ADAPTING BRITAIN’S RAILWAY SYSTEM TO CLIMATE CHANGE

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Introduction

Britain’s climate is unique, being influenced by the Gulf Stream and by the European land mass: it exhibits extreme variations in climate and weather patterns. In recent years extreme weather and weather variability has caused significant damage and service disruption to the railway and its operations, some weather events including storms late in 2015 being attributed to climate change.

Since 2003 the British railway industry has studied railway systems’ resilience to current and future weather and climate, with specific research projects commissioned including the 2008 RSSB-funded study into impacts on coastal railways http://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue/t643 and in 2011 the wider ranging joint RSSB/ Network Rail ‘Adapting to extreme climate change’ http://www.rssb.co.uk/Pages/research-catalogue/T925.aspx.

The 2011 research provided information on the vulnerabilities of Britain’s railway to projected climate change, and where possible, indications of the degree of change in risks. In many ways it raised more questions than answers; it highlighted the limitations of research and knowledge as constraints to the understanding of the impacts of climate change. These constraints were linked to the availability of scientific and asset management data at the relevant scales for analyses. This research recommended a significant programme of further work to build on the findings and deliver a step change in the knowledge of climate change vulnerabilities, and the development of assessment tools, to improve the resilience of the railway to severe weather and the impact of climate change. This work became the RSSB/ Network Rail ‘Tomorrow’s Railway and Climate Change Adaptation’ (TRaCCA) programme which supports UK Government aims; for improving the resilience of the nation’s infrastructure, adopting a ‘systems thinking’ approach, and reducing the costs of running the railway.

The TRaCCA programme therefore took a ‘whole system’ approach, investigating the dependencies across sub-systems, for example geology/ earthwork/ track/ wheel/ rolling stock/ traction motor/ power transmission/ passengers/ freight/ maintenance activities, and identified crucial external interfaces such as supply chain, energy provision and reliance on the road transport network.

Detail on all the outputs and previous research studies can be found via the UIC/ RSSB ‘SPARK’ web portal http://www.sparkrail.org.

TRaCCA provided a ‘knowledge bank’ of over 470 records on climate change and railways from a world-wide trawl of research and practice; reference sources of these may be found in SPARK.

The work has identified the following key points:

- The impacts of climate variability demonstrate increased value by including socio-economic benefits when carrying out economic appraisal of rail resilience investment;
- The climate in southern Britain in 2080 will be similar to that of France currently; its railway operations are also comparable to those here;
- Britain’s railway is a world leader in terms of managing risks due to climate variability and understanding the vulnerability of our assets – there is ‘no silver bullet’ that can easily increase the resilience of our current railway network;
- Prototype metrics have been proposed, which can be used to assess the resilience of the railway in a systemic way;
- New asset vulnerability tools have been demonstrated;
- Climate change will impact across asset life cycles requiring changes to railway standards and asset policies;
- Infrastructure systems are interdependent requiring a multi-agency response to climate change.
TRaCCA is a world-leading piece of work, which has examined the climate change impacts on the railway system, involving contacts from other parts of the world, and which features in the UK government’s National Adaptation Programme.

Research methodology

The resilience research programme was developed with the understanding that outcomes needed to be relevant to stakeholders, and bridge the link between research and implementation of actions in the rail sector. The programme aimed to maximise the benefits gained from research at the earliest opportunity and set out to allow recommendations to be considered and quickly implemented where appropriate. The programme was divided into two phases, Phase 1 aimed at providing significant increases in knowledge and Phase 2, a series of nine ‘tasks’ investigating economics, ‘System of systems’ concepts, metrics, overseas railways and climates, and ‘Geographical Information Systems’ (GIS). Evaluation exercises were included at the end of each phase to aid governance and manage the programme direction.

The work was contracted to consortia led by ARUP with the following partners:

- Beckford Consulting
- British Geological Survey
- CIRIA
- JBA Consulting
- Met Office
- Transport Research Laboratory
- University College London
- University of Birmingham

RSSB provided the ‘client’ leadership with support from Network Rail and John Dora Consulting.

The project drew upon expertise and knowledge from across the rail industry, railway organisations from across the world (with help from UIC – the International Union of Railways); UK Government departments including HM Treasury, Transport Scotland and the Department for Environment, Fisheries and Rural Affairs; and major infrastructure operators such as the Environment Agency and National Grid.

The tasks brought expertise together in a series of targetted workshop sessions where outputs were drafted, circulated, reviewed, challenged and resolved with a high degree of collaborative effort.

An approach based on consideration of the railway as a ‘System of systems’, was used to pull together the final task outputs. Case studies have been developed to demonstrate the potential value of new approaches; particularly for the economics of climate change adaptation investments, ‘System of systems’ approaches; metrics; and GIS modelling.

Phase 1: Climate and resilience challenges for the railway industry

Phase 1 was structured around five questions:

1. How will UK climate and weather change in the future?
2. What are the impacts of climate change and extreme weather on Great Britain’s railway currently, and how might these change over coming decades?
3. What is Britain’s rail industry doing to respond and adapt to the potential impacts of projected climate change and extreme weather?
4. What else can be done by Britain’s rail industry to respond and adapt to the potential impacts of projected climate change and extreme weather over the short, medium and long term?
5. What additional decision support frameworks, approaches, and tools, does Britain’s rail industry need to take cost-effective action to respond and adapt to the potential impacts of projected climate change and extreme weather?
Phase 1 helped to answer questions 1-3 and partially 4. Phase 2 has been able to tackle questions 4 and 5. The scope and comprehensive coverage of the answers means that they cannot be covered in this paper; full details are in SPARK and examples of the key findings for Q1 to Q4 are included below.

**Q1: How will UK climate and weather change in the future?**

By the 2080s all areas of the UK are projected to become warmer on average, more so in summer than in winter. Increases in the summer mean daily maximum temperature are projected to be up to 5.4ºC in parts of southern England and up to 2.8ºC in parts of northern Britain.

**Q2: What are the impacts of climate change and extreme weather on Great Britain’s railway currently and how might these change over coming decades?**

Network Rail records showed that, between April 2006 and March 2014, there was an average of approximately 1.6M delay minutes a year equating to over £400M of weather-related delay costs during the same period – an average of approximately £50m a year. Delays from weather-related causes result in payments, between Network Rail and train operating companies, as part of the industry regulatory compensation regime.

To quote one example of change, of heat-related rail buckling, several studies were found that quantified the costs and impacts associated with rail buckle risk management. All forecast an increase in numbers of buckles and attendant costs. The magnitude of the projected increases will vary across the UK and will range between a three-fold and ten-fold increase by 2080.

The Phase 1 report lists other rail-related impacts of high temperatures, noted as occurring in the current climate but not quantified in the available literature. Climate change means that these impacts could increase for the railway. Two examples mentioned are the overheating of electrical equipment in lineside cabinets, and an increased heat stress risk for outdoor workers.

The Phase 1 report continues similarly to list impacts due to other weather hazards:

- Increased and decreased precipitation (primarily on earthworks, flood scour at bridges and flooding generally)
- High sea levels and storm surge
- High winds
- Lightning and electrical storms

**Q3: What is Britain’s rail industry doing to respond and adapt to the potential impacts of projected climate change and extreme weather?**

Climate change and extreme weather issues are clearly recognised by the rail industry. They feature in the Technical Strategy Leadership Group (TSLG) Rail Technical Strategy document published in 2012 and in Network Rail’s Route Weather and Climate Change Resilience Plans published in 2014.

Gaps were identified in current design and management procedures, however the programme has influenced priority work in these areas. Summaries of work underway by the industry, or still needed, to address these gaps are highlighted in the reports categorised by the European Technical Specifications for Interoperability sub-system headings.

**Q4: What else can be done to respond and adapt to the potential impacts of projected climate change and extreme weather over the short, medium, and long term**

Over 200 recommendations have been identified to improve resilience of the railway to climate change impacts. These were ‘themed’ and split into short-term recommendations (actioned and/or implemented before the end of Control Period 5 (March 2019); medium-term recommendations - actioned and/or implemented within 5 to 15 years, and long-term recommendations - actioned and/or implemented beyond that.

This is an overview of Phase 1 themed recommendations:
• Develop infrastructure design and maintenance approaches, especially for earthworks;
• Consider lifecycle costing and adaptive pathways approaches, including considering re-routing of key routes;
• Integrate data about assets, weather events and operations to improve predictive modelling and response;
• Improve the industry’s ability to model and predict the impacts of combined and successive weather events;
• Improve the quality and comprehensiveness of asset data and related information, especially for critical or sensitive locations;
• Integrate infrastructure and weather data better, across time and systems;
• Review weather-related operational thresholds and learn from other countries;
• Address the contribution of rolling stock design to climate change resilience of railway as a whole;
• Improve communications about weather events and climate change, throughout the industry;
• Strengthen the integration of historical data about weather events, incidents, impacts and cost.

Phase 2: Learning points

Phase 2 comprised nine tasks and its outputs include the following:

• Recommendations for tools and methods to improve the economic appraisal of climate-change adaptation investments;
• Reviews of GIS-based methods to integrate many of the metrics currently captured by the industry;
• An appraisal of GIS-based climate and weather risk identification tools, graded by their utility for risk management;
• Insights into critical interfaces and dependencies, from the use of ‘System of systems’ methods; these identified areas inside and outside of the railway system such as of train/infrastructure/weather;
• A comparison of places across the globe where today’s climate is similar to that projected for Britain’s railway in the future;
• A compendium of resilience measures from railways abroad;
• Proposals for implementation including changes to policies and standards;
• Proposals for new metrics that permit more robust, accurate analyses of railway system resilience and vulnerability to weather and climate (and potentially other) hazards than current metrics allow;
• A ‘joined-up’ approach for all the above based upon ‘systems thinking’.

Specifics outcomes from Phase 2 Tasks

Task 1: Economic appraisal of climate change adaptation investments

Spending decisions related to adaptation and resilience are not adequately considered in ‘traditional’ transport economic appraisal methodologies. This was found to be because the methodologies fail to capture many of the economic and social costs of transport disruption due to an extreme weather event. Phase 2 proposes an approach to the definition of a baseline for an adaptation strategy, and how to assess what level of intervention is required when both the risks and the rewards costs and benefits of the intervention are uncertain. A future climate change resilience appraisal framework is recommended, based upon the existing comprehensive frameworks within the Department for Transport (DfT) ‘WebTAG’, and HM Treasury ‘Green Book’, guidance.

A case study was prepared to illustrate the advantages of such an approach, taking into account recommendations from Tasks 3, 4 and 5, and described benefits increasing tenfold over the traditional, ‘WebTAG’ approach.

Task 2: Learning from other countries with similar railways and climate
Current overseas climates were compared with the British future climate, and railway organisations with similar characteristics to Britain’s railways identified. Broad-scale analogue countries for the projected British climate in the mid and end of the 21st century were identified as France, Netherlands, Belgium, Germany and Denmark. Only France appears as both a mid-21st century and end-21st century analogue.

Information was sought from overseas railway administrations to establish ‘state of the art’ learning for extreme weather mitigation. This exercise confirmed that Britain’s railway is the most advanced in understanding climate change impacts and that no overseas administration could offer any ‘silver bullet’ that could solve any climate-related hazards.

Three themed ‘fact sheets’ focusing on measures identified for the management of the effects of flooding, heat and winter on the railway have been prepared and are available in SPARK – one example is shown in Figure 1.

**Task 3: Metrics and the rail network**

Workshop activities studied metrics that support the management and adaptation of the rail network with rail and other infrastructure sector organisations present. Task 3 found:

- There are few metrics directly related to helping railways manage weather and climate change, these few focus on flooding and winter weather related issues;
- There seems to be little link between ‘condition’ [of asset, performance etc] and ‘cause’ of the condition;
- Uncertainty associated with long term climate change effects makes it difficult to attribute roles and responsibilities;
- No single organisation can drive the required changes;
- Resilience/ adaptation metrics must be robust for these performance characteristics to be reliable and consistent for the long-term;
- Options for development of an holistic resilience metric proposes some form of ‘journey availability’ metric to satisfy the resilience and reliability requirements. This can be used as the performance requirement against which short- and long-term adaptation activities can be assessed.

**Task 4: Benefits of using ‘Systems thinking’ approaches**

This provided a review of systems-based risk and vulnerability of the railway, ‘mapping’ a system of systems representation of the railway and suggested how the railway can be grouped into a number of sub-systems. The importance of the interactions and interdependencies
between the sub-systems was highlighted, including the different timescales and perspectives and the key external systems that would affect operation of the railway and how they would affect the railway sub-systems.

Figure 2 shows the railway represented as a system of systems with the arrows depicting interdependencies within and outside the overall system:

Task 4 also identified a nested, multi-level model, a ‘universal set’ of participants in the provision of railway services and grouped them according to ‘provision’ or ‘influence’, depicted in Figure 3.

The levels are described thus:

- **Socio-Political**: having reference to the long-term social and/or political value of the ongoing service provision (0-50+ years);
- **Strategic**: having reference to the long-term future provision of the infrastructure necessary to the provision of services (0-30 years);
- **Operational**: having reference to the physical provision of the infrastructure necessary to services (0-5 years);
- **Local/Specific**: having reference to the short to medium term provision of railway services (0-18 months).

This helps to understand how, by acting at their ‘level of influence’, (that is within their legitimate constraints) organisations at each level actively create the performance environment of the next level ‘down’. In terms of capability for adaptation management:

- Action at the level of the formation of transport policy (socio-political) creates the performance environment for action at the level of rail policy (strategic);
- Action at the level of rail policy creates the performance environment for infrastructure provision (operational); and,
- Action at the level of infrastructure provision creates the performance environment for the delivery of rail services (local/specific).

A significant consequence of this is that the participants at any and all levels have no formal control (apart from that over their internal processes) over the environments they are creating for ‘lower level’ organisations. They must, however, interact in such a way as to create a performance environment that prioritises and/or incentivises appropriate behaviours on the part of those organisations.

Task 4 recommends taking a system of systems perspective in developing risk and vulnerability assessment tools, and a case study was prepared to examine power station fuel supply security on this basis.
Task 5: Geographic Information Systems

This task examined the relevance and application of GIS to climate change and extreme weather decision-making. It reviewed existing GIS-based tools for identification and assessment of risk and vulnerability for infrastructure assets. A review of GIS-base hazard and vulnerability assessment tools from railway and other infrastructure organisations was undertaken which was able to categorise the tools on a 1 to 5 scale.

Among the recommendations from Task 5 were the following:

- Short-term benefits can be realised from the application of available weather susceptibility maps for the determination of vulnerable parts of the rail network;
- Such tools can be utilised together with the significant data held by Network Rail, and from failure investigations of asset vulnerability to facilitate failure prediction;
- The railway should be characterised as a system of systems in relation to vulnerability to weather effects and geographical features;
- Data must be compiled and communicated in a consistent way that takes into account the three-dimensional nature and interconnectivity of the railway.

A series of exemplar short, medium and long term goals for decision making using GIS based vulnerability assessments has been compiled.

Conclusions and recommendations

The research has led to a step-change in the understanding of the need for adaptation of Britain’s railway system, based on a robust, wide-ranging and in-depth analyses of climate science and railway data. The project has examined such diverse areas as ‘metrics’, ‘economics’, ‘standards’ and ‘performance thresholds’, all of which are relevant to the study of climate change impacts. The creation of a resource within the ‘SPARK’ portal has allowed easy access to the knowledge gained.

Many recommendations have been made for further study or implementation, the timescales and responsibilities for which will vary. The key conclusions from the programme are:

- The impacts of climate variability demonstrate increased value by including socio-economic benefits when carrying out economic appraisal of rail resilience investment;
- The climate in southern Britain in 2080 will be similar to that of France currently; its railway operations are also comparable to those here;
- Britain’s railway is a world leader in terms of managing risks due to climate variability and understanding the vulnerability of our assets – there is ‘no silver bullet’ that can easily increase the resilience of our current railway network;
- Prototype metrics have been proposed, which can be used to assess the resilience of the railway in a systemic way;
- New asset vulnerability tools have been demonstrated;
- Climate change will impact across asset life cycles requiring changes to railway standards and asset policies;
- Infrastructure systems are interdependent requiring a multi-agency response to climate change.

Looking forward, it is anticipated that the rail industry will work with Government, Academia and the UK Research Councils in order to progress the far-reaching recommendations from this work. This in turn will bring the learning into policy and practice, the aspiration being that such that Britain’s railway system becomes adapted to the future climate via a long-term, evidence-based investment programme.