was Head of Performance. Brian was also Head of the National Operations Centre (NOC) before being drafted into lead a National Review of the effects of Summer weather on the railway. Brian's fascination with the railway is inherited from his father who worked as an engineer on the railway for over forty years.

Network Rail contracts a weather forecast supplier to deliver two to five-day forecasts that are aligned to the five regional divisions across Scotland, England, and Wales. Each of the five regional divisions is split into individual Routes.

The weather forecast provider aligns geographical forecast areas across each Region with Delivery Units (DUs). For example, within Scotland Region there are five geographical forecast areas, these are:

- Perth
- Glasgow
- Highland
- Motherwell
- Edinburgh

Delivery Units are where the general maintenance teams are situated. This includes the response vehicles, tools, spares, equipment, and staff. Delivery Units are not only resourced for track but also for 'Off Track' activities such as drainage, vegetation management and earthworks etc. In addition to this there are other maintenance specific depots such as Overhead Line located along the Route.

Alignment of geographical forecast areas to Delivery Units demonstrates that the forecasting tools at the industries' disposal were and are still designed with the intention of responding to weather related incidents and recovering the train service once the weather event has passed. Response and recovery of incidents is a mature process within the rail industry and receives a great deal of focus, in resource, training and competencies. By contrast, the planning activities have historically not had the same focus as the response. A large part of the current transition in the management of weather is the development of the planning activities to get them to the same maturity as response and recovery. Routes and Regions are currently developing leading indicators and preparing plans to benefit the passengers and freight users.

Weather forecasting currently plays a critical role in how the industry responds and recovers from impending weather events in a two to five-day time frame. Once the forecast is received by email to each control centre (ROC) across the National Network it is assessed by the Route Control Manager (RCM), or equivalent role to see if any risks have been forecasted over the five-day period of the forecast. It is then distributed across the entire Region. Thresholds are set for each weather parameter that define the risk to the network, (these are referenced in the weather management standards).

The thresholds for all weather parameters are set around four core alert levels, and each of these levels has an assigned colour code, as follows:

- Normal - Green
- Aware - Yellow
- Adverse- Amber
- Extreme- Red

This simple colouring of alert status allows the teams within the ROCs to expedite a judgement on whether to initiate any actions required in accordance with their Extreme/Adverse weather management plans (E/AWMPs). See figure 1.

If an extreme threshold for a weather variable is breached within the forecast the control team will initiate what is known as the Emergency Weather Action Teleconference (EWAT). This is a five-day process in alignment with the 5 forecasted days. The EWAT process follows five stages from the initial 5 day forecast to the day of the event.

On receipt of a forecast where an extreme threshold has been breached five days in the future, for example where 'Extreme' has been alerted for 'Rain' on Sunday, on a forecast issued on the Wednesday the control will initiate the five-stage process.

The first stage is 'awareness'. On the Wednesday an RCM will issue the forecast highlighting the potential risk for the Sunday. Delivery Units will be made aware of the alert by the control over the course of the following day. Using the example, on the Thursday, if the alert status remains extreme for the Sunday the RCM will move to the next stage 'Preparation'. A teleconference will be convened and chaired by the RCM. EWATs have a templated attendee list, dependant on the weather risk but will invariably include Delivery Unit Maintenance teams, Train and Freight Operators, Structure teams, Off Track Teams, Earth Works Teams, Train Running Controllers and Communication Teams.

Agendas for EWATs are templated and on these calls a weather forecaster will provide a summary of the event forecast as well as the confidence levels associated with the alert status and any localised risks. For example, a variation of risk at a coastal location compared to the risk further inland. This may include elements such as high tides and 'over topping'.

In addition to the controls, individual bespoke forecasting tools have been developed in collaboration with asset owners, where known individual asset vulnerabilities exist. Asset groups have an array of vulnerabilities and some bespoke forecasting services have been developed over the years through information gathered at Incident Learning Reviews (ILRs). Some of these bespoke forecasting services include:

- OLE: temperature forecasting,
- Third Rail: conductor rail icing forecasts,
- Track: critical rail temperature (CRT) forecasting,
- Lightning: Lightning forecasts
- Earthworks: Precipitation Analysis Tool (PAT)

There is a broad-brush approach to thresholds set for each of the bespoke forecast asset group suite of tools. These are very much derived from the specified tolerances in the original design. What these thresholds do not take account of is the condition of the individual asset or the variety of asset designs, for example OLE assets and the varieties that make up their individual vulnerabilities.

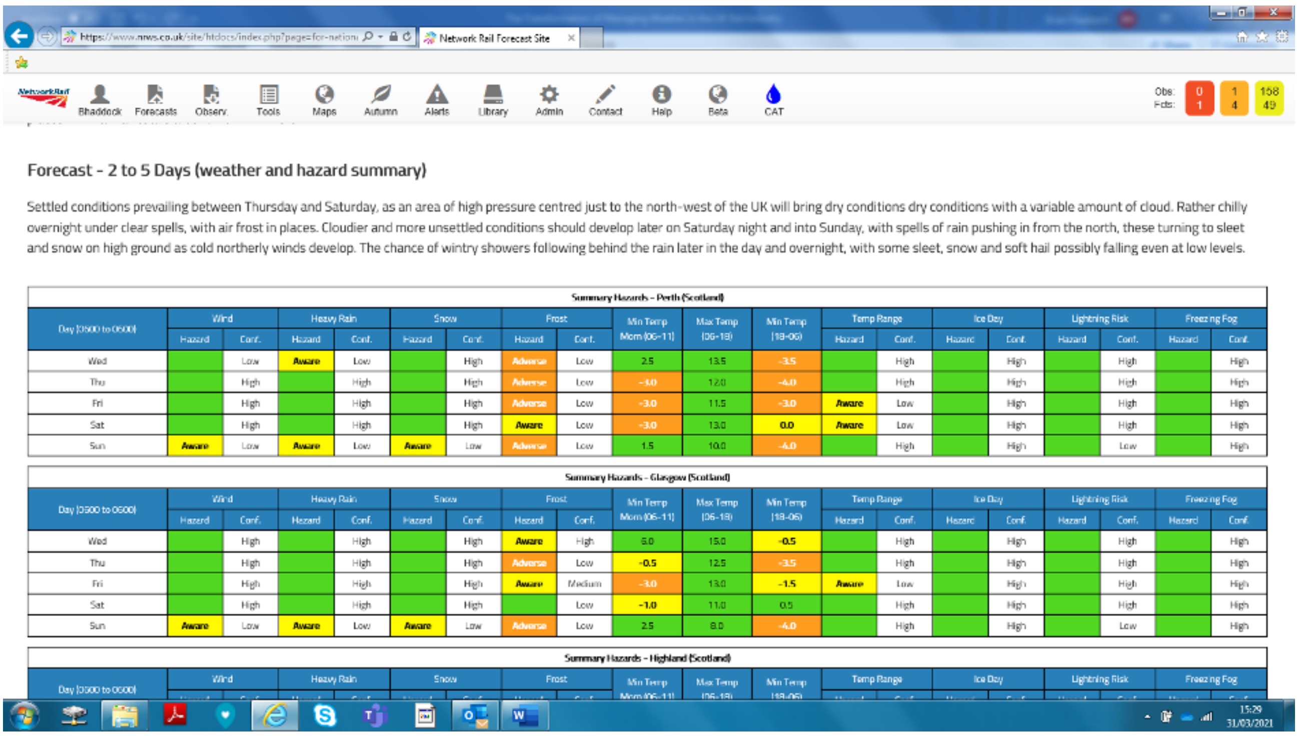
The risk profile between a portal OLE stanchion and a head span OLE configuration for forecast wind gusts is known to differ dramatically from historical incidents where wires have come down, but the industry 'extreme' threshold for wind gusts is 59< mph. When this extreme is breached in a forecast anywhere on the National Network, a blanket 50mph speed restriction is implemented.

This is regardless of whether the line has a portal or head span OLE design, or if there isn't any OLE at all within the geographical forecast area that has breached the wind gust threshold. This, of course, is in part due to the fact that wind gusts cause other objects such as trees and other debris to be blown onto the running lines. Much work needs to be undertaken to determine thresholds such as wind gusts for different types of assets, including OLE.

These thresholds need to include the design configuration, the asset condition, (including the maintenance cycles), and the local environmental factors. Through the work of the industry forum the Seasonal Challenge Steering Group (SCSG), the detailed scientific data required to form a robust system risk-based model is being developed called the Seasonal Agnostic Railway Model (SARM). Rather than focus on train performance (PPM), the SARM is looking at metrics that reflect the impact on individual passenger journeys, considering operational concerns such as the frequency of train service and the criticality of particular service groups. The Model is synthesising and expanding on progress made historically where individual asset types have assimilated weather and asset data.

Since 2015 Earthwork engineers, (in isolation from other asset types and general operations), have been developing a tool that might just be the catalyst for a wider operational model. The Precipitation Analysis Tool (PAT) provides a very good example of how various forecasting tools with NR's current forecast service have been blended to create a bespoke tool for Earthwork engineers. Each of the 190,000 earthwork sites poses a potential risk to the running of trains. Earthwork engineers from each Route worked with the forecasters to develop an alert tool that determines the risk of each site based on the forecast of precipitation, as water is the main cause attributable to earthwork failures, whether that be a lack of it or too much of it. Each site is plotted along the line of route using the standard location references within the rail network known as the 'Engineering Line of Reference' (ELR). Radar data, used to illustrate the intensity of the forecasted rain fall, combined with the data that describes the antecedent conditions at each earthwork site along the ELR allow a threshold parameter to be set by the Earth Work Engineer for each site. If the rainfall threshold is breached on any of the individual earthwork assets, the Earthwork engineer will then feedback the risk to control who will apply the correct mitigation. This often results in slowing trains by the imposition of a speed restriction. In the worst case all train movements may be required to stop.

Seasonal Preparation and Continual Improvement (vision)
Since the tragic accident at Stonehaven the development of the Convective Alert Tool (CAT), and more importantly the Operational Route Sections (ORS) created for the tool, has provided the rail industry with an opportunity to manage weather in a more dynamic way compared to the past. The convective rainfall event that led to the accident at Stonehaven was a very localised event and one that is difficult to forecast using the current tools that, as we have seen, forecast for an extensive geographical area. In the case of Stonehaven, the geographical forecast area (Perth) covers an area from the West Highland Coast of Scotland to the East Coast of Scotland, incorporating railway termini from Kyle of Lochalsh in the West to Wick and Thurso in the far North to Aberdeen in the Eastern



Forecast - 2 to 5 Days (weather and hazard summary)

Settled conditions prevailing between Thursday and Saturday, as an area of high pressure centred just to the north-west of the UK will bring dry conditions dry conditions with a variable amount of cloud. Rather chilly overnight under clear spells, with air frost in places. Cloudier and more unsettled conditions should develop later on Saturday night and into Sunday, with spells of rain pushing in from the north, these turning to sleet and snow on high ground as cold northerly winds develop. The chance of wintry showers following behind the rain later in the day and overnight, with some sleet, snow and soft hail possibly falling even at low levels.

Summary Hazards – Perth (Scotland)

Day (0500 to 0600)	Wind		Heavy Rain		Snow		Frost		Min Temp Morn (06-11)	Max Temp (06-18)	Min Temp (18-06)	Temp Range		Ice Day		Lightning Risk		Freezing Fog	
	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.				Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.
Wed		Low	Aware	Low		High	Adverse	Low	2.5	13.5	-3.5		High		High		High		High
Thu		High		High		High	Adverse	Low	-3.0	12.0	-4.0		High		High		High		High
Fri		High		High		High	Adverse	Low	-3.0	11.5	-3.0	Aware	Low		High		High		High
Sat		High		High		High	Aware	Low	-3.0	13.0	0.0	Aware	Low		High		High		High
Sun	Aware	Low	Aware	Low	Aware	Low	Adverse	Low	1.5	10.0	-4.0		High		High		Low		High

Summary Hazards – Glasgow (Scotland)

Day (0500 to 0600)	Wind		Heavy Rain		Snow		Frost		Min Temp Morn (06-11)	Max Temp (06-18)	Min Temp (18-06)	Temp Range		Ice Day		Lightning Risk		Freezing Fog	
	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.				Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.
Wed		High		High		High	Aware	High	6.0	15.0	-0.5		High		High		High		High
Thu		High		High		High	Adverse	Low	-0.5	12.5	-3.5		High		High		High		High
Fri		High		High		High	Aware	Medium	-3.0	13.0	-1.5	Aware	Low		High		High		High
Sat		High		High		High		Low	-1.0	11.0	0.5		High		High		High		High
Sun	Aware	Low	Aware	Low	Aware	Low	Adverse	Low	2.5	8.0	-4.0		High		High		Low		High

Summary Hazards – Highland (Scotland)

Day (0500 to 0600)	Wind	Heavy Rain	Snow	Frost	Min Temp Morn (06-11)	Max Temp (06-18)	Min Temp (18-06)	Temp Range	Ice Day	Lightning Risk	Freezing Fog

Figure 1: Example of a 2-5 day forecast for Perth and Glasgow forecast areas with a variation of alerts.
Source: Met Desk 31.03.21

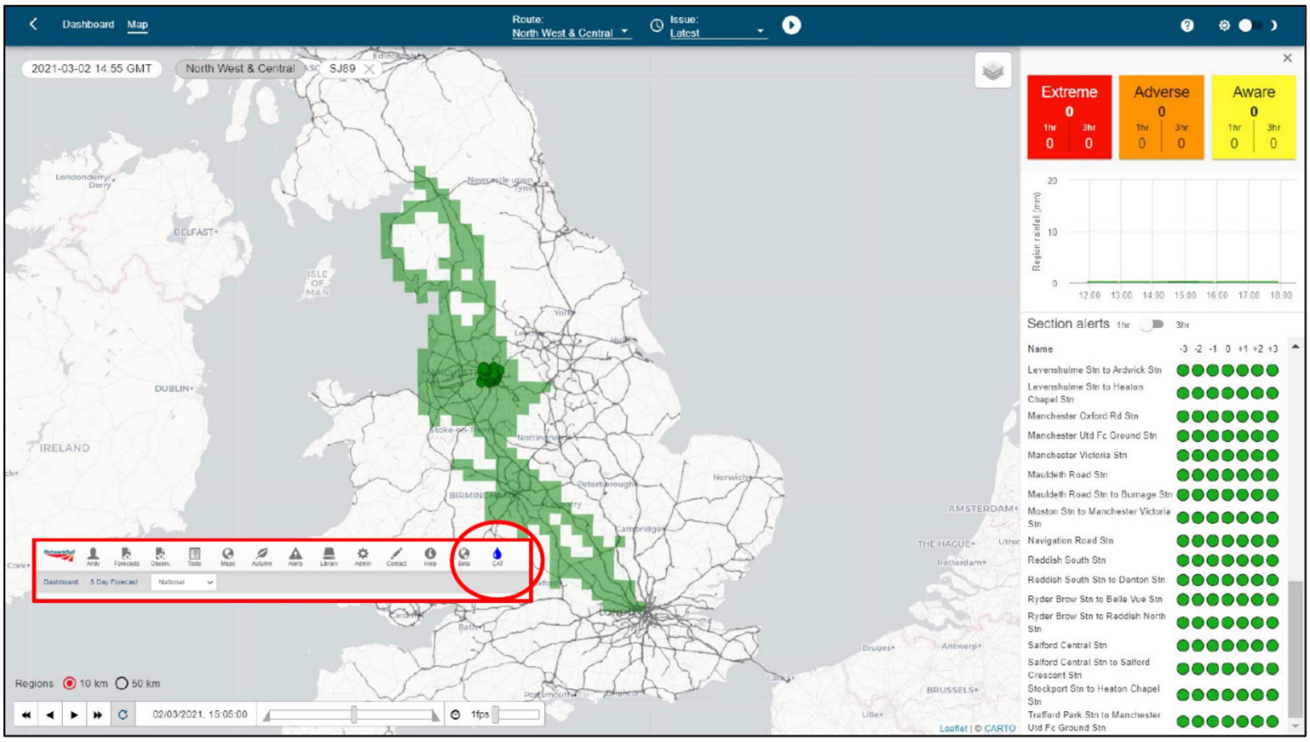


Figure 2: Screen shot of the Convective Alert Tool on NW&C Region. Source: Met Desk

peninsula. All of these locations have orographic and topographic differences that are fundamental to the way in which the weather impacts the area, and more specifically the local rail networks.

Stonehaven clearly demonstrated that a review of not only how the rail network could benefit from new forecasting capabilities but also how the risk is managed at a localised level was required.

Rather than the static 24/7 rolling 2–5-day tabulated forecasts, the CAT utilises the radar data to trigger alerts within an ORS. An ORS is a section of the operational railway broken down into easily recognisable points, (A to B), for the benefit of a driver. Most ORS are based on station-to-station points. Where the distance between two station points is greater than five miles or where a line branches off from the main line then an ORS may be defined using the junctions or some other fixed geographical asset that a driver can easily recognise. An alert within an ORS allows a more localised response compared to the wider geographical response from the geographical forecast areas used for the 2–5-day forecast. See figures 2, 3 & 4.

Historically large areas of the rail network would be placed under a blanket speed restriction when a risk is highlighted across the entire geographical forecast areas, and as we have seen some of these geographical forecast areas are very large and can have a negative effect on performance for more than one service group and for more than one operator. Comparatively, alerts provided by the CAT along a single stretch of rail line, between stations, allows for a targeted imposition of reduced speed over the affected area. This reduces the overall impact on performance for all other services that run over the entire length of line.

The ORSs provide further opportunity to undertake more detailed analyses of the impacts of other weather events to localised sections of the railway, such as the impact of temperature and wind. When these impacts are analysed together, in relation to the local environment, a systemic picture of the vulnerabilities can be drawn for each ORS.

Utilising detailed information of the condition of the assets within each ORS the SARM is being developed by Professor John Beckford in collaboration with Network Rail, which aims to determine the overall system resilience for any particular ORS given the forecast weather event. Depending on the weather forecast parameters the SARM will provide a series of options available to Control regarding the provision of the train service based on the predicted availability of the network, factoring in how the known asset condition will react to the forecast event. Aggregation of how the ORSs will react allows an overview of how an entire service group is likely to be compromised by any given weather event, determining the expected level of available route and the correct service to match the expected availability.

As the accuracy and granularity of weather forecasting science develops, an accurate impact profile for each service group can be provided. Timetables can be developed to reflect the expected availability that provide passengers with travel information prior to the forecasted weather event. As the impacts of weather events are experienced over these service groups lessons learnt, reviewed, and fed back into the modelling will refine the timetable, ensuring balance between safety and reliability.

Accurate, granular forecasting at the ORS geospatial level not only provides the passenger and freight users with pre-planned levels of expected services on areas that are affected, it will also provide information regarding service groups that are not affected or affected to a lesser degree. Currently, as highlighted previously blanket speed restrictions are imposed over large geographical areas aligned to the current 2–5-day forecast. As the tools are developed to assimilate asset and forecast weather data at a localised level targeted imposition of speed restrictions can be deployed where needed, leaving adjacent lines of route to potentially run as normal if they are unaffected. Such a targeted approach means that diversionary routes become available, and the train movements do not have to reduce speed or cease over such a large geographical area.

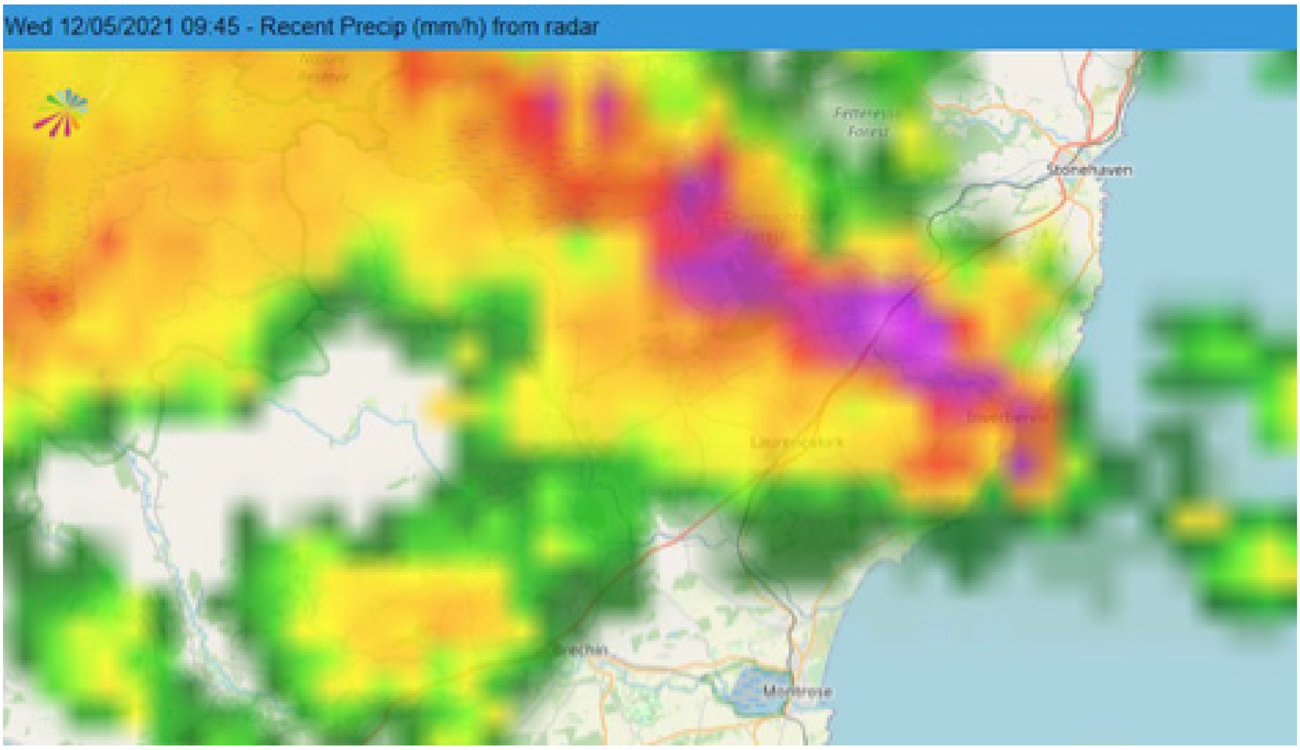


Figure 3: Rainfall Radar at 0945 BST 12.05.21. Laurencekirk site of landslip that day. Source: Met Desk.

The SARM will in the future provide the options for train service levels. With feedback loops into the SARM the model will learn from experiencing weather events, enabling seasonal and climate variations to be built into the options that it provides the Controls with on determining the level of service. The SARM will also highlight the systemic vulnerabilities within each ORS and will be able to measure the aggregated impact of these across the service group, informing asset engineers of where renewals and maintenance should be targeted to improve the experience of passengers and freight users.

Figure 4: CAT Alerts triggered at 0945 BST.
Source: Met Desk.

Future seasonal management will be informed by the aggregated service group risk and leading indicators between operators and the infrastructure owners can be developed to measure the continual reduction of impact each season has to the reliability of the network.

The SARM is pivotal to the development of a ten-year weather strategy that has been agreed at an Industry level to deliver the vision of:

> *A safe and seasonally agnostic railway by putting passengers and freight users first.*

The industry vision will be delivered through three goals. Goal one of the strategy is to minimise the seasonal bump. Goal two is to excellently implement key route strategy and Goal three is to avoid or excellently manage out-of-control events. Essentially all three goals lead to a review of our current processes and drive the 'input' measures of the model at a local level, down to individual ORSs.

Currently the SARM is being developed between Reading and Newbury on the Great Western Railway with input from technicians, Route Asset Managers and engineers that own this part of the network.

As the SARM develops a greater understanding of the asset condition and how it is affected by various weather types, at a local level it helps to inform the seasonal management teams of individual tasks that require attention and priority for each season. These are being evolved through machine learning within the SARM to enhance and systematise the EWAT process providing the controls with options for train service provision.

Over the course of the next few months Network Rail will be working in partnership with Professor Paul Davies from the Met Office as part of the Weather Advisory Task Force in running a research and development proposal of weather data through the SARM. Network Rail are also working with Professor John Beckford and Loughborough University to validate and stress test the SARM as it develops into a full blown decision support tool.

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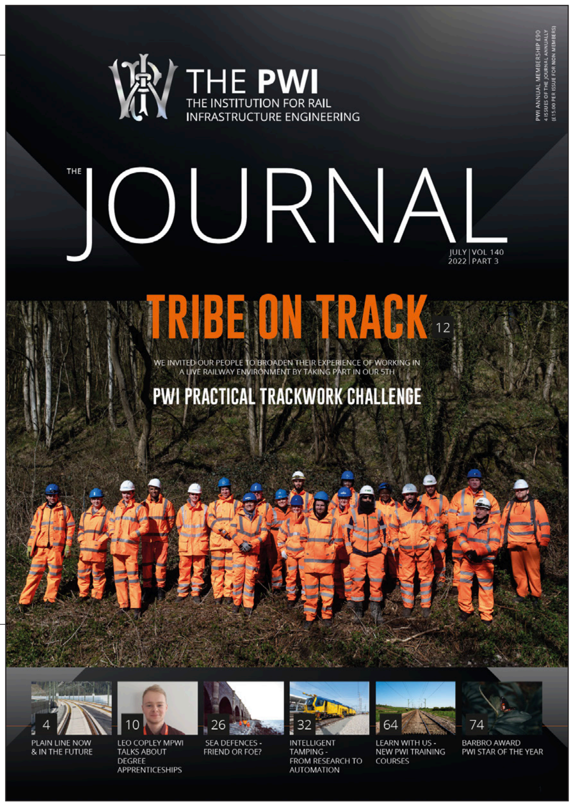

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