Understanding and utilising data for a seasonally agnostic railway

By Dr Brian Haddock, Dr John Beckford

Executive summary: This study considers how the Rail Industry might make better use of data to manage 'seasonal bumps' in performance related to extreme adverse weather events. It explores conventional responses and then proposes a new approach rooted in cybernetic modelling of the data enabling adaptive and preventative actions to be taken. We show how more effective use of data in a coherent whole system model can help identify areas of risk and enable anticipatory, mitigating actions.

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

Section 1: Background and introduction

Each year with seasonal changes and changing weather patterns, the UK railway experiences 'seasonal bumps' causing delays and cancellations. This research explores systemic interactions and interdependencies arising on the UK railway, embracing the information generation and decision processes that enable weather-related decision making to address those. The objective is:

> *"To deliver a 'seasonally agnostic railway' as a safe, resilient, complex adaptive system".*

The System of Systems under consideration

The principal system is the whole UK operational railway (both below and above the railhead) as shown in **Figure 1**.

Our study focuses on three sub-system elements of this overall cyber-physical system:

- Emergency Weather Action Teleconference (EWAT)
- Weather forecasting
- Asset management data.

The UK Railway follows a system of planning and decision represented in **Figure 2**. Non-weather events are excluded from consideration.

Research synopsis

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

The aim is to develop knowledge, insights, information systems and operational practices to enable a seasonally agnostic railway. The study for the Safer Complex Systems Research Group, RAE, is being delivered as part of the ongoing SAR Model project considering weather and asset data and forecasting potential.

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 for its intended purpose and to identify any 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 cybernetically designed system capable of integrating meteorological, asset and operational data to enable assertions about probable future performance.

Integration of data will enable assertions about future performance and the effect of preventative maintenance interventions.

Context and approach of the research

The project aims to support the Network Rail weather resilience strategy team in developing a transformational approach to

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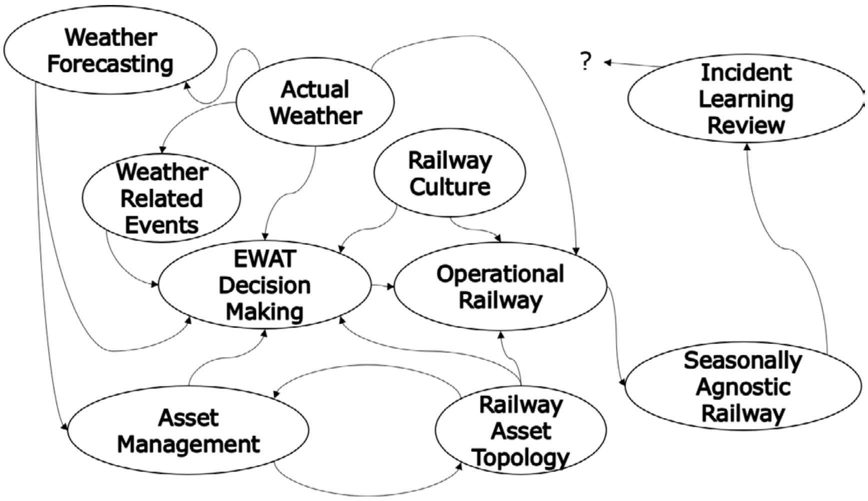

Figure 1: An extreme weather System of Systems

reducing service compromise and failure and fulfil commitments to passengers and freight carriers. The approach will use information about performance to inform both corrective and pre-emptive 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, using information:

- To enable and sustain adaptation;
- To embed lessons learned in the architecture of the railway system;
- To improve reporting systems;
- To 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. The outcome, though distanced temporally and spatially, can then be evaluated in context with the aim of generating an increasingly weather resilient railway.

Section 2: Analysis and insights

A notable challenge is that much of the data held by the railway is in unstructured or semi-structured formats.

Extreme weather response

The traditional extreme weather response system used by the railway is an Extreme Weather Action Teleconference (EWAT).

The EWAT process is intended to enable the railway to make short term adaptations to timetables and operating decisions in order to mitigate the effects on the railway and its passengers of extreme

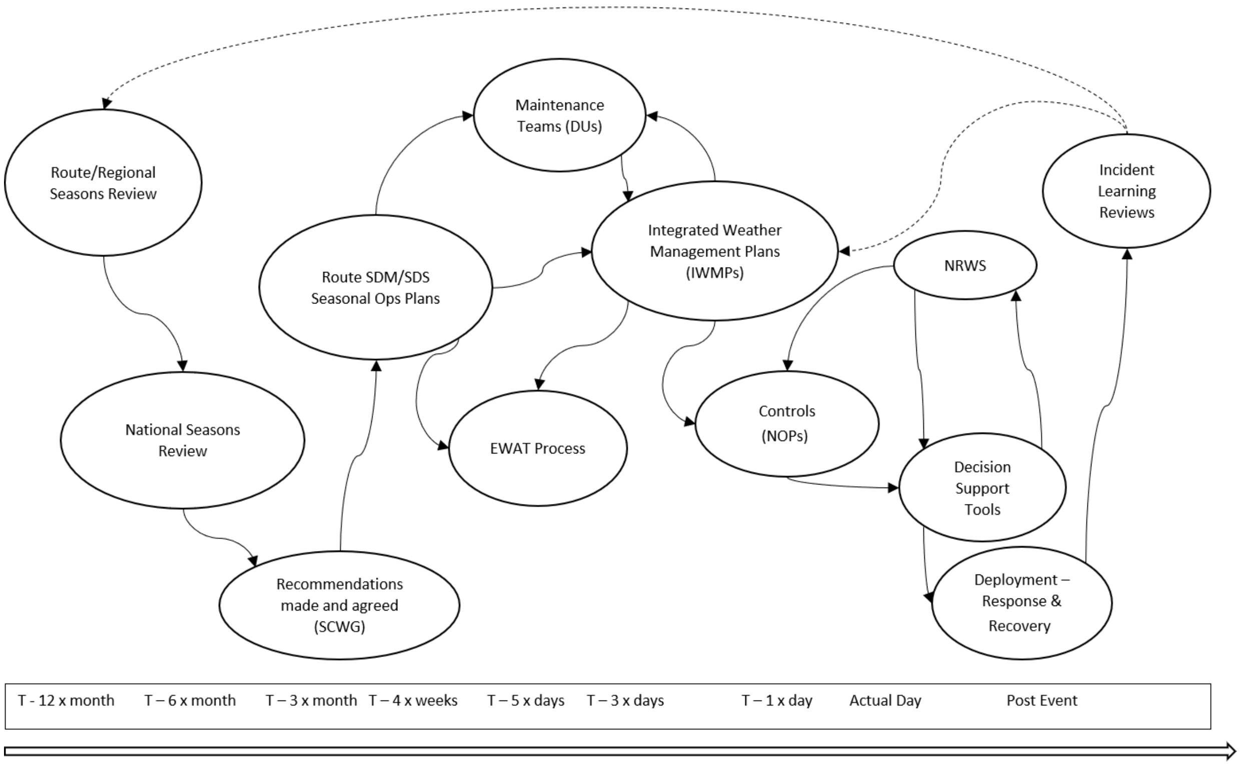

Figure 2: Current system of planning and decision

weather events. Weather forecast providers (MetDesk) deliver two-day to five-day forecasts that underpin the industry response to impending events. The forecast process is as follows:

- Received by email at each control (ROC) nationally;
- Risk assessed by the Route Control Manager (RCM) or equivalent;
- Distributed across the entire region.

Thresholds are in place for each weather parameter that define the risk to the network around four core alert levels of Normal, Aware, Adverse, Extreme. This simple coding of alert status allows the teams within ROCs to expedite a judgement on whether to initiate any actions in accordance with their extreme or adverse weather management plans (E/AWMPs). If an extreme threshold is forecast to be breached, the control team initiates an EWAT, the five-day process following five stages from the initial forecast to the day itself (**Table 1**).

Critique of EWAT

EWATs are considered to provide the principal benefit of reassurance to senior leaders that the forecasted weather has been considered. However:

- Outputs of EWATs do not provide a quantitative summary of the risk exposure or options of train service provision;
- Reduced train service provision not validated against the working timetable is informationally inadequate leading to confusion for the station staff around which services are, or are not, being provided to passengers along with confusion about speeds and cancellations.
- On main lines, with more than two train operators running services over most sections, there is increased potential for conflicting decisions, particularly where freight services are involved;
- There is no informational connection between seasonal planning and the EWAT process;
- EWATs have become institutionalised, perhaps undertaken to demonstrate compliance rather than because they make a difference;
- Information is often unstructured and oral;
- Mitigations proposed are conditional;
- Large numbers of attendees inhibit effective communication.

The Convection Alert Tool (CAT): Review and critique

Since the accident at Carmont, the rail industry has adopted defined sections of permanent way known as Operational Route Sections (ORS) and developed the Convective (Rain Event) Alert Tool to manage the impact of extreme weather. The first permits fine grained weather forecasting as a means of alerting operators? to imminent risk and allows for the imposition of speed reduction to only the affected area. This acts to minimise the overall performance impact for all other services. 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 (ORS), is a significant change. Building on the development of the Precipitation Analysis Tool (PAT), developed from the RAIB Class Report on Landslips, 2015, the CAT was its logical extension.

Critique of the implementation of CAT

An 'Earthwork Sprint' Programme set up shortly after the accident at Carmont consisted of three work streams, each led by a discipline

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: delivery units 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 Delivery Units.
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

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 was 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 Network Rail mandated that a tool would be delivered by Easter 2021 in preparation for the summer 2021 convective season.

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.

Network Rail brought in a 'Programme Delivery Team' with little knowledge of what had been agreed under the three 'sprint workstreams'. The National Weather Team and MetDesk knew 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 table-top scenario took place with just a single region and while a scope was established:

- No formal research or evaluation methodology was adopted;
- No control measures were used;
- No independent observers were involved.

The Programme Delivery Team focused 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.

Following the single trial CAT was rolled out nationally across all ROCs, although experience showed a 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.

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. 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 was regularly asked by the Programme Delivery Team how the process was working within controls and how the deployment of CAT was being received by train drivers.
- The Programme Delivery Team was 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 others' subject matter expertise.

This request alone is indicative of an operational function that perceives itself as 'fire fighting'.

Asset Data, Asset Management and the Seasonally Agnostic Railway (SAR) Model

The idea of a seasonally agnostic railway arose from a series of conversations between Dr. Brian Haddock and Dr. John Beckford. Beckford developed with Haddock a shared model of the challenges confronting the railway and an understanding of how those challenges might be addressed to develop a digital model of the railway with simulation, learning and adaptiveness inherent in its design.

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. 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.

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 non-conformance;
    - 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 and 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, and 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 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 might changing those constraints 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 that would enable pre-emptive and corrective action to be taken at all levels and time scales.

The model also needs 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.

This device adopted is a potentiometer 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 the expected benefit.

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.

For each operational route section there will need to be three interacting homeostats (**Figure 3**):

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

Figure 4 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.

Figure 5 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.

Figure 6, 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

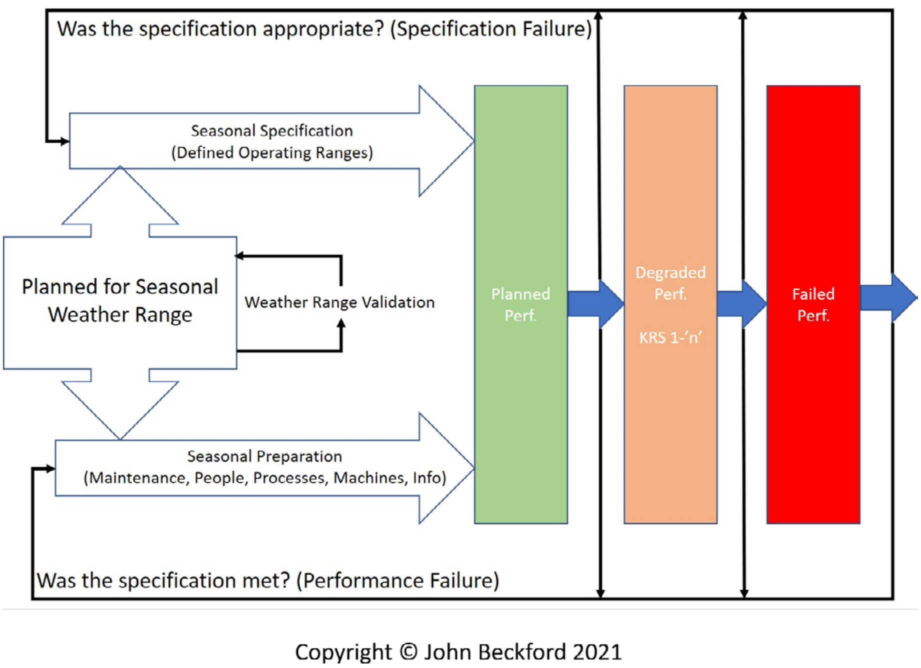

Figure 3: Conceptual Model 1

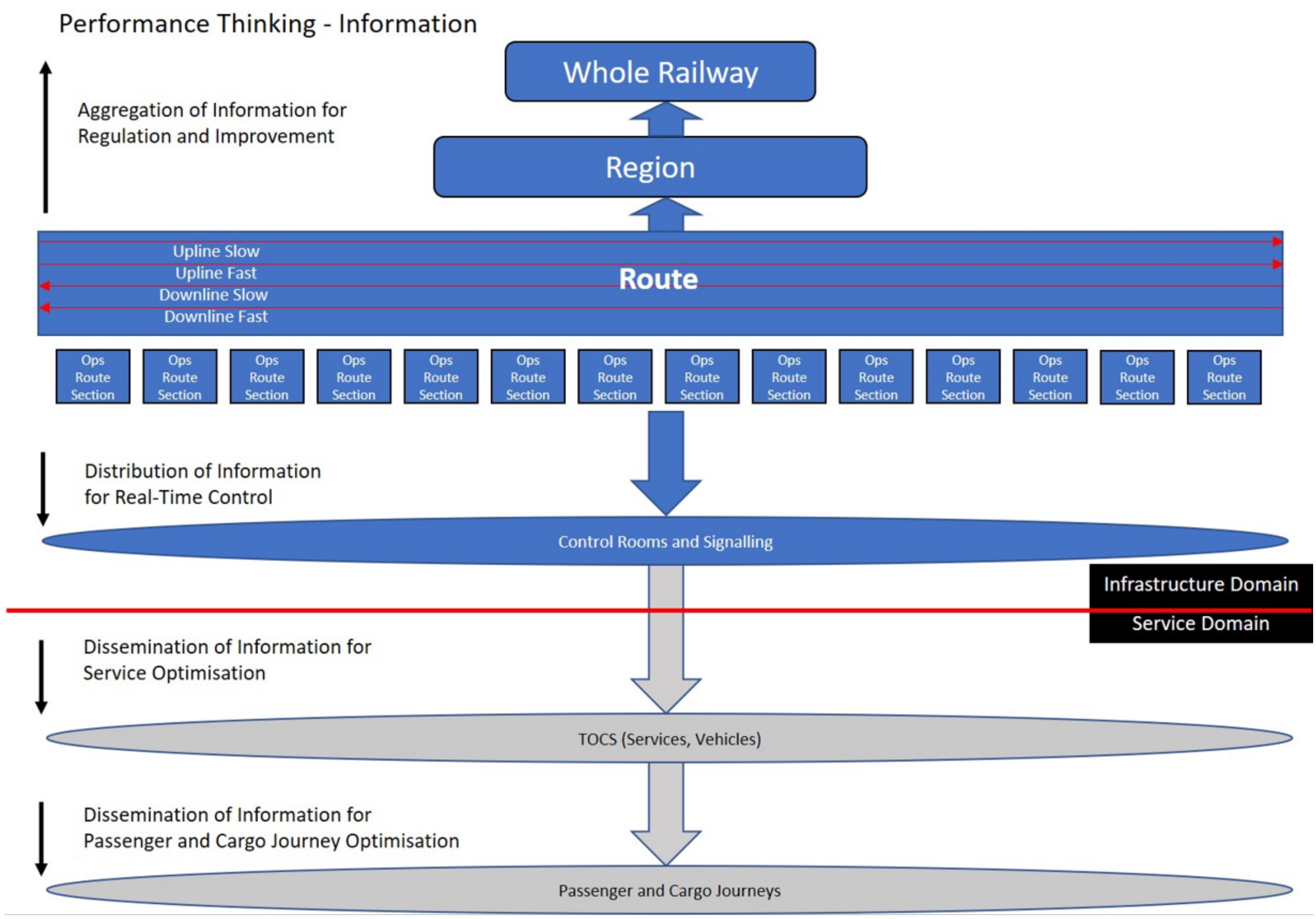

Figure 4: Conceptual Model 2

it is dependent and which are dependent upon it.

Progress on the Seasonally Agnostic Railway

Initial models were created that successfully demonstrated the logic of the model using synthesised data.

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.

Key findings from SAR development

The SAR model is a substantial work in progress that is expected to be in development for two or more years beyond the date of writing. It is a substantial contributor to the 10 Year Weather Resilience Strategy of the UK Rail Industry and is both challenging and informing the short- and long-term actions and activities.

There are for now a number of 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;
- We have not yet been able to identify specifications or standards for some assets;
- 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 subsequent phases of the work.

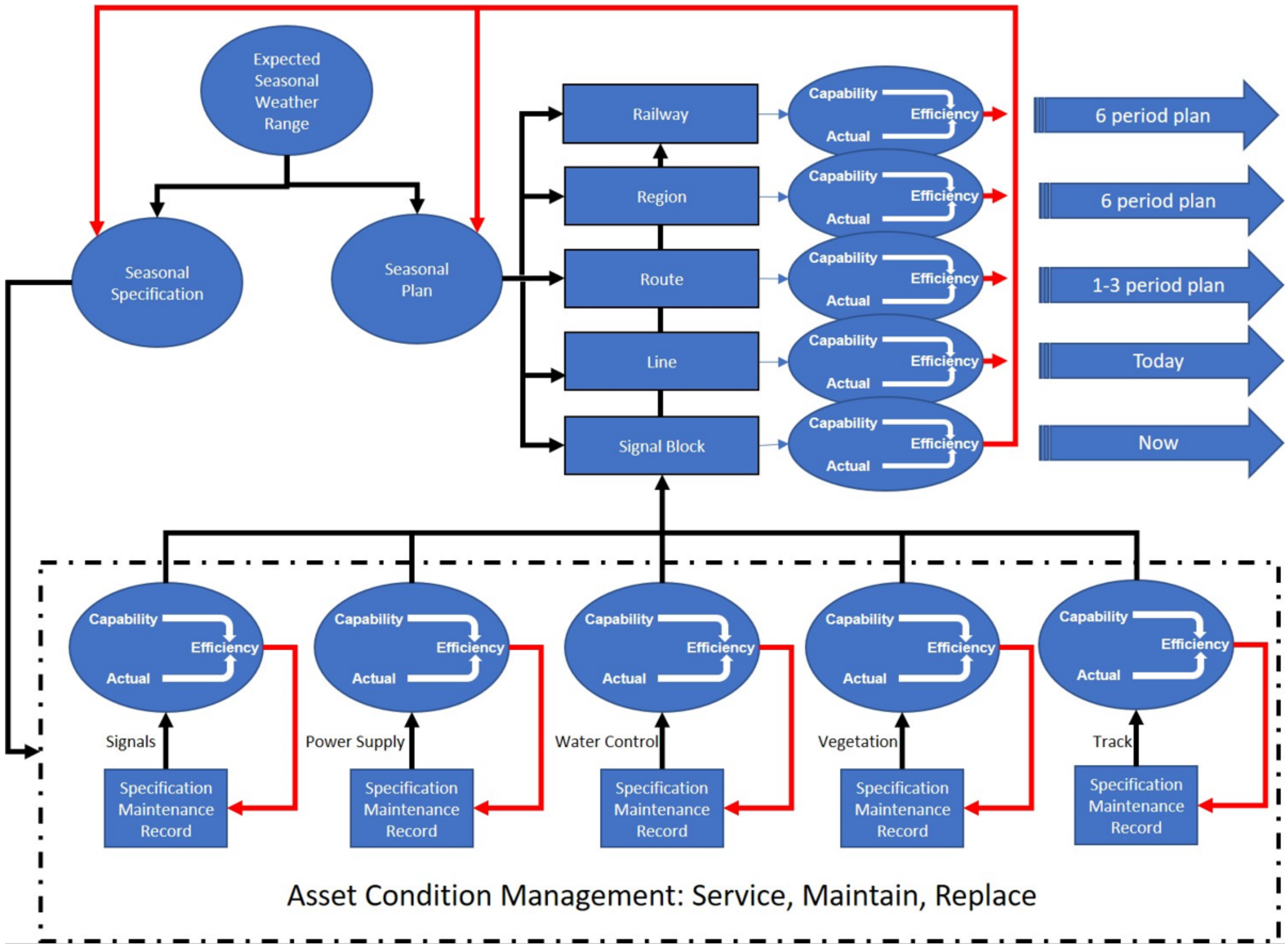

Figure 5: Conceptual Model 3

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

Section 3: Discussion and transferable learnings

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 that have implications for operational safety and performance. The SAR 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, unsystemic;
- 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 similar? organisation.

The utility of the systemic approach rooted in cybernetics is becoming apparent and the ability to embrace the entire 'hard' aspects of the system are proving invaluable as is the idea of structural recursion in which 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 the:

- Design and implementation of new systems;
- User awareness and education;
- Identification structuring and organisation of data;

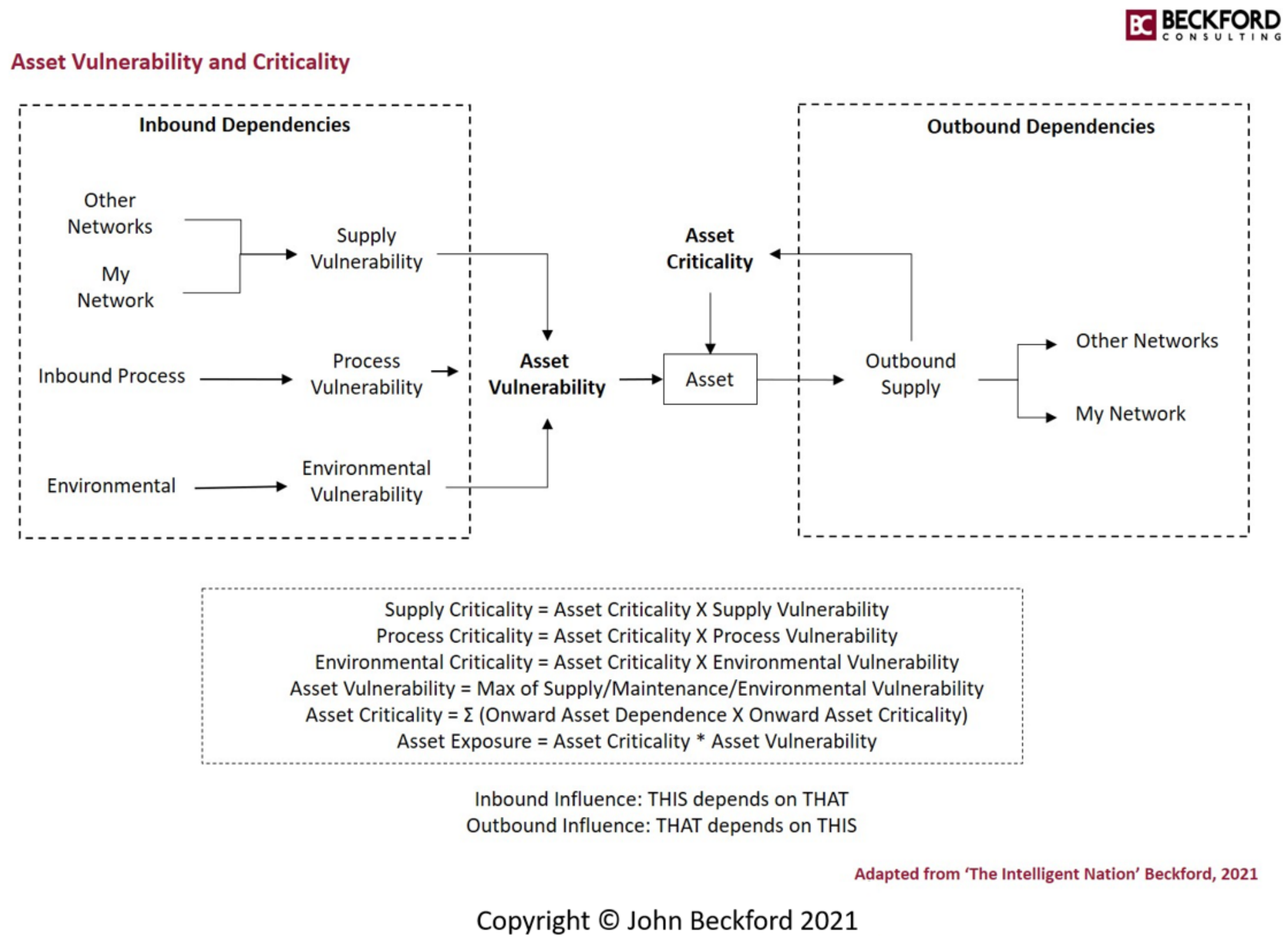

Figure 6: Conceptual Model 4

- 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.

References

Beer, S. 1985 Diagnosing the System for Organisations, Wiley, Chichester, UK
https://beckfordconsulting.com/wp-content/uploads/2014/03/Introducing-VSMethod.pdf

Beckford, J. 2017 Quality: A Critical Introduction, Routledge, UK

Beckford, J. 2021 The Intelligent Nation, Routledge, UK

Beckford, J. 2020 The Intelligent Organisation, Routledge, UK https://www.sciencedirect.com/science/article/pii/S1877705815038631

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