Understanding and utilising data for a seasonally agnostic railway

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Abstract: This study reviews the challenges being experienced by Network Rail in the provision of information for operating decisions under conditions of extreme weather. Reflecting briefly on the events at Carmont in August 2020, the paper considers the effectiveness of three responses, the reactive Extreme Weather Action Teleconference (EWAT), the development and deployment of a Convective (Rain Event) Alert Tool (CAT) and the research-based development of a Seasonally Agnostic Railway Model (SARM) being designed to enable preemptive and preventative action and information. The paper concludes with consideration of lessons for the railway and a distillation of lessons transferable to enhance the safety of other complex systems. The principal finding is concerned with the availability, reliability, and validity of data for decision-making.

Contents

Tags: seasonal failure, extreme weather and climate, national railway systems, asset management and performance, cybernetics, artificial intelligence, error prevention, systemic modelling, culture, prediction

1. Introduction

Each year with seasonal changes and changing weather patterns, the UK railway experiences 'seasonal bumps'. The impact of these ranges from increases in delays experienced by passengers, through cancellations and service substitutions, to collisions or derailments, sometimes with fatal consequences. The accident at Carmont in August 2020 is a recent example of an adverse, seemingly weather-related, event which stimulated some of this work but on which further comment would be inappropriate.

This research draws on weather-related events, asset data, information systems, and decisions to explore systemic interactions and interdependencies arising on the UK railway. The main complex system of systems being considered embraces the information generation and decision processes for the provision and use of asset and weather data to enable weather-related operational decision-making in Network Rail.

Using data from multiple sources, the rail industry objective from which this research project is derived is "to deliver a Seasonally Agnostic Railway as a safe, resilient, complex adaptive system".

Resilience here refers to the ability of the system to sustain performance while the safety dimension rests in the ability of the railway to generate and exploit the data necessary to make risk-mitigated operating decisions at varying geospatial and temporal scales in relation to all services. As the research progresses, early results derived are being brought to bear in preparation for the coming winter.

2. The system of systems under consideration

The principal system is the whole UK operational railway (both below and above the railhead). Embedded systems include:

- the network and topology of railway assets that constitute 'the railway' these initially include:
  - track, signals, and movement control systems; earthworks and drainage; structures; and power supply equipment
- actual weather
- weather forecasting
- asset management system(s)
- the EWAT decision-making system
- the railway culture
- the operational railway
- incident learning review.

An initial view of the elements with their interactions and interdependencies is provided in **Figure 1**.

The preliminary system of systems as presented is just one high-level interpretation of the elements involved. It was chosen as adequate and sufficient for the initial purpose rather than complete. It will evolve as the project progresses and as the importance or relevance of new information informs our thinking. Our study focuses on three subsystem elements of this overall cyber-physical system and consider the human led interactions between them. These elements are:

- **EWAT:** operational decision events convened to consider impacts of anticipated weather and appropriate responses

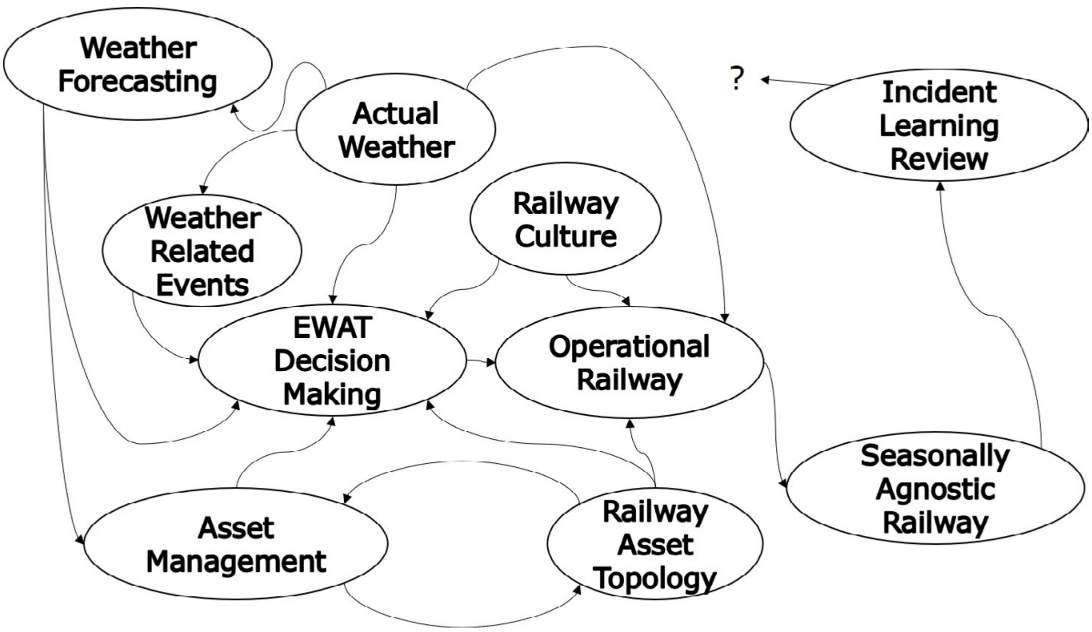


Figure 1: An extreme weather system of systems

- **Weather forecasting:** in particular, the recent development and deployment of the 'Convective Alert Tool' (CAT) (an information subsystem) with a focus on deployment
- **Asset management data:** in particular, the availability and utility of data with a focus on prevention and pre-emption of failure.

It will be important in the wider work with which this exposition fits to comprehend whether and how the topology of the assets both affects and is affected by weather events.

The UK Railway does follow an annual system of planning and decision for weather preparedness into which the 'Extreme Weather System of Systems' fits. An initial representation of that system is provided as **Figure 2**.

There are a significant number of non-weather events that affect safety, availability, and performance of the railway at a variety of levels of aggregation. We acknowledge the potential interaction between seemingly non-weather-related events and weather. These are being regarded as beyond the scope of this initial research.

All attempts to be systemic demand the adoption of boundaries which can appear arbitrary. In this case the boundary has been chosen as a recognition of the scale of the overall system into which this work fits and the limits of inquiry that the host organisation would recognise as legitimate. We accept that alternative interpretations of both the system and its boundary may have equal validity. Here we have followed the dictum of Stafford Beer (1985) to accept that "a model is neither true nor false but more or less useful".

3. Research synopsis

The overall research described here explores the belief that current information systems, sources of data, methods of data collection, reporting models, and control methodologies are not fully fit for their purposes. The absence of meaningful actionable information arising from these deficiencies exposes the railway to risk of compromise to and failure of journeys.

National Performance Board (a rail industry body) in December 2020 said:

> *"In order to be more certain that we know how to maximise weather resilience and to be able to better forecast the effect of changes in the weather, we need to be able to more reliably attribute changes in output measures to changes in the weather and to the effect of our weather resilience measures."*

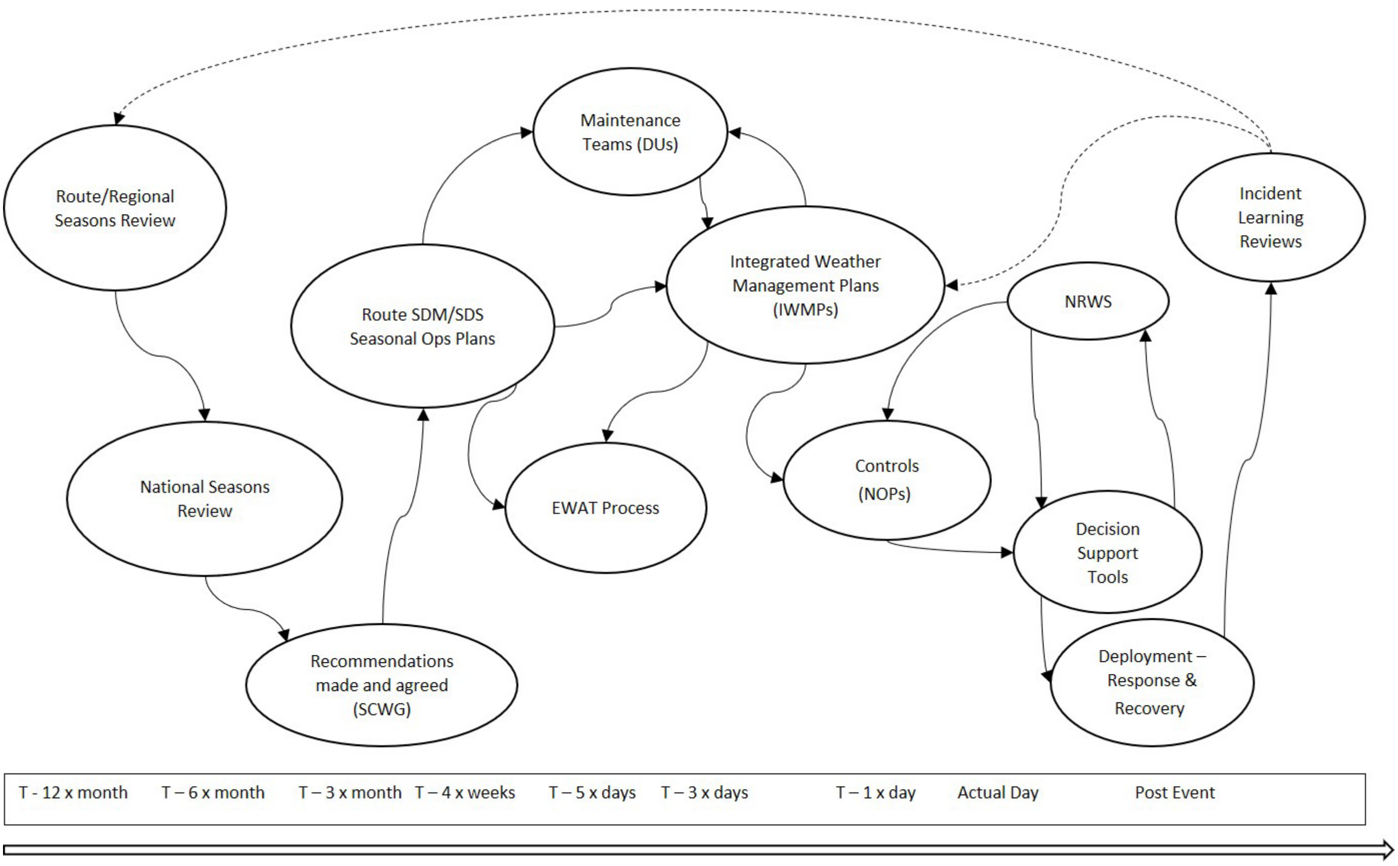


Figure 2: Current system of planning and decision

That report acknowledged that, working with established methodology, it was difficult, if not impossible, to determine the benefit received or cost borne by passengers, freight carriers, service operators, or infrastructure providers from work undertaken to improve weather resilience.

The research aims to explore whether Network Rail holds and uses the data, metadata, information processing, decision, and adaptation structures to enable its safe, resilient operation as a complex system. If deficiencies are identified, the researchers propose mitigating or ameliorating actions including developing proof of concept and prototype solutions. The initial stages of the research are concerned with testing beliefs about the quality of data and information and developing proof of principle approaches to a solution.

This preliminary work will inform the Weather Resilience Strategy for the railway industry in the UK. The aim is to develop knowledge, insights, information systems, and operational practices to enable a seasonally agnostic railway which will:

- have a high level of resilience to the effects of seasonal and severe weather
- be adaptively capable of pre-emptive implementation of amended timetables and/or contingency plans where necessary for safety and reliability
- be able to minimise the most adverse effects of severe weather on service delivery for passengers and freight.

3.1. Research objectives and novelty

The three objectives for this research are to:

- establish whether the data provided for weather-related planning and operational decision-making is sufficient to its intended purpose and to identify gaps
- increase the ability of the railway to adapt in operational and planning decisions both temporally and spatially for safe operation reduction in failure risk
- increase the availability and appropriateness of asset and weather data to support decision-making.

A novel factor is that while data is used to support operational running decisions, it has not previously been brought together in a single system capable of integrating meteorological, asset, and operational data to enable assertions about probable future performance. The model proposed is cybernetic in character, composed of interconnected and interdependent homeostats (self-regulating feedback systems). It will aggregate results along lines of route and vertically through systems to enable a view of performance at every level of embedment, from the operational route section to whole railway with a funnel of uncertainty looking forward 6 months. The method will generate self-regulating activity and highlight the locations of specific performance-inhibiting asset vulnerabilities.

Integration of data will enable assertions about future performance ahead of critical decision points AND the effect of safety and operational performance asset maintenance preventative interventions. It will enable understanding of the difference that asset interventions make to safe operational running under extreme conditions.

3.2. The RAE study

The study for the Academy Safer Complex Systems programme is being delivered as part of the ongoing SARM project. The study will influence the direction and content of that project to generate improvements in safe, reliable performance. These improvements are expected to address these main areas:

- the provision of data about the interaction between proactive maintenance of weather-vulnerable assets, specifically:
  - wind
  - temperature
  - precipitation
  - the structuring and characterisation of that data referring to its appropriateness to the task
- the utilisation of data about weather-related asset performance and reliability to:
  - inform an adaptive maintenance and preparation cycle for the assets
  - address the effectiveness of seasonal preparatory work at infrastructure, rolling stock, and staff levels
  - reinform asset management activity
- the ability to provide both forecast and foresight insights to:
  - reinform decision-making at immediate, intermediate, and seasonal intervals from temporal, geospatial and organisationally hierarchical viewpoints
  - affect the methods and means by which new systems and models of information provision are deployed by, at least, Network Rail.

The gap analysis proposed herein is expected to lead to initial considerations about what might be done differently to reduce any safety-related data gaps.

3.3. Context and approach of the research study

The wider project aims to support the Network Rail weather resilience strategy team in developing a transformational approach to enabling the railway to reduce service compromise and failure and keep commitments to passengers and freight carriers. The approach will use information about performance to inform both corrective and preemptive decision-making. This will ultimately embrace all assets (linear and mobile) and entire passenger and freight journeys. The underlying approach adopts cybernetic principles and tools. These use information to:

- enable and sustain adaptation
- embed lessons learned in the architecture of the railway system
- improve reporting systems
- enhance maintenance and delivery programmes.

It has been agreed that no work should be undertaken in sustaining weather resilience that is not informative about the state of performance, informed by prior knowledge, and connectible to the economic and social outputs required. As work is done, information needs to be captured about its desired impact and that expectation will be integrated into models of performance. The outcome, though distanced temporally and spatially, can then be evaluated in context and the findings both fed back to the original source and used to inform the wider railway. The aim is to generate an increasingly weather resilient railway.

3.4. Methodology

There are three subsystems (see Figure 1) that act as information and instruction sources and condition performance under extreme weather conditions. These are:

- the weather forecasting system
- the asset management system
- the EWAT decision system.

Information flows from the weather forecasting and asset management subsystems affected by the subsystems called 'Railway Asset Topology' and 'Railway Culture' come together in the EWAT decision system to inform operational decisions. Topology affects what operating decisions can be executed within the limitations of the physical layout of the network, while culture modifies decisions such that they fit within the cultural norms and expectations of the other actors. Neither explicit nor codified, cultural 'fit' is a powerful influence.

To develop an understanding of the problem situation, the following steps were taken, some going beyond the requirements of the RAE study, to inform the wider work:

- identify, codify, and critique relevant information, processes, and decisions
- comprehend current practices across the railway embracing infrastructure, service provision, and journeys (freight and people) as well as the information that flows through and around them
- develop principles for measurement, opportunities, and deficiencies in current information flows relative to those principles and explore alternative (sometimes proxy) forms of measurement
- develop and test 'proof of principle' approaches to reporting as a means of experiment and rapid adaptation
- migrate successful proofs to operating models and practices.

The overall research will take place over an extended period of engagement. A notable challenge, drawing from early inquiries, is that much of the data held by the railway is in unstructured or semi-structured formats which generate challenges in its use. This report considers only the first few months of inquiry and is intended to provide both a useful report to the Safer Complex Systems programme and a milestone for the larger project.

4. Extreme weather response

4.1. Background event

There has been a mass of work arising in immediate response to the tragic train accident at Carmont on the 12 August 2020 where three people lost their lives. One of those responses is a Convective Alert Tool (CAT) created in collaboration with Network Rail and MetDesk (weather data provider) and intended to give a very near-term warning of an impending extreme convective rain event. Before we consider that tool though it will be helpful to review the traditional extreme weather response to which it may contribute.

4.2. EWAT

In this section we will introduce the EWAT process, describe what it is, and how it uses weather and other data. We will discuss the process of its implementation and how it is intended to contribute to operational safety. The section will end with a critique of the EWAT tool and identification of our learning.

Weather forecast providers (MetDesk) deliver two-day to five-day forecasts broadly aligned to the five regional divisions of Network Rail across Scotland, England, and Wales, each of which is further divided into individual routes. The geographical forecast areas are broadly aligned with Delivery Unit (DU) boundaries, although the forecast is not rail specific, rather a historic alignment. For example, within Scotland Region there are five geographical forecast areas, these are (**Figure 3**):

- Perth
- Glasgow
- Highland
- Motherwell
- Edinburgh

Delivery Units are locations where the fully equipped general maintenance teams are situated. They are resourced for both on-

Figure 3: Weather forecast areas

and off-track activities such as drainage, vegetation management, and earthworks. Other specialist maintenance depots, such as for overhead lines, are located along the routes. The alignment of geographical weather forecast areas to delivery units suggest that the industry forecasting tools are designed to enable recovery of the rail service after a disruptive event rather than to pre-empt or prevent such disruption. An exception to this is when a snowstorm has been forecast with high confidence in which case a snow timetable is implemented. This does not protect the assets but mitigates risk to passengers and freight.

Response to and recovery from adverse incidents is a mature process within the rail industry and receives a great deal of focus in resource, training, and competencies; planning and pre-emptive activities have not had the same focus. A large part of the current transition in managing weather responses is developing thinking and processes to achieve equivalent maturity. Routes and Regions (Network Rail Business Units) are currently developing leading indicators and preparing plans to benefit the passengers and freight users.

Weather forecasting (2–5 day) underpins the industry response to impending events. The process is as follows:

- forecast is received by email at each Route Operational Control (ROC) nationally
- forecast is assessed by the Route Control Manager (RCM) or equivalent for risks
- forecast is distributed across the entire Region.

Thresholds (referenced in weather management standards) are set for each weather parameter that define the risk to the network around four core alert levels:

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

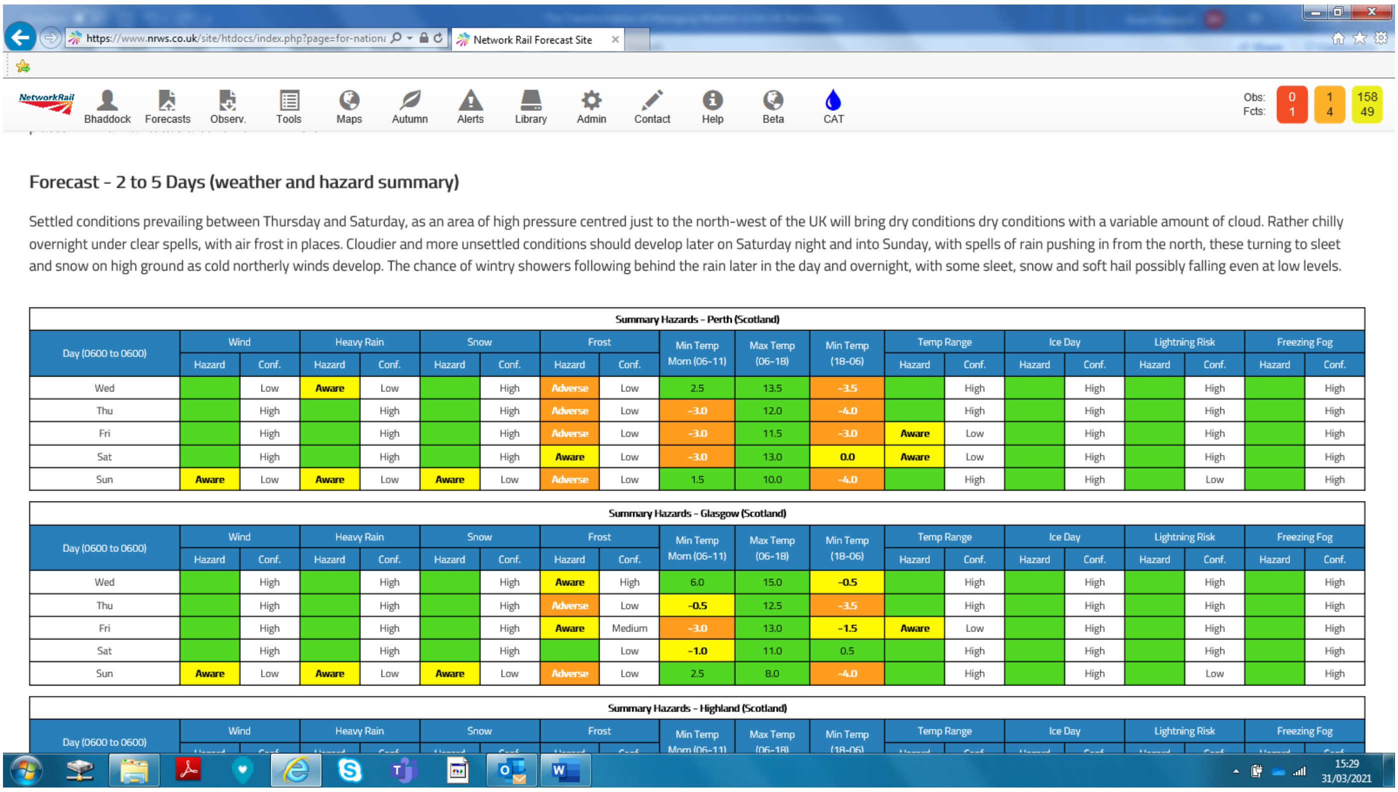
This simple colouring of alert status allows the teams within ROCs to expedite a judgement on whether to initiate any actions under their extreme or adverse weather management plans (EAWMPs) (**Figure 4**).

If an extreme threshold for a weather variable is forecast to be breached, the control team initiate an EWAT. This is a five-day process in alignment with the five forecasted days following five stages from the initial forecast to the day itself. Figure 4 shows a Wednesday forecast indicating an extreme alert for rain on Sunday, leading Control (operational despatchers) to initiate the EWAT process via the RCM. This has six stages as shown in **Table 1**.

Route EWATs have a role and weather-risk-defined attendee list including Train and Freight Operators, Train Running Controllers, Delivery Unit Maintenance, Communication, Structure, Off Track, and Earthworks Teams. Agendas for EWATs are predefined and include a summary of the event forecasted, the confidence levels associated with the alert status, and any locally specific risks.

Complementing the EWAT process, bespoke forecasting tools, arising from incident learning reviews, have been developed in collaboration with asset owners to address individual asset vulnerabilities. Constituting an embedded system of systems within EWAT, these assets include:

- OLE (Overhead Line Equipment): temperature forecasting
- third rail: conductor rail icing forecasts
- track: critical rail temperature (CRT) forecasting
- lightning: lightning forecasts
- earthworks: Precipitation Analysis Tool (PAT) outlined in the next section.



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 (0600 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 (0600 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 (0600 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 4: 2–5 day forecast for the Perth and Glasgow forecast areas with alerts
Source: MetDesk 31.03.21

Stage 1	**Business as Usual**	
Stage 2	**Awareness**	Day one: an RCM will issue the forecast highlighting the potential risk for day five (as per Fig. 4). Day two: DUs will be made aware of the alert by the control. Day five: If the alert status remains extreme move to the next stage.
Stage 3	**Preparation**	Day two/three: teleconference convened and chaired by the RCM. Engage with TOCs and DUs.
Stage 4	**Respond**	Day four/five: monitor changing weather and effects in real time, reassess actions, and review decisions.
Stage 5	**Recover**	Day five and after: develop consensus with other parties on recovery plans. RCM has sole decision authority on the recovery plan.
Stage 6	**Review**	Identify what went well or not, identify improvements, promulgate lessons.

Table 1: EWAT process

There is a broad-brush approach to thresholds setting for each of the bespoke forecasted asset group suite of tools. The thresholds are derived from tolerances in the original design of those elements. These thresholds cannot take account of either the condition of any individual asset or the variability in asset designs. For example, from historical incidents it is known that the risk profile between a portal OLE stanchion and a head span OLE configuration for forecasted wind gusts differ dramatically (See **Figure 5**). When the extreme (wind gust > 59 mph) is forecast to be breached, anywhere on the national rail network a blanket 40 mph speed restriction is implemented, regardless of the head span OLE design even if there is no OLE within the geographical forecast area that has breached the wind gust threshold. 40 mph restrictions are only applied for convective events, NR standards (NR/L3/OPS/045/3.17 Weather Arrangements and NR/L3/OPS/021/05 High Winds) still say

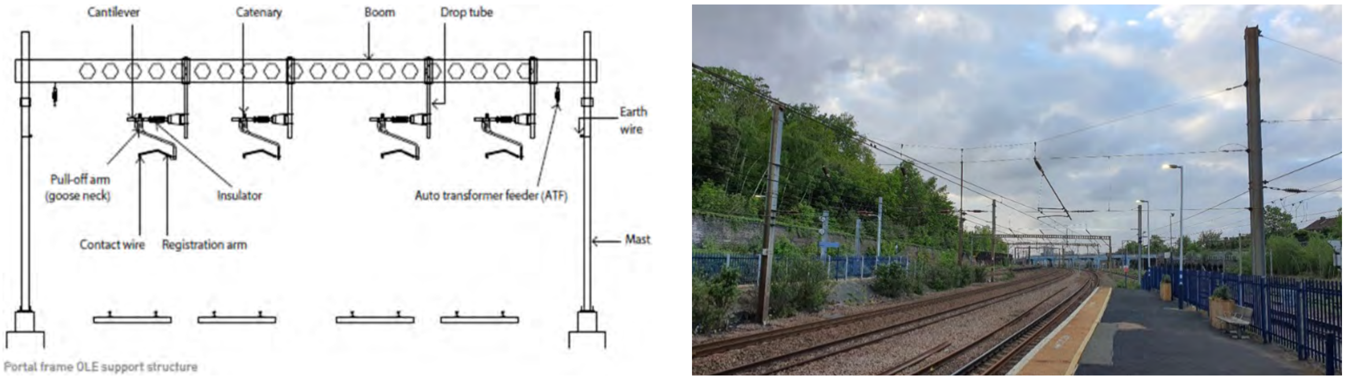


Figure 5: Portal OLE (left) and head span OLE (right) configurations

50 mph for "gusts of 60 mph or over" or "mean speeds of 50 mph or over". This is in part because of risk of other objects such as trees and other debris being blown onto the lines. These gross reactions are indicative of a lack of granularity in forecasting, the absence of contextually useful asset data, and the limited sophistication of decision processes in response to adverse forecasts (**Figure 6**).

4.3. Precipitation Analysis Tool (PAT)

Each of the 190,000 (one hundred and ninety thousand) earthwork sites (cuttings or embankments) on the rail network poses a risk to the running of trains. Water, whether too little, or too much, is the main cause of earthwork failures. The PAT provides a very good example of how various forecasting tools with National Rail's current forecast service have been blended to create a bespoke tool for earthwork engineers.

Earthwork engineers from each route worked with the forecasters to develop PAT which assesses the risk at each site based on forecast precipitation. Each site is plotted along the line of route using the standard location references known as the 'Engineering Line of Reference' (ELR). Radar data, used

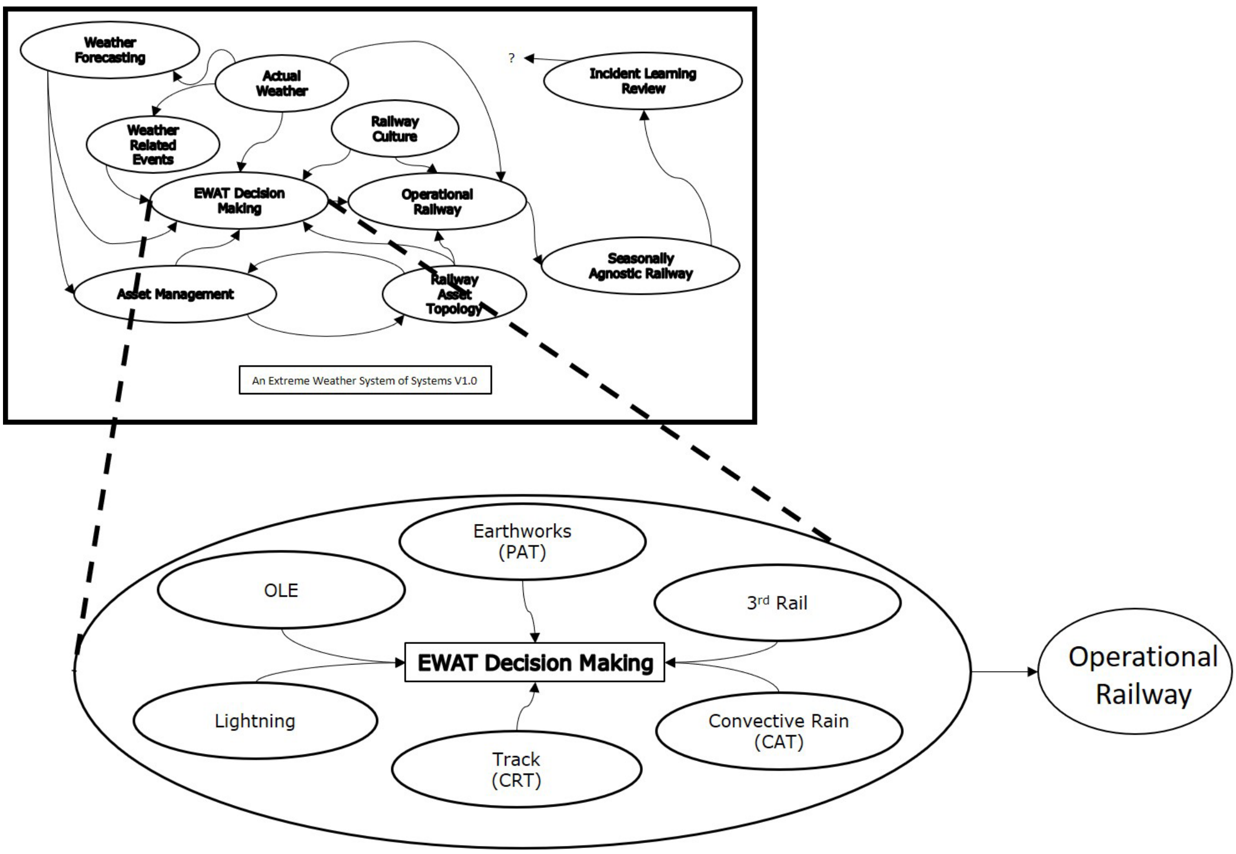


Figure 6: EWAT – embedded system of systems

to illustrate forecasted intensity of the rain fall, combined with the data that describes the antecedent conditions at each earth work site allows a threshold parameter to be set by the earthwork engineer for each site. If any rainfall threshold is breached, an alert will be provided to the earthwork engineers who inform controllers who apply the correct mitigation. This often results in speed restrictions slowing trains or in the worst-case ceasing train movements.

4.5. Critique of EWAT

EWATs are considered by the National Rail executive and the wider industry to provide assurance that the Routes and Operators have done all they can to be ready for the forecast weather based on its expected severity.

While there is a standardised approach, the specific topographical nature and the geographical prevalence of varied weather parameters means that EWAT outcomes are not consistent from one region to another. The differences make it hard to measure what a 'good' EWAT looks like using traditional comparisons and they do not lend themselves to understanding the performance and safety impact on passengers and freight users.

The principal benefit of an EWAT is reassurance to senior leaders that the forecasted weather has been considered. EWAT notes are supplied from every Route to the National Operation Centre (NOC) to provide evidence of compliance for all routes with the relevant standard (NR/L2/OPS/021 Weather – Managing the Operational Risks, June 2019). The data provision and collation approach currently in use does not generate information structured in a manner from which useful learnings from past experience can readily be developed.

Most EWATs focus on resource gaps, often at T–2 or T–1 days with a focus on the deployment of response and recovery staff, or 'watchmen' for certain critical assets such as 'heat watchmen' to look out for track buckle. Route EWATs also focus on engineering work and cancel planned work if it cannot be deemed safe, while a National EWAT, an escalation, provides the opportunity for adjacent or connecting routes to share resources if required.

Outputs of EWATs do not provide a quantitative summary of the risk exposure or options of train service provision. In exceptional cases (heavy snow fall forecasted in South East) an EWAT may consider implementing a Key Route Strategy (KRS) or 'snow timetable'. In most cases these are not validated with the working timetable (WTT) and are simple amendments to provide a reduced timetable such as a weekend service, and some branch lines simply will not run.

Reduced train service provision not validated against the WTT does not provide enough information, leading to confusion for the station staff about which services are or are not being provided to the passengers. This confusion arises through inconsistent, asystemic application of reduced speeds and cancellations across varying service groups, traction types, and vehicle sets coupled to inadequate information flow to staff and passengers. It can often cause delay or cancellation of freight services as the system prioritises passenger services over freight. Where two Train Operating Companies (TOCS) run on the same lines, one may impose a speed restriction while the other may not. This generates reactionary delay as one service running at normal line speed catches up with another running at reduced speed. This conflict results in more signals showing yellow (warning) and red (stop) aspects slowing the overall system. On main lines, with more than two train operators running services over most sections there is increased potential for conflicting decisions. Freight services use most of the national network but run at a maximum of half the line speed of passenger services when speeds are limited. The combined effects of the variability in reduced speeds compounds confusion and actual train paths (timings) stray further from those intended.

There is no informational connection between seasonal planning and the EWAT process, except when a route is running its Rail Head Treatment Trains (RHTT) or, Anti-Icer Multipurpose Vehicles (MPV) in the Southern Region and Merseyrail. There is no other time when train borne mitigation is taking place directly influenced by the weather forecast.

If the WTT is not affected by the EWAT process, the passenger and freight operators experience only disbenefit, that is, loss of punctuality and services, as delays are imposed on them by others. Commonly, operators sharing a route and infrastructure do not willingly agree on their amended plans and in most cases choose to continue to run at line speed. The EWAT process does not challenge this, instead it records it and sends it to the NOC. Network Rail does not typically challenge the TOC to reduce their services because by doing so it may enable the TOC to claim Schedule 8 compensation. It is possible that the financial arrangements bias operators' decisions in such a manner as to ensure fault lies with National Rail rather than themselves.

EWATs have become institutionalised, perhaps undertaken to demonstrate compliance rather than because they make a difference. When attending a National EWAT a route will often first declare that it has undertaken its own EWAT before providing detail about resources and so on. Participants on National EWATs are often senior people and include external agencies such as Department for Transport (DfT) and the Office of Road and Rail (ORR) who would very rarely attend Route EWATs.

EWATs were attended as observers. While the events were well ordered and systematic in considering the threat and risks, much of the information provided was in an unstructured, spoken format. Also, many of the approaches and mitigations expressed were highly conditional and thus generated much uncertainty about the actual decisions and commitments. The large number of participants contributing to each event, coupled to unstructured information, disparate organisational interests, and the absence of a clear standard of performance means that while records would show that 'action was taken' it would be difficult to provide evidence of the value of any particular contribution or to either capture or learn from the decisions made. To paraphrase, those who do not learn from their failures are doomed to repeat them and, in this case, the structure and organisation of the EWAT, in particular the lack of structure in data and decision capture, would inhibit any lessons being learned.

5. The Convective Alert Tool (CAT): Review and critique

In this section we introduce the Convective Alert Tool (CAT), describe its origins, what it is, and how it uses weather data. We then discuss its implementation, how it is intended to contribute to operational safety and provide a critique.

5.1. Origins of CAT

Since the accident at Carmont the rail industry has adopted two new means of managing the impact of adverse weather events in a more dynamic manner. These are the idea of an Operational Route Section (ORS) and the development of the Convective (Rain Event) Alert Tool. An ORS is set to become the basis of weather forecast granularity in the future and is defined as a section of the operational railway broken down into easily recognisable points for the benefit of a driver such as two stations or stopping points. If the route control centre receives an alert driven by the weather forecast, a cautionary broadcast is made directly to the driver through the GSMR radio. The distance from end to end of an ORS allows the driver to make an emergency brake application (**Figure 7**).

Very localised rain events such as that at Carmont, which was forecast as an adverse rather than extreme event until the 3.00am forecast on the day of the accident, remain difficult to forecast using existing extensive geographical area tools. Post-event analysis now records it as a 1 in 100 year event. In the case of Carmont, the geographical forecast area (Perth) covers an area from the west to the east coasts of Scotland embracing railway termini from Kyle of Lochalsh in the West, to Wick and Thurso in the far North, and Aberdeen in the East. Each area has particular orographic and topographic differences that are fundamental to the way in which the weather impacts the

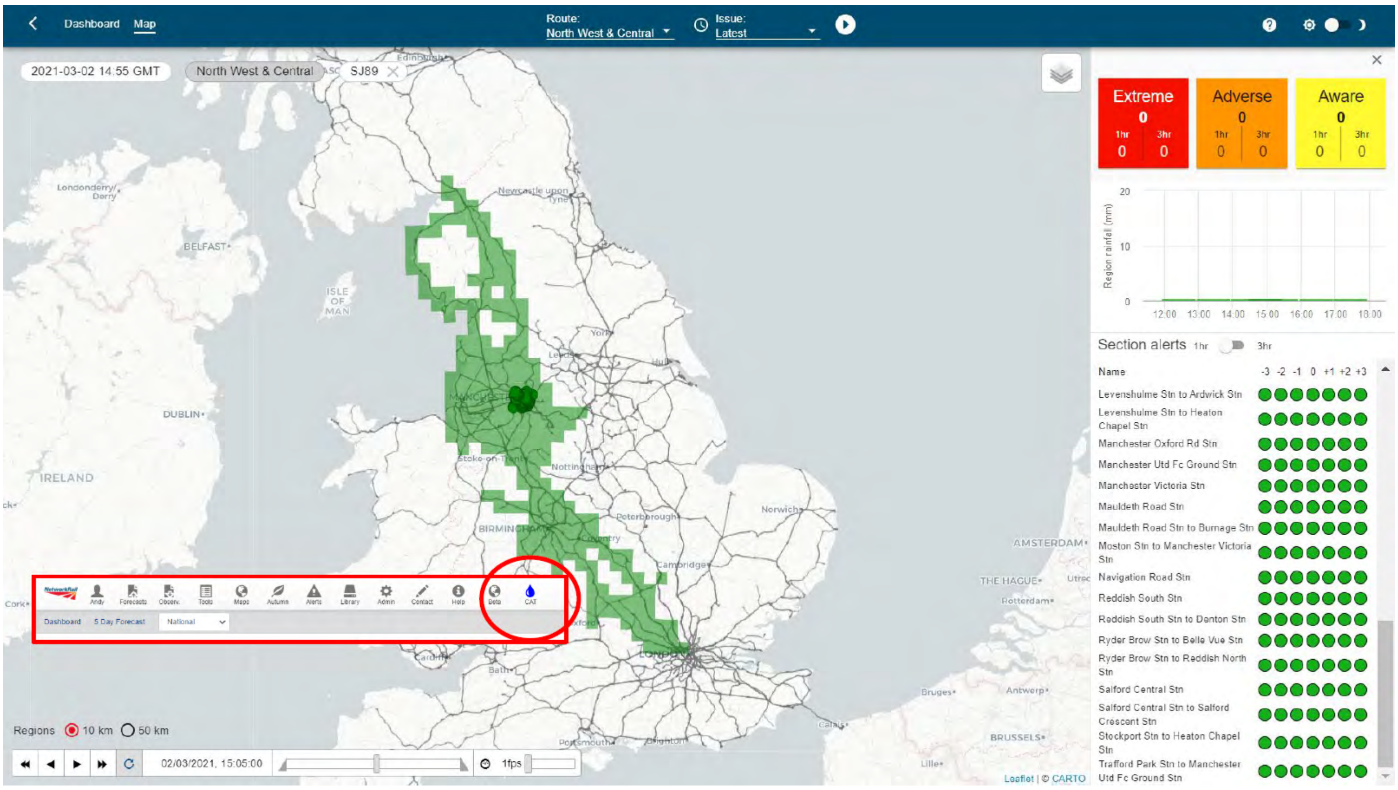


Figure 7: Screenshot of the Convective Alert Tool on NW&C Region. Source: MetDesk

rail networks. Carmont clearly demonstrated the need for a review not only of how the rail network could benefit from new forecasting capabilities but also how it might manage the risk at a localised level.

Rather than the conventional 24/7 rolling 2–5-day tabulated forecasts CAT (Fig. 7) utilises weather radar data to trigger alerts within an ORS. This allows a more focused geographic operational response compared with the wider response from the areas used for the 2–5-day forecast.

Unlike the conventional blanket restrictions already described, a CAT alert (Fig. 8) shown to affect only a single, relatively short rail line between stations allows for a targeted imposition of speed reduction directly to only the affected area. This serves to minimise the overall performance impact for all other services that run over the entire length of line or interact with it, such as dependent or connecting services, shared platforms, shared vehicles, intersections, and junctions. Similarly, acknowledging the latency in information transmission, the shorter the time between forecast and event, the greater the accuracy and the smaller the consequential or systemic impact.

Figure 8 shows how the weather radar indicates much more precisely the geographic area affected by the convective rain event while **Figure 9** indicates how the alert is presented for decision purposes, the red spot highlighting the area of peak risk.

5.2. Critique of the implementation of CAT in ROCs

Moving from a large-scale, rail-network-unaligned five-day forecast updated every twenty-four hours to a forecast alerting tool updated every five minutes over a small, specific geographical area, wholly aligned with the rail network (i.e. an ORS) is a significant change. It constitutes a paradigm shift for people in ROCs.

The 3.00am daily email with the red, amber, green (RAG) status five-day lookahead enables an RCM to provide a weather event risk for the coming 24 hours and make decisions about the level of train service provision for that day (following the EWAT process as necessary). Convective rainfall risks indicated in the five-day forecast are blended out across the 24-hour period across the geographical forecast area, so the detail of the stochastic and localised risk associated with those events is lost, or homogenised.

Building on the development of the Precipitation Analysis Tool (PAT), developed from the Rail Accident Investigation Branch (RAIB) class report on landslips, 2015, the CAT was its logical extension. A critical issue with this logical extension was that it failed to take into account that PAT was co-developed between Earthwork Asset Engineers and the forecast provider and is extensively exploited by asset engineers within DUs. Paper-based

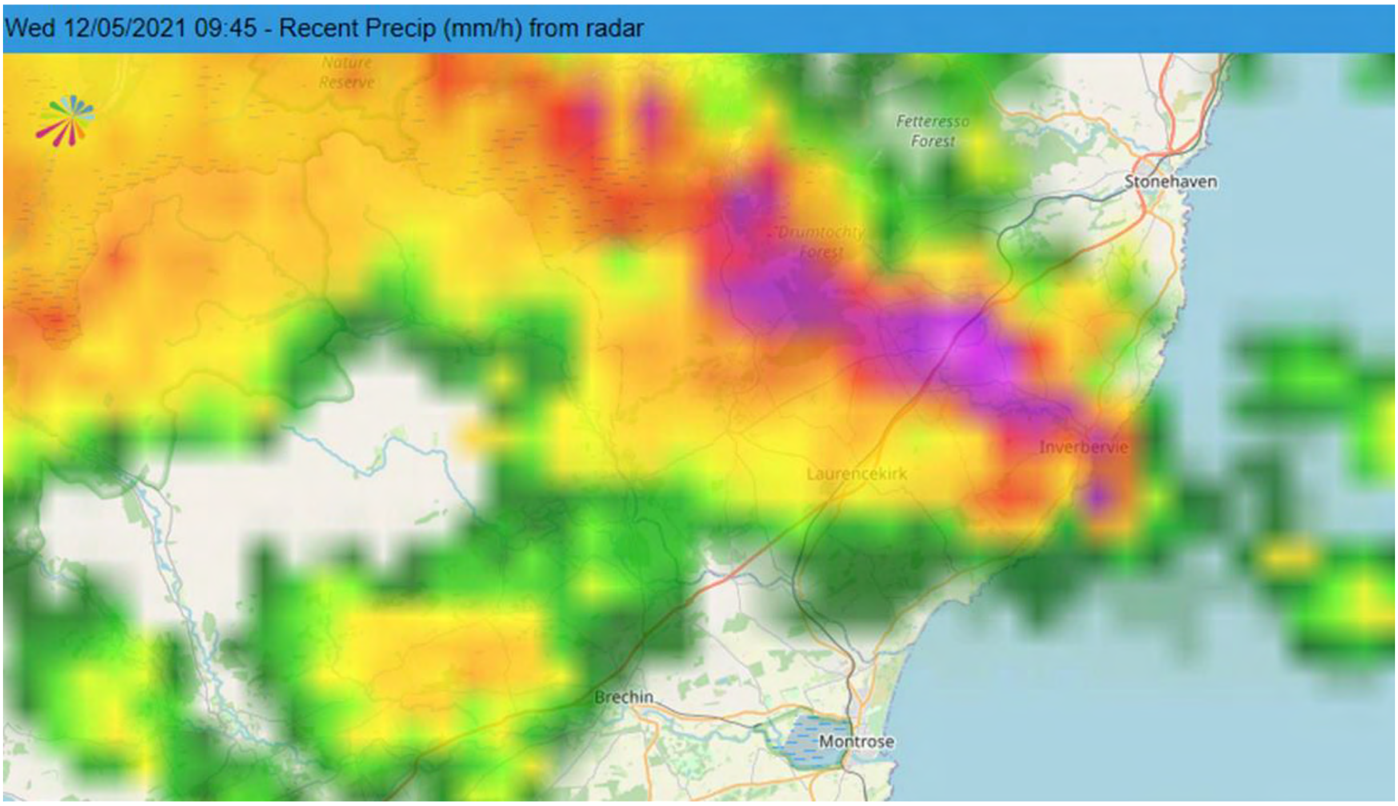


Figure 8: Rainfall radar (9.45am BST 12.05.21). Carmont, site of landslip. Source MetDesk

Figure 9: CAT Alerts triggered at 0945 BST. (Key: • • • = line of route). Source MetDesk

information regarding the high-risk earthwork sites is provided to the ROCs where they are used as aides-memoires. As such, they are outside the principal information and decision flow and unlikely to inform a discussion or influence a decision. Although asset managers are expected to inform EWATs of risks and mitigations, that such information is available does not ensure its use. While an initial assumption was that CAT would be a logical extension of the PAT, the objective of providing near real-time information via GSMR meant that a geographical parameter (the ORS) was required that drivers would be able to recognise.

An 'Earthwork Sprint' programme set up shortly after the accident at Carmont consisted of three work streams each led by a discipline expert and convened first in September 2020:

- meteorological information
- earth work information
- operations standards and implementation.

A solution had to be developed quickly as Network Rail were under pressure to provide a date for the delivery of a tool that would essentially mitigate, or at least reduce the risk of, another 'Carmont' accident. Given that the accident was associated with convective rainfall, National Rail mandated that a tool would be delivered by Easter 2021 in preparation for the 'convective season', that is, Summer 2021.

The decision to 'deliver' the tool by this date, essentially meant that there would be no opportunity to stress test the tool through real convective events. Little consideration was given by senior leaders to the capability of the forecast providers in meeting the deadline. An incorrect assumption was made that MetDesk had an extensive Research and Development Team that could immediately get started on this new system development. As with many commercial weather forecast providers, they have very limited resource for research and development. A second assumption was that MetDesk were solely focused on delivery for Network Rail, whereas in truth Network Rail are one of many clients.

Increasing the complexity, Network Rail brought in a 'Programme Delivery Team' that began working to a different end deadline to that set by the executive at the start of April. The new team had little knowledge of what had been agreed under the three 'sprint workstreams'. Much time was spent between the National Weather Team and MetDesk in understanding both contractual obligations and capability.

Relationships between the National Weather Team and MetDesk have been forged over many years. MetDesk were determined to build on this and test the tool to meet the deadline in order not to let down neither the National Weather Team nor the wider industry. Their reputation within the wider rail industry was at risk with the project plan timelines recognised as unrealistic by the senior team within MetDesk. Both the National Weather Team and MetDesk were aware that effective implementation of CAT would take many months of iterative stress testing with both users and developers using clear criteria

In practice, only one tabletop scenario took place with just NW&C Region. While a scope was established, no formal research or evaluation methodology was adopted, no control measures were used, and no independent observers were involved. This should have been an opportunity for the Rail Safety and Standards Board (RSSB) to be involved but the steering group that led the NW&C trial consisted only of the RCM, members of the National Weather Team and the ROC for NW&C. A single historic event was trialled through the system in this exercise and it provided no information beyond the volume of alerts becoming unmanageable by the early evening. The Route Controllers had to implement blanket speed restrictions over a vast area of the network just as happened in the actual event and under the previous decision system.

Fourteen actions emanated from the tabletop against which the steering group were to monitor progress. All these actions were derived by the control staff themselves and many were opinions which should have generated substantial discussions to achieve clarity and convert them into defensible operational recommendations. However, rather than this formal approach, the raw feedback was documented as actions, some of which were sent directly to MetDesk before their validity had been reviewed and tested. This caused development delay as they inevitably came back to the National Weather Team for clarification. Communication channels were lost between MetDesk and Network Rail where lines of accountability for the use or misuse of the tool became blurred.

The Programme Delivery Team were directed by senior leaders to focus on delivering for the control staff, the end users, which at one level was logical but missed the point that the granular information could be further used to undertake analysis and drive learning. The approach to focus purely on control staff was detrimental to the wider and long-term success of the tool. Substantial time and energy were lost through the lack of clear communication between expressed user needs, understanding what is possible from the meteorological data platform, and the application of information to enhance safer operations. The Programme Delivery Team continued to focus solely on the delivery of the tool to control staff, defining success as the completion of the functional tool rather than its utility in safer decision-making in the longer term.

The Programme Delivery Team also did not recognise the boundary between Network Rail and MetDesk in locating liability when either the information provided is not used or where some elements of the available information are hidden or suppressed. Potential reputational damage is an issue for all parties.

Following the single NW&C trial, CAT was rolled out nationally across all ROCs. While MetDesk provided online training in the use of the system, many ROCs are joint operations where the TOC controls are collocated and some claimed that they were not made aware of the system. In May 2021 the CAT triggered many alerts in ORSs on the East Coast Main Line (ECML) and there was pressure on York ROC to switch off the tool completely as the London and North Eastern Railway (LNER) were having to implement reduced line speeds over vast areas on the ECML.

LNER reported that they did not know about the roll out of the tool, and they had not been consulted. This information distribution failure is concerning as the drivers receive advisory notices through their in-cab GSMR radio. In the case of LNER it transpired that the Single Point of Contact (SPOC) for Eastern Region had not reviewed the input data about the ORSs. The average number of data points between start and finish points within an ORS is around 5 but some of the ORSs on the ECML covered such a large area of railway that up to 200+ data points could have been alerting for a single ORS. This example shows the significant challenge in making the CAT functional in providing a safer railway. Ownership of the ORS information is a concern, as it signifies that the objective of CAT is not understood in its entirety, a particular concern when prior adverse events are considered.

It is not clear whether the Programme Delivery Team chased up and confirmed with the owners (Regional SPOCs) regarding the level of detail required for the ORS information. The provision of the details of the ORSs directly to MetDesk to go into the live system was, in some cases, provided by people with little relevant experience. It is unclear how this information was provided in raw form for MetDesk to upload without being reviewed or checked.

Tight deadlines and the belief that a spreadsheet sent to MetDesk cleared the action of providing the ORS information demonstrates a lack of understanding with regard to the importance of data integrity for the wider use of the tool for analysis. It also demonstrates a lack of understanding about the ramifications this had for the performance of the rail network. LNER suffered considerable delay due to incorrect information and even when this was realised no one was held accountable.

The cultural response to CAT is very interesting and highlights the lack of true engagement in the longer-term use of such tools for learning. In LNER the tool itself was blamed for 'over alerting' when the forecast precipitation did not match the observation data, or subjectively did not 'feel' like that much rain. In the case of the Laurencekirk Case Study, 'it felt like there was more rain' than forecast even though the observational data clearly demonstrated that the forecast was correct (a level that did not exceed half of the threshold to activate an extreme alert in CAT).

Resource management was not considered in getting CAT established within Routes and Regions. Control teams running an operational railway are fully occupied, yet no one was taken out of their daily role to ensure that the tool was understood, and no work was undertaken to establish who was accountable for the end to end process. The very nature of the original three workstreams in the sprint did not help this situation:

- The meteorological workstream team were regularly asked by the Programme Delivery Team about how the process was working within controls and how the deployment of CAT was being received by train drivers.
- The Programme Delivery Team were not part of the original sprint, in fact most of the team did not know of the three original work streams.
- Confusion was caused through the Programme Delivery Team often putting leaders of the original workstreams under pressure to comment on other's subject matter expertise.

After several months of CAT operation, consistent requests have been received from ROCs through the Programme Delivery Team to reduce the volume of alerts to fire only at T–3 hrs, rather than T–1 hrs. Again, this confirms that the controls are set up culturally to respond and recover rather than pre-empt and prevent. There is no discussion or requests about how better they could use the T–1 hr information within CAT, nor how they might use the archive to undertake a deep dive analysis to help inform future decisions at specific ORSs.

More explicitly, the request from many ROCs was to have CAT alert when the tool is switched off to notify the controls to switch on the system in order that they can then receive the alerts. This request alone is indicative of an operational function that perceives itself as 'fire fighting'.

6. Asset data, asset management and the SARM

This work is ongoing, we will relate the progress to the date of reporting with reference to the quality of data.

6.1. Preamble

In this section we will introduce the asset management approach and SARM process, describe what it is and how it uses weather and other data. We will discuss the process of its implementation and how it is intended to contribute to operational safety. We will outline the SAR process of design, initial data collection, and prototype development. The idea of a seasonally agnostic railway arose from a series of conversations between Dr Brian Haddock and Dr John Beckford. Beckford, using VSMethod (webref 1) developed with Haddock a shared model of the challenges confronting the railway and an understanding of how those challenges might be addressed through organisational cybernetics incorporating data science, machine learning, and asset management to develop a digital model of the railway with simulation, learning, and adaptiveness inherent in its design. What follows is built on this richly systemic, multidisciplinary understanding of the problem and its context.

The use of ORSs provides an opportunity to undertake detailed analyses of the impacts of weather events, such as wind, temperature, and precipitation on localised sections of the railway. When such impacts are synthesised with an understanding of the local environment, a systemic picture of the vulnerabilities may be drawn for each ORS. Thereafter, utilising information of the condition of the assets a systemic model can be developed that asserts overall system resilience for any particular ORS given the forecast weather event. The model will provide a series of choices to the railway with regard to the provision of the train service based on the predicted availability of the network reflecting the likely response of every asset to the forecasted event.

Aggregation of how the ORSs will react, expressed in delays imparted to services, allows an understanding of how an entire service group (a line of route) is likely to be affected by any given weather event enabling the provision of a deliverable service. Such a systemic understanding brings together data from weather forecasting, asset specification, asset condition, and planned services in an integrated whole. The product of its calculations is a forecast weather impact on the timetable at different levels of temporal and spatial granularity. The benefit is the ability to inform:

- passengers of likely impacts before they travel
- operators of the impact on their vehicles and crews
- asset managers of the assets they must address to anticipate, prevent, or mitigate failure risk.

As the accuracy and granularity of weather forecasting develops, an accurate impact profile for each service group can be developed. Timetables can be developed to reflect the expected availability and provide passengers with travel information before the forecasted weather event. As the impacts of weather events are experienced over these service groups, lessons are learned, reviewed, and fed back into the modelling to refine the timetable, ensuring a 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, but also information to service groups that are less or unaffected. As the tools are developed to assimilate asset and forecast weather data at a localised level, targeted imposition of speed reductions can be deployed where needed, leaving unaffected adjacent lines to run as normal. Such a targeted approach means that diversionary routes become available and train movements will only be slowed at specifically affected locations where there are known vulnerabilities.

The project has connected to two other significant and valuable related projects. One is seeking to geolocate every track asset, while another is mapping the vulnerable earthworks across the railway.

6.2. Initial model

In developing the idea of a seasonally agnostic railway we generated, in consultation with stakeholders, an operational definition; a precise, measurable, objective statement about what that means and provide a framework against which progress and contributions can be assessed.

The work was informed by several key ideas from quality management (Beckford, 2017) and cybernetics (Beckford 2021):

- a Learning Cycle based on 'Plan, Do, Check, Act'
- the cost of nonconformance – the costs incurred through failure, both to the railway, to its clients and the wider society which is currently measured by the idea of 'delay minutes'
- the value of non-failure – the economic, environmental, social, political benefits gained through success
- a strategy drawing on the ideas of organisational adaptiveness as the key to survival, including engagement, and autonomy of the railway community.

A performance model that measured whether the desired outcome was achieved needed to include:

- the expectations of passengers and freight users
- the expectations of all other stakeholders operational, organisational, political
  - the capability of the railway – addressing the ability of the railway to deliver passenger and freight services under a range of conditions
- the range (and limits to) weather conditions, to which being seasonally agnostic applies (which will need a consistent supply of relevant weather data to generate the reporting context against which performance can be measured)
- the cost and value of necessary adaptive behaviour
- the potential of the railway – what constrains performance and how changing those constraints might enable performance to be improved
- the actual performance – the capture of data necessary to report performance in a form and format suitable for analysis and interrogation at a rate and frequency which would enable pre-emptive and corrective action at all levels and timescales.

The model also needs access to data that links current performance with prior preparedness (maintenance) action, that is, a need to link the performance of an asset with its maintenance regime. This allows the determination of a connection between asset maintenance and asset availability/reliability of sufficient validity to inform decision-making (which might, for example, increase or reduce the frequency of maintenance action). Any approach, to be useful, will adopt the cybernetic structure of a learning cycle (a homeostat). A homeostat compares what happens with what was expected to happen, the gap between them acting to stimulate corrective and preventative action.

An overall view of this shows (**Figure 10**) a 'core process' (a rail journey) made up of a series of tasks which connect together to deliver the service, each task (T) made up of a series of procedures

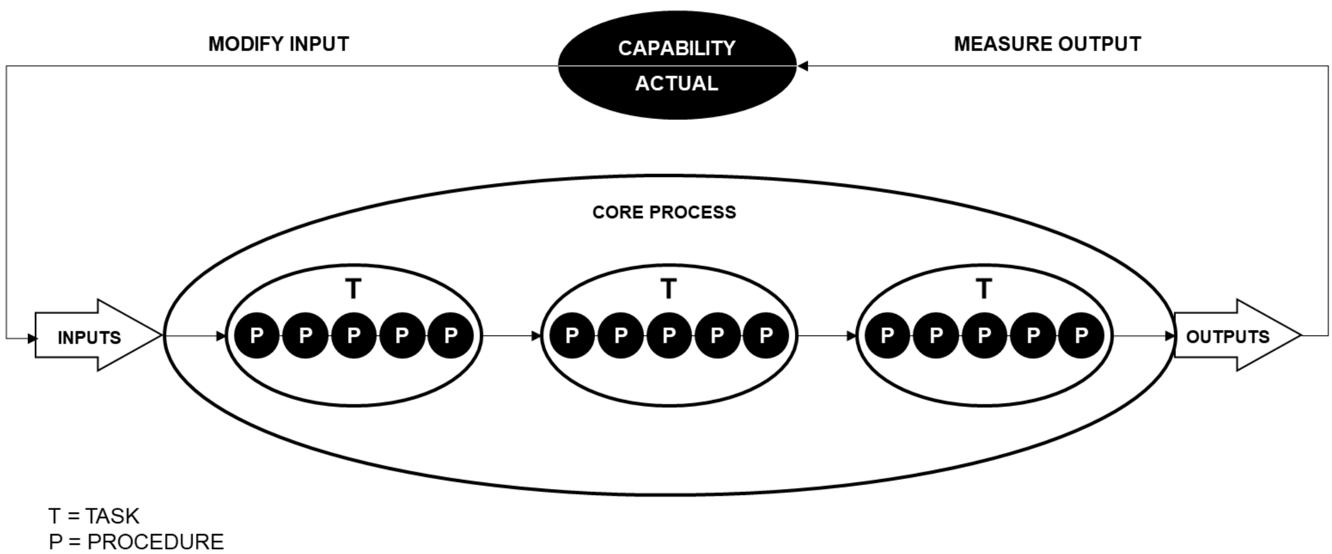


Figure 10: A journey homeostat. From The Intelligent Organisation, Beckford 2020

(P) embedded in the overall process. Each of those steps would also contain its own learning cycle (a homeostat or PDCA cycle) driving improvement both on each element and in the whole.

Each cycle (each P and T in the previous diagram) looking like **Figure 11**.

This device adopts the notion of a potentiometer (**Figure 12**), reflecting not just what was done, but how what was done compared with what was expected. This provides a measure of the effectiveness of the action and enables comparison of otherwise dissimilar things. The results are compiled in a data and reporting system that provides a consistent structure and language to inform the development of the model and an objective view of whether:

- performance is improving or deteriorating
- seasonal preparedness activities are delivering expected benefit.

The structure identifies the location (timing, process, geography, organisational responsibility) of any problems or issues identified.

Critically, the railway will be able to use the model and its contained data to make useful assertions about the future, that is, to make assertions about what is likely to happen if no changes are made AND direct attention to the changes most likely to deliver benefit. This combination of ideas enabled conceptual solutions.

Figure 13 suggests that, for each operational route section there will need to be three interacting homeostats:

- Homeostat One will reflect on the difference between the weather predicted and the weather experienced.
- Homeostat Two will reflect on the fit between the weather predicted and the specification of the assets to cope with that weather.
- Homeostat Three will reflect on the preparedness of the assets to deal with the weather as experienced.

Failure of any of the three loops will mean a degraded (amber) or failed (red) performance of the railway.

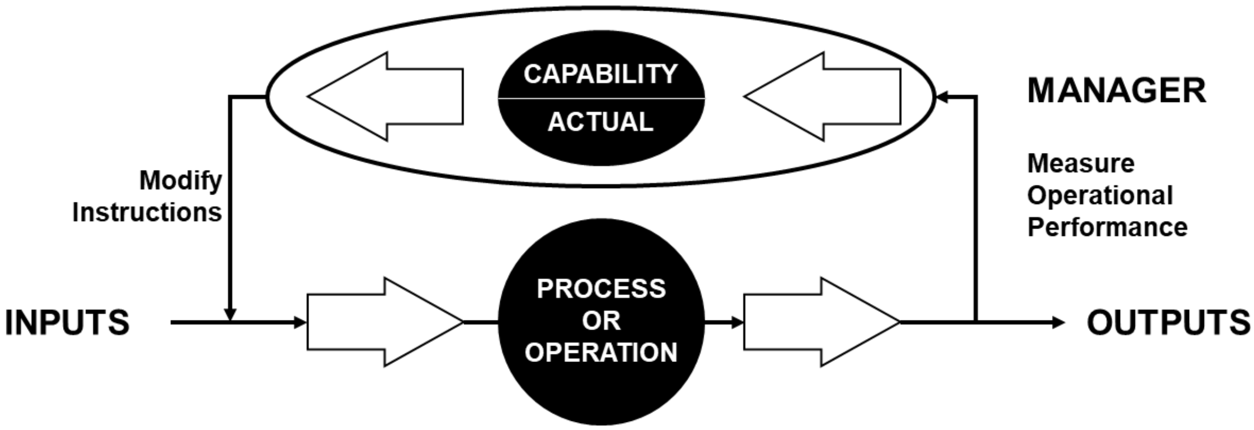


Figure 11: Individual homeostat. From The Intelligent Organisation, Beckford 2020

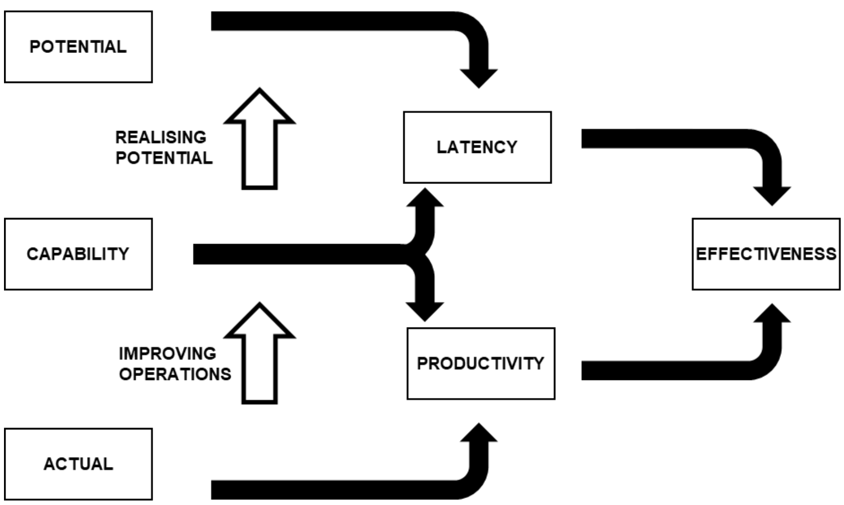


Figure 12: The potentiometer. From The Intelligent Organisation, Beckford 2020

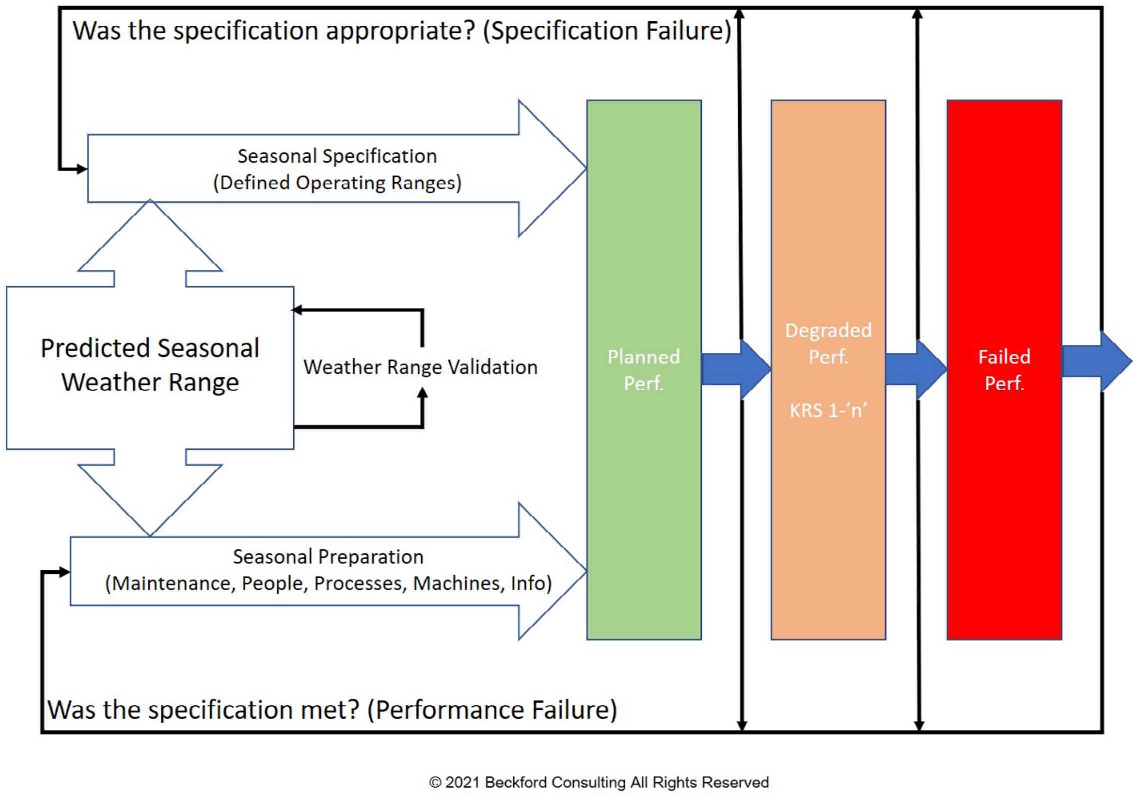


Figure 13: Conceptual model 1

The aim is to be able to anticipate and pre-empt such degradation.

Figure 14 provides an indicative architecture through which information about impacts collected at ORS level can be distributed 'up' to network controllers and managers and 'out or down' to service operators, passengers, and freight carriers. This architecture, gathering data in near real time at the ORS level and working with weather data at the same level of granularity, eradicates delays in local reporting and facilitates rapid aggregation of results, since all the core calculations are conducted at that local level minimising processing requirements. Localisation reduces the latency of decision compared with contemporary practice and precisely collocates events, assets, and impacts eradicating the need for later data mining and interrogation. Each of the ORS-level homeostats enable local learning and adaptation within a consistent, railway wide framework.

Figure 15 shows how data collected can be aggregated into performance information at every level from the class or type of asset to ORS, the line, the route, and the whole railway. Performance information will be fed back, enabling modification and adaptation of both the learning model and its predictive capability. For each time period, the model will make assertions, varying in accuracy with the time period projected, enabling pre-emptive corrective/preventative action to be taken to inhibit failure of those assets which are vulnerable to weather impacts – whether that be locally driven by immediate need or part of a seasonal adaptation and preparedness plan.

Figure 16, a conceptual model for an asset criticality and vulnerability index, based on prior work of Beckford and Dudley (Beckford 2021), systemically demonstrates how the criticality of each asset varies with the status of each of the other assets on which it is dependent, and which are dependent upon it. This dynamically based assessment of criticality, applied to every asset with the results dynamically reported, enables a systemic perspective on pre-emptive and corrective actions. It highlights how, as each challenge is addressed, a new potential point of failure is exposed. Ultimately it will enable a methodology for prioritising maintenance and repair activity based not on the asset but on the effect of the performance of the asset on the performance of the railway system. We will be able to see how failure propagates through the system and which interventions are most likely to prevent that propagation.

6.3. Progress on the seasonally agnostic railway

A series of proof-of-concept models were created which

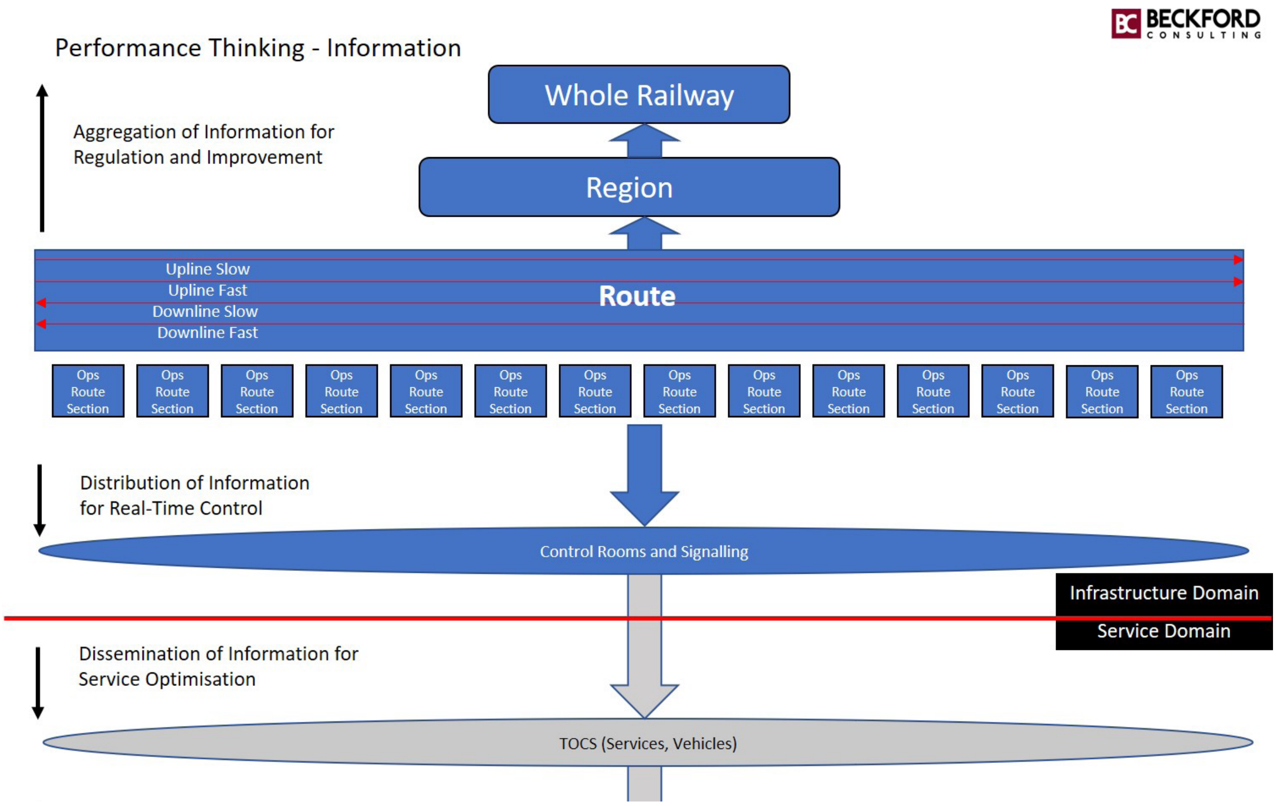


Figure 14: Conceptual model 2

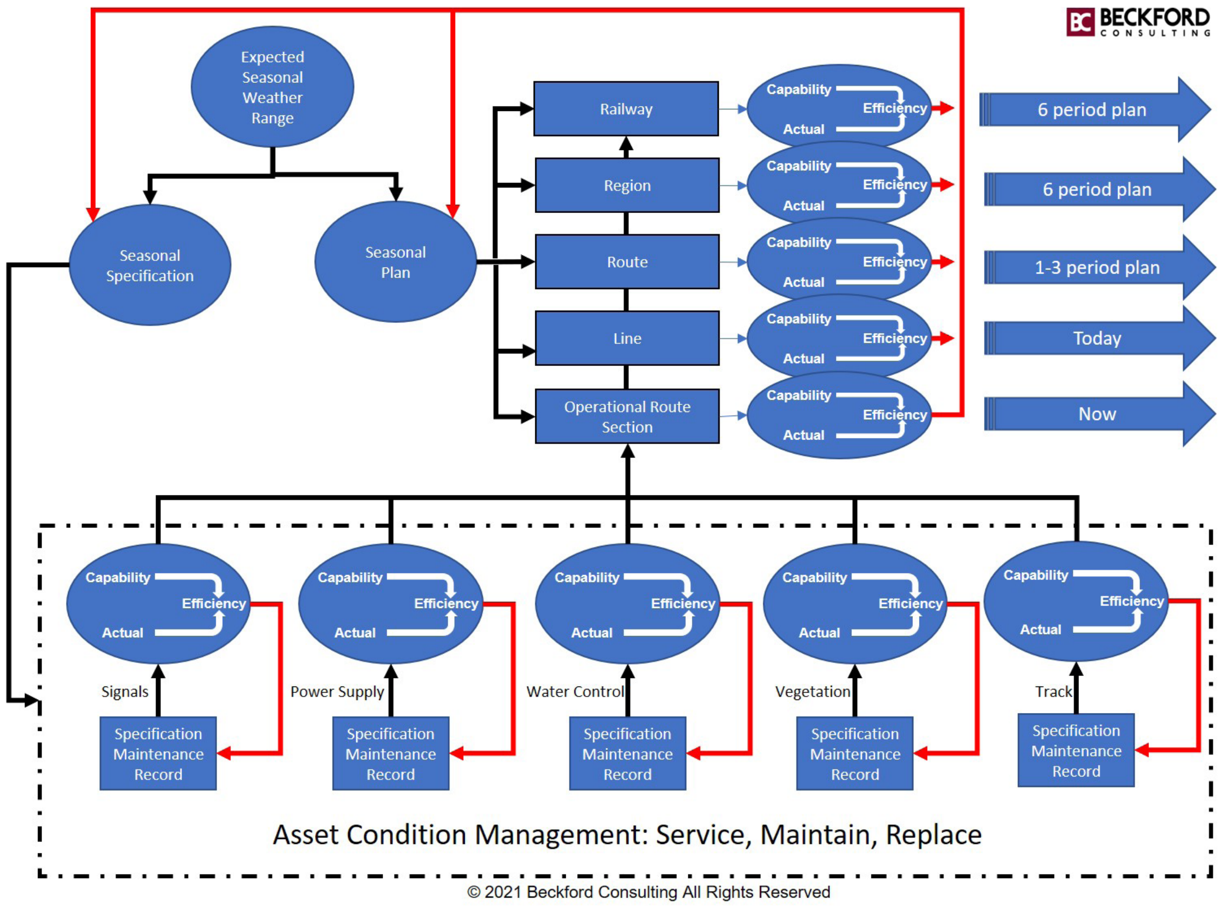
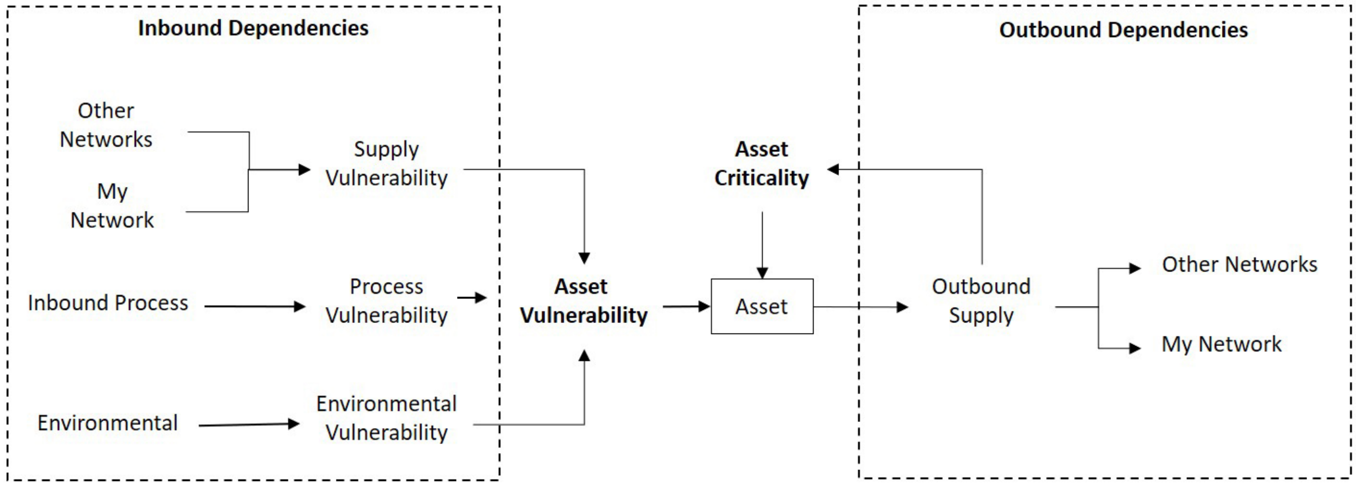


Figure 15: Conceptual model 3

Asset Vulnerability and Criticality



Supply Criticality = Asset Criticality X Supply Vulnerability
Process Criticality = Asset Criticality X Process Vulnerability
Environmental Criticality = Asset Criticality X Environmental Vulnerability
Asset Vulnerability = Max of Supply/Maintenance/Environmental Vulnerability
Asset Criticality = Σ (Onward Asset Dependence X Onward Asset Criticality)
Asset Exposure = Asset Criticality * Asset Vulnerability

Inbound Influence: THIS depends on THAT
Outbound Influence: THAT depends on THIS

Adapted from 'The Intelligent Nation' Beckford, 2021

Figure 16: Conceptual model 4

successfully demonstrated the logic of the model to Network Rail and supporting consultants. These needed to use synthesised data and through a series of online workshops and discussions we:

- demonstrated and evolved the core ideas of the approach
- illustrated how the model will work and what benefits could be derived
- discerned and categorised the initial sets of track-related asset data to be collected for each ORS
- identified categories as: earthworks, gauge, signalling, the track itself, power supply (third rail and OLE), structures, drainage, signals and crossings.

It is recognised that during the course of the project we will not only need to test the accuracy, veracity, and continuing validity of the data but also extend the research to include vehicle and station asset data as well as the working timetable and the mix of rolling stock on any particular line of route (different classes of rolling stock are impacted differently by extreme weather). The size of the data gathering request must not be underestimated.

With the intention of moving from proof of concept to prototype we have selected three ORS's on the Western Route (between Reading and Kintbury) and have engaged with asset and route managers responsible for that area to provide the data. These managers were participants in workshops where the project objective and challenges were outlined, the rationale explored and explained, and the importance of their contributions elaborated.

These ORS's active participation in the development of the model is recognised as critical to its acceptance as a useful tool at a later stage when the model is being tested against existing approaches. A second purpose, but of equal importance, was to work with them to determine the availability and appropriateness of data for the model and expose deficiencies and/or inaccuracies in data. From a research perspective, knowing what data is NOT available continues to be as important as knowing what data is available. Gaps in the data serve to highlight any challenges faced by decision-makers.

During November 2021, working prototypes of the SAR Model using both real and synthesised data have been demonstrated to both the rail industry Seasonal Challenge Steering Group (which includes representatives from all major parts of the industry) and the Central Engineering Leadership Team from Network Rail. The model received enthusiastic endorsement from both groups and the demonstrations have secured their support in closing data gaps and enabling access to key supporting resources.

6.4. Key findings from SARM development

The SARM is a substantial work-in-progress which is expected to be in progress for two or more years beyond the date of writing. Network Rail is co-funding, with the Centre for Information Management at Loughborough University, two PhD studentships to conduct research in particular areas including AI/Machine Learning and the challenges of working with 'dirty data'. It is a substantial contributor to the 10-Year Weather Resilience Strategy of the UK Rail Industry and is both challenging and informing both the short- and long-term actions and activities, including the development of the Weather Academy and operational tools such as CAT.

Over the most recent months the focus of the research has been on capturing and codifying asset data in a manner suitable for use in the model. The data collection process has been designed to accommodate and acknowledge where data does not exist, and it is expected that the model will be developed using synthetic data where necessary, but in parallel with a version using live data. It is hoped that the differences between the two will provide the insights necessary to stimulate corrective action.

There are for now several key findings from the work in relation to asset data:

- It is held in different systems for different purposes; there is no single source of 'truth'
- data management, capture, curation, and use all appear weak
- much is held in unstructured or unsearchable form (for example in a standards document) where it cannot easily be retrieved or applied
- specifications or standards for some assets have not yet been identified
- the process of data retrieval is currently very labour intensive
- much decision making about managing incidents and risks relies on the personal knowledge and expertise of individual asset managers more than on systematic application of data. Consideration of this expertise is to be addressed in the next phases of the work.

The emerging model is being designed to deal with the challenges of dirty or absent data though this will clearly have impact on forecasting accuracy.

7. Conclusions and transferability

Our preliminary conclusions in relation to the project under consideration and the specific ambition to develop safer complex systems are that there are systemic issues with railway data which have implications for operational safety and performance. The SARM is intended to help overcome these. The challenges are:

- inadequacy of change management processes
- failure to integrate new tools with old
- culture, behaviours
- approach to management is fragmented, siloed, and not systemic
- lack of meaningful information
- scale and rate of change are substantial matters.

It would be reasonable to expect that many of the issues identified with Network Rail would be replicated in any other large-scale, mature infrastructure system and that similar challenges would apply.

It would be equally reasonable to assert that a systemic approach to modelling the organisation in the manner outlined here and informed by a similar understanding would enable identification of ways in which risk could be reduced and performance enhanced for any other organisation.

The utility of the systemic approach rooted in cybernetics is becoming apparent. The ability to embrace the entire 'hard' aspects of the system are proving invaluable, as is the idea of structural recursion. Here an invariant data structure (in effect a fractal) applied to each ORS enables rapid scaling and application of the approach to multiple locations simultaneously without the need for large scale interventions.

There are transferable lessons to be developed about:

- design and implementation of new systems
- user awareness and education
- identification structuring and organisation of data
- multi-partner working in complex systems diagnosis and therapy
- the risks arising from siloed thinking and imparted to complex systems
- the use of positional power and influence to demand solutions that are 'right now' rather than 'right'
- the challenges facing any mature infrastructure organisation in addressing complex, data-based challenges, from within the traditional expertise and knowledge base of the particular sector.

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Glossary

CAT: Convective Alert Tool, a system for predicting convective rain events

Delay minutes: the number of minutes the train is late multiplied by the number of passengers

DU: Delivery Unit

ELR: Engineer's line of reference

EAWMP: Emergency or Adverse Weather Management Plan

ECML: East Coast Main Line

EWAT: Emergency Weather Action Teleconference

KRS: Key Route Strategy: a modified timetable running reduced services

GSMR: Global Systéme Mobile Rail

LNER: London and North Eastern Railway

Metadata: data about data including a related ontology and master-data management

MPV: Anti-Icer Multipurpose Vehicles

NOC: National Operations Centre

OLE: Overhead Line Equipment

ORR: Office of Road and Rail (Regulator)

ORS: Operational Route Section

PAT: Precipitation Analysis Tool

RAIB: Rail Accident Investigation Branch

ROC: Route Operational Controls

RCM: Route Control Manager

RHTT: Rail Head Treatment Trains

RSSB: Rail Safety and Standards Board

Schedule 8 compensation/payments: Compensation to an operator for the unavailability or limitations of the Network Rail infrastructure which inhibits their ability to run to standard timetable

Seasonal Bump: weather-related shifts in normal operations

SARM: Seasonally Agnostic Railway Model

SPOC: Single Point of Contact

System: a set of elements or components interacting to a common end

System of Systems: a set of systems in dynamic interaction with each other

WTT: working timetable

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