1 Executive Summary

The railway industry faces many challenges both in the short and longer term. Looking into the future, socio-economic changes are expected to present particular challenges\(^1\). The industry has to balance the network's immediate needs against its medium to long-term requirements to ensure that it can continue to function reliably and safely as well as addressing the public and political expectation for increased capacity on a network that is at its limit.

For some years, however, the annual budgeting cycles and the fragmented nature of the industry has hampered strategic thinking. Decades of under funding and the significant changes that have occurred over the past few years, have left the companies working within the industry, and Network Rail in particular, busy trying to address the many challenges to maintaining and running the network cost-effectively today. There are also severe resource constraints and cost cutting pressures imposed due to having to play 'catch up' and bear down on the recent years’ cost escalations. Therefore, currently there is little time or resource available to look beyond the short to medium-term in spite of the fact that there is a strong realisation that unless the industry adopts more systematic strategies that align short and long term imperatives it will invariably keep returning to inefficient ways of operating.

The challenge for the railway sector will be to manage climate change threats in an optimal way within the context of these other drivers, improving their capability to respond to extreme weather events in the short to medium term and building appropriate levels of resilience into the asset base for the longer term.

A number of extreme weather initiatives have been and are being implemented. In Network Rail (responsible for managing the infrastructure), these are in general aimed at achieving improved weather forecasting and a faster reaction to extreme events through the implementation of operational and emergency responses. There are also examples of longer term asset based responses, for example taking the opportunity to install enhanced drainage whilst other planned track or civils related renewals or replacement works are being carried out. Network Rail (NR) has recently created the posts of Extreme Weather Mitigation Engineer and has had a Weather Strategy team in place since 2004, providing a mechanism for raising climate change impacts to the NR Civil Engineer, Chief Engineer and Director of Operations. This provides a reporting line to the board as well as to the

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\(^1\) Examples of socio-economic variables to consider include: additional housing requirements in the south-east increasing demand on routes already running near capacity; the flexible and changing work patterns’ effect on travel patterns; home working changing the peak travel demand; increases in passenger numbers due to increased UK tourism; de-urbanisation leading to shifts in population; and the impact of congestion charging and tolls on the motorway network pushing more freight on to rail.
regulator (ORR) at future Periodic Review negotiations. However, in general there is no systematic consideration of climate change in business decision-making, nor do current investment processes, or engineering or railway standards support this.

The DfT/SRA (now solely under the control of DfT) and the ORR (and to some extent TfL and the PTEs) are now the main drivers for shaping the railway industry as part of a more integrated and systematic ‘publicly specified, privately operated and maintained’ railway. While the heavily regulated nature of the industry may be seen to introduce barriers to innovation and effective response to climate change, there are levers in place to make change happen - if regulators ask for it, then it will be provided (for a price). However, given the more pressing need to enhance network capacity and improve reliability at present levels of public investment there is currently little regulatory pressure to address climate risks in the longer term. Until this changes, adaptation is likely to be confined to areas already experiencing problems. This may lead to sub-optimal decision-making over the longer term.

While it may be too early for the Railway industry to take adaptive actions in most cases, the decision not to take action should be a positive one, based on a proper understanding of the risks, rather than a default position arrived at through lack of consideration. The consequences of doing nothing or delaying planning and adaptation to the impacts of climate change may include:

- Insidious decline in performance and reliability
- Increased costs (emergency repair costs are generally ten times higher than planned maintenance costs)
- Permanent loss of network in particularly vulnerable areas
- Increased risk of sudden failures and consequent safety impacts
- Loss of reputation and public confidence
- Failure to meet PSA targets (DfT)

Taking action too early however risks over, or inappropriate, adaptation. The railway industry needs to be able to optimise its plans for maintaining and improving safety and performance in the light of the predicted climate changes, permitting future review in the light of new data.

A key concept developed by UKCIP is ‘adaptive capacity’. This is the ability of an organisation to adapt to the variety of circumstances it might face in the future – tackling its current weaknesses and building on its perceived strengths. Building adaptive capacity is a way for organisations to safeguard themselves against major uncertainty, and could involve developing skills, reviewing decision-making systems and processes, and increasing organisational flexibility.

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*Note: This case study was carried out between December 2004 and August 2005 during a period when the railway industry was undergoing substantial changes.*
This research suggests that the key areas that need to be addressed to build adaptive capacity in the railway sector are:

**Raising Awareness:**
Leadership and better incentives are needed to drive awareness of the issues throughout the sector. However, given the public nature of large parts of the industry this could only occur if there is a clear steer from the Government. Given both the private and the quasi commercial nature of the industry, there also needs to be clear definition of responsibilities for addressing climate change impacts (i.e. defined separately for Network Rail, the Train Operating Companies, Defra, UKCIP and others such as ODPM and the Treasury to address, for example, capacity and transport planning).

**Data, models and methods:**
At present there is insufficient knowledge to fully quantify the effects of climate change (negative or positive) on business performance. Data needs to be collected in a format that supports development of this knowledge including improved data on the condition of assets, passenger demand, their deterioration with use and weather, and the impact of this on performance.

Climate change data needs to be expressed probabilistically (UKCIP currently has work underway to do this) and provided in a format that can be used by those who have to develop project business cases and maintain corporate risk registers.

There needs to be encouragement to carry out research and to integrate findings – particularly to develop a long term systems based model of the infrastructure and the impacts of weather climate change into the future.

**Systems, structures, people and processes**
NR and industry stakeholders need to identify the important information/triggers for action, critical thresholds etc.

Relevant national, European and international standards need to be reviewed and updated to make reference to the challenges presented by climate change and provide explicit guidance to the designer, builder or maintainer. We understand that UKCIP has started working with professional institutions to address this.

Climate change considerations should be embedded in routine risk management and decision-making processes to ensure, among other things, that opportunities to build resilience at marginal cost (win wins) are identified.

The current investment case methodology and decision structures need to be re-evaluated to ensure that the impacts of very long-term, less tangible, uncertain or social benefits can be assessed realistically alongside more short term costs and benefits.

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3 Including the Railway Group and the Network Rail Line standards, particularly those that principally address the civils, the permanent way and the rolling stock assets.
2 Introduction

This case study report is structured as follows:

- Description of the Railway Sector:
  - What characterises the sector; the market forces and supply networks etc,
  - What are the Key Success Factors (KSFs) for this sectors and key socio-economic drivers
- How might climate change impact on the sector
- What decisions structures are adopted by the sector, how do these impact their ability to adapt to the above impacts and their willingness to plan for adaptation, and
- How can the sector improve and build capacity for adaptation; what do others need to do to support this.

3 Approach

The project has used proven risk and business analysis techniques to build up a rich picture of the impacts of climate change, possible adaptations, willingness and ability to adapt, and barriers and incentives to adaptation in two case study business sectors: transport and major food retailing and their supply networks. Information has been gathered through interview and literature review, and a railway sector case study workshop on 13 May 2005. In the workshop we explored how the sector, with the support of policy makers can address the risks from extreme weather and build on its current strengths to improve its adaptive capacity.

The study examines how the railway industry could build capacity in the broadest sense and not at solutions to specific technical issues. We have also concentrated on issues that the industry can tackle directly with their suppliers not externalities such as the loss of the national grid due to extreme weather over which they exert little control and that would impact every business in the UK. Managers, however, need to be aware of these risks and have responses in place to mitigate them as appropriate.

3.1 Selection of Case Studies

The rail industry was selected because it:

- Has a big influence on the UK economy and patterns of societal interaction,
- Is highly influenced by the weather, and
- Has not been addressed in previous work.

The railway industry is asset intensive, safety critical, heavily regulated and subsidised. It is dependent on fixed location infrastructure with some assets having lives of more than 150 years. Specialised rolling stock are designed and manufactured to ride across specific parts
of the network. We expect lessons learned here will be relevant to other asset intensive regulated industries such as telecoms, water, electricity and gas.

4 The Sector

4.1 Key Industry Characteristics

The railway industry is an asset intensive industry, regulated until recently by the Strategic Rail Authority (SRA) for train operators and the Office of the Rail Regulator (ORR) for the infrastructure provider, Network Rail (NR). It is funded both by passenger fares and freight customers, and primarily by public subsidy provided at national level. Figure 1 illustrates the key influences, including the financial flows, within the railway industry.

Figure 1: General Structure of the Railway Industry

(Financial Flows and Influences)

Although the main railway industry organisations are private companies, they are heavily regulated, and government policy towards the industry as well as levels of finance provided

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4 This case study has to be read in consideration of forthcoming and fundamental structural and organisational changes that are about to be implemented within the industry. These are described in Section 4.2 below.
by government to support infrastructure investment or subsidise passenger services, are very influential in determining the behaviour of railway companies. In particular, to date the SRA has incentivised TOCs through the terms of their franchises, and the ORR carries out a periodic funding review every five years to determine the level of public finance and investment requirements for NR (the next review period starts in 2006 and negotiations are currently underway).

Railway Group Standards, developed and maintained by the Rail Safety & Standards Board (RSSB) are also important drivers of behaviour within the railway industry. All Railway Group members (TOCs, NR, ROSCOs, train manufacturers, equipment suppliers and maintainers etc) are required to comply with these standards, which are aimed at ensuring safety is maintained across the industry, but also influence many other aspects of operations.

Franchise terms and conditions strongly influence the way in which TOCs think about long-term planning. At present the SRA’s strategy is to limit future franchises to 7 years, with the option for a further 3 if the franchisee performs well, so any franchisee must make a return on investments over this period. Since the expected life of new rolling stock is 30-40 years, franchise holders need to be sure that any residual life of the rolling stock remaining after the end of their franchise is properly accounted for when the franchise ends, to ensure they can get an appropriate return for the investment they have made.

For NR, their key task is managing the infrastructure assets, against a range of potential risks of which climate change is one. At present climate change is not one of their key operational or strategic priorities.

4.2 Forthcoming Changes

In 2004, the Secretary of State for Transport presented a White Paper to ‘enable the railway industry to deliver the services required by customers by looking again at the regulation of safety and progress made in improving performance and controlling costs’. The proposed changes in the regulatory system will take a few more months to implement fully. These changes include:

- The Department for Transport (DfT) is taking direct charge of shaping the strategy for the industry, setting its outputs and determining the overall level of public funding,
- The abolition of the Strategic Rail Authority (SRA),

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5 The sector is both heavily regulated and subsidised and the existence of two such constraints underlines the need for integrated policy making by different parts of government; central, local and European.

6 Rolling stock leasing companies

7 For example First Great Western consider that longer franchise lengths would encourage them to invest in new rolling stock immediately, whereas the current system means they will extend the life of existing trains for as long as possible. However, the DfT do not agree with this. Its view is that rolling stock design and innovation should not be individual TOC business model driven, as this will not ensure it meets system-wide requirements – see below.

8 These outputs will be based on the Secretary of State’s high-level output requirements for the infrastructure, passenger and freight train services.
The transfer of the SRA’s strategic responsibilities and financial obligations to the DfT and other bodies, including its roles in awarding Train Operating Companies’ (TOC) franchise agreements and monitoring performance under them,

New regulatory and contractual arrangements between the DfT and NR; it being given overall responsibility for the performance of the network, including leading industry planning, setting timetables and directing service recovery from disruption,

The reduction in the number of TOC franchises and their closer alignment with NR’s regional structure to encourage joint working between NR and the TOCs at a local level,

More decision-making being passed down to Passenger Transport Executives (PTEs) and devolved administrations, including the Mayor of London, who will have an increased role in relation to rail services in Greater London through Transport for London (TfL),

A greater role for community rail partnerships in improving the management of rural branch lines, and

The transfer of responsibility for regulating rail safety from the HSE to the Office of Rail Regulation (ORR), which will retain responsibility for independent economic regulation. The ORR will operate a new process that takes into account funding limits and outputs set by the DfT, and will take over responsibility for rail safety regulation from the HSE.

The white paper also proposes that NR should take on certain additional responsibilities including:

- Drawing up route utilization strategies for approval by the DfT,
- Devising efficient and clear timetables,
- Directing overall network operations and getting services back to normal after incidents and delays, and
- Improving the operational performance of the network.

The various structural elements and regulatory regime for the railway industry are described in more detail below.

### 4.3 Policy and Regulation

#### 4.3.1 Health and Safety Commission/Health and Safety Executive

The HSC/E is the regulatory authority for health and safety on the railways: within the HSC/E the framework of safety legislation is currently enforced by Her Majesty’s Railways Inspectorate (HMRI). Train operators and NR must have a railways safety case, approved by the HSE that sets out how they will operate their trains, stations, track and civils infrastructures, signal and depots.

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9 Certain aspects of its role may be transferred to Transport for London (TfL), the ORR or NR

10 N.B. responsibility for regulating rail safety will be transferring from the HSE to the ORR
4.3.2 The Office of Rail Regulation

The ORR is the independent economic regulator of the monopoly and dominant elements of the rail industry. Its principal function is to regulate the operation of the rail infrastructure by NR. With reference to TOCs, it is primarily responsible for granting licences (without which they cannot operate), for setting licence conditions and for enforcing some of them11. The ORR is responsible for approving or directing the terms of contracts granting access to stations, depots and track. Track access agreements establish rights regarding among other things the number and frequency of trains that can be operated and the stops that they can make. The ORR is also responsible for amending and enforcing the Network Code, which is the central commercial code for the railway industry.

The direct grants for NR, currently determined by the ORR, now will come straight from DfT.

4.3.3 The Strategic Rail Authority

The SRA’s (read DfT) main role is to provide strategic direction for the railways. It is subject to directions and guidance from the DfT and its statutory obligations cover among other things, negotiating and awarding TOCs’ franchises, including specifying the services to be provided by them, and monitoring their subsequent performance.

Proposed services within the Greater London area are also subject to directions and guidance to the SRA from the Mayor in association with TfL.

The SRA’s regulatory functions are focused on enforcing the TOCs’ passenger and station licences. The SRA is responsible for setting service levels and quality of service standards (where appropriate in conjunction with relevant PTEs and, in Scotland, with the Scottish Executive).

The SRA manages the bidding process, consults other parts of the industry and stakeholders where necessary, evaluates the bids, selects the franchisee and negotiates details of the franchise agreement. Once the franchise is let, the SRA is responsible for monitoring performance and ensuring the delivery of franchise commitments. In the event of persistent poor performance, the SRA can require the TOC to implement remedial programmes. Ultimately the franchisee may be in default under the franchise agreement and the SRA can withdraw the franchise.

The SRA also regulates certain rail fares through the TOCs’ franchise agreements but the TOCs are free to set any unregulated fares according to normal commercial considerations.

The DfT works on a three year spending review period, in line with other government departments and this is much shorter than the industry’s planning horizon. However, the DfT does have other longer term funding guidelines that give the industry an indication of the levels of investment planned for transport, including specific sums for rail, over a ten year period. For example, the ten year plan for transport, published in 2000, set out long-

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11 Presently, the SRA also enforces the consumer protection conditions of the licences. The ORR is responsible for enforcing the TOCs’ passenger and station licences.
term funding guidelines up to the year 2010/11\textsuperscript{12}. In the Spending Review 2004 these amounts were increased by £0.5bn per annum. The details are set out in Annex A of the DfT publication “The Future of Transport, a network for 2030”.

**Rail Franchising**

The first-generation rail franchises were intended to create business opportunities for franchisees to exploit, subject to regulation and an obligation not to let services fall below specified base levels. Franchisees were free to add extra services above these base levels. In 2002 the SRA issued a Franchising Policy Statement\textsuperscript{13}, recognising that although the first round franchising had contributed to passenger growth, investment and stronger marketing, they had not delivered all of the outcomes expected at privatisation. They had also failed to provide the franchisees with incentives to improve their quality of service. Moreover, the expected cost reductions had not been achieved and franchisees had been unable to withstand financial shocks caused by external factors. At the same time, the SRA had carried out a review of capacity utilisation strategy that identified benefits from combining franchises into larger units.

The SRA’s new approach was to specify service levels and quality standards more precisely than before and then expect operators to deliver them. The new franchise agreements thus identify both the criteria for rewarding a successful franchisee and the penalties for poor performance, focusing franchisees on delivering reliable performance, meeting passenger needs and constraining short- and long-term cost increases.

The new franchise model is more prescriptive and places more emphasis on defining outputs that must be achieved. The SRA consider that risks should be allocated in ways that enable franchisees to bear them over the life of the franchise. The new franchises therefore reduce the franchisees’ vulnerability to external factors through revenue support and revenue share arrangements. The franchise agreements now last for seven years, and the SRA is obliged to offer a three-year extension if key performance targets are met – but during this time it cannot pay dividends when financial targets are not met, except with the SRA’s prior consent. However, incentives are included to reward projects with a payback period longer than the franchise term.

This approach does not leave much scope for individual innovation by TOCs in areas such as rolling stock design. It is intended that future rolling stock requirements, design, specification and procurement strategies have to be whole-life based and have a more system wide perspective, relying on available technology, with built-in obsolescence and modularity.

\textsuperscript{12} http://www.dft.gov.uk/stellent/groups/dft_about/documents/page/dft_about_503944-15.hcsp#P1073_156276

\textsuperscript{13} Under the first-generation franchise agreements, the level of service provided by a TOC had to fulfil a passenger service requirement specified by the SRA. This specified a minimum level of service and maximum journey times. It was then free to add additional services subject to its ability to obtain train paths for the services from NR. This was/is particularly difficult through congested sections of the network. In the second generation, the SRA specifies in detail the precise level of service that the franchisee must provide in a ‘service level commitment’. It may only operate a service level below that specified in its service level commitment with the approval of the SRA. It may operate a service level above this with the SRA’s approval.
4.4 The Train Operating Companies (TOCs)

The TOCs are also private companies, and are profit-driven organisations. They lease their rolling stock from the three UK Rolling Stock Companies (ROSCOs). Some, such as Virgin, have procured their vehicles directly from manufacturers, using different and very specific business/franchise models.

The SRA requires TOCs to prepare a train plan showing the proposed allocation of its train fleet to meet service level commitments. The TOC has to prepare a plan that meets target passenger demand, minimises the need to stand for more than 20 minutes after boarding a peak service, and reduces overcrowding.

The franchise agreements set key performance indicators that measure a TOC’s performance in areas important to passengers. The performance regimes are enforcement-based, setting minimum targets that the TOC has to achieve (e.g. financial rewards and penalties for punctuality, short train formations and timetable changes, plus cancellations, capacity and service delivery). Other aspects of performance (e.g. quality standards for train condition, station environment, information provision, security and ticket sales) may be subject to a service quality regime, measuring the TOC’s performance against benchmarks for key performance indicators in the franchise agreement. If the TOC’s performance against these benchmarks falls into certain defined bands, incentive payments or penalties are made.

The TOC is given very little flexibility about the services it is expected to operate. Its freedom of action in reducing services is constrained by the service level commitment. It is in theory free to add additional trains, however, given that the network is almost operating at capacity there is little scope for this in practice, particularly in the South-east and the Priority A Routes.

The TOCs are now indemnified by the SRA against increases in NR’s access charges that result from any review by the ORR and for certain other external cost changes. The SRA also contain the TOC’s level of revenue risk by including revenue and risk sharing arrangements for the later years of the franchise. The SRA now adjusts franchise subsidy/premium payments to reflect any changes in required outputs, for example service changes.

4.5 Network Rail

NR operates, maintains and renews the infrastructure, including track, signalling, bridges, tunnels and depots under a network licence. Its responsibilities include: control of the

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14 The routes on the national rail network are classified by the ORR and DfT as being Policy A, B or C Routes (A=primary/South-East, B= freight and C=rural). The Secretary of State (SoS) for transport produces his high-level output requirements for the railway network which the ORR then translates into a total investment picture to tell the SoS what level of service he can expect for the public investment. The ORR will use cost and performance data from previous years and established treasury VfM criteria. Once the investment figure is agreed, NR’s asset management strategy will then assume specific obligations and requirements in respect to each of the three different types of national route. What NR cannot do is to change the overall mix of what is spent on what type of route. The decision regarding the appropriate mix between high-speed commuter, freight and rural services is entirely a political one.
network, which includes operational functions; remote control and communications; train traffic; control and monitoring of signalling; traction power equipment; electro-mechanical equipment; passenger information display system; security; timetable production and all associated safety requirements.

Franchisees must enter into track access arrangements with NR under a regime regulated by the ORR. NR also owns the railway stations in the national rail network and directly operates 17 of the major stations, including the London termini other than St Pancras.

Maintenance and renewal account for more than half of NR’s spending on the network. If they do not maintain and renew the infrastructure effectively, there is a risk of serious delays and cancellations to trains, a poor or potentially unsafe service to rail users, and increased costs in the future to make good deterioration in the condition of the assets.

Ensuring the safety of those who use or work on the railways is a key concern (also for those responsible for regulating rail services). NR is responsible for the safety of their operations and for overseeing the safety operations of others who work on the railways, such as contractors and train operators. Although the HSC/E currently have prime responsibility for regulating H&S on the railway, the ORR have a statutory duty to take into account the need for safety and the advice of the HSE.

NR’s network is made up of four main types of asset: track; structures, such as bridges and tunnels; stations; and signalling equipment. The quality of information on the condition of these assets is improving (from a poor state of knowledge before privatisation).

NR is a private company but it is not required to make a profit, only to meet its costs. It is overseen by its Members, who represent the same influence over the company as shareholders would, were it still a Plc. Its objectives as an organisation are to deliver a safe and reliable rail network. It is given considerable direct and indirect government funding (a total of £4.5bn last year) to invest in maintaining, improving and enhancing the rail network. It is currently faced with a major investment backlog and having to bear down significantly on cost escalations. This is a major constraint which means it has to devote a large part of its resources and effort to managing its assets for short-term performance whilst ensuring safety and controlling costs. This strategy may be at the expense of the longer-term aspirations of enhancing the network by building additional capacity or being able to make a robust case that investing in long-term climate change adaptation projects is a wise use of scarce resources.

Public subsidies contribute significantly to the income of the railway industry and NR. Through subsidies from central and local government, to train operators, the tax payer can be considered to be the indirect source of a significant proportion of NR’s income. The train operators’ other sources of income come from passenger and freight revenue. They in turn pay access charges to NR. This constitutes NR’s main source of income, the remainder being made up by activities such as property management and facilities leasing, particularly in and around stations.
Because NR’s revenue comes from selling train paths to train operators, it has some incentive to increase availability of train paths/capacity but there is currently estimated to be only another 10-15% additional capacity left to be squeezed out of the network.

**Developing Business Cases within NR**

NR’s current focus is on small scale renewals of assets based on their condition, rather than on larger scale renewals of groups of assets according to their age. If infrastructure asset or operations managers think that there is a requirement to do certain pieces of work on the network, in each instance they have to make a ‘case’ for such project investment by developing a business case for investment. There are established processes and procedures for developing and proposing a business case.

The stimulus for NR’s investment decisions is often concerns about safety, capability, the condition of assets, and the future performance of the business if investment does not take place. Investment requirements are considered according to the particular asset condition and the line performance that needs to be addressed - not by making a case across the whole network. The actual basis for the investment decision may be to replace an asset; save operational costs; achieve expansion or growth; or a reactive investment in response to a particular safety risk or reliability problem.

The key parameters and uncertainties built into an investment case are asset condition against thresholds, current and future performance (e.g. expressed in terms of delay minutes and penalties), capital and operational expenditure estimates, payback periods, internal rates of return/discount rates and safety/performance benefits. However, often information (e.g. on assets’ deterioration with use and weather and the impact on performance) is not good enough to allow NR to adopt a robust case without running the risk of unexpected failures of equipment or assets in service, or a decline in the long-term health of the network. Performance is costed differently depending on whether the route in question is a Priority A, B or C route, according to DfT/ORR classification. Consequently, calculating delay times suffered by passengers in a way that allows all causes to be attributed and analysed in a consistent way across the system is difficult in spite of the fact that NR is a very data rich organisation.

An important influence on NR is the discount rate that is used to justify investment. This is currently set at around 6% - down from 8% during the Railtrack era - making it difficult to make the case for long-term benefits of asset renewal decisions. In contrast Defra – based on Treasury guidance recommends a rate of 2.5% reducing to 2.0% then to zero for

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15 Despite warnings, the planning departments of many of the councils in England and Wales have allowed properties to be built in flood hazard areas. During 2003, there were 600 developments, mostly residential, many major, permitted on flood plains in England and Wales against the advice of the Environment Agency. The UK government is also proceeding with developments in the Thames Gateway on the edge of London where the housing density will be as high as 200 dwellings per hectare in places. The current plans by the Office of the Deputy Prime Minister (ODPM) for housing developments, particularly in the south east, are entirely at odds with what can actually be provided realistically by the rail network. Therefore, socio-economic changes are the principal, long-term driver of economic damages from severe weather and also important in determining the range and effectiveness of risk management activities.

16 What is less clear is if changes driven through the need to adapt to the impacts of climate change should be seen as renewals or enhancements i.e. should NR maintain the network to 1993 levels/weather assumptions with anything over and above being regarded as an enhancement?
public investment in long-lived structures such as flood defences, especially where there are wider social benefits to be taken into account.

Critical to any project evaluation is the identification of the risks that will affect it. NR (and the sector as whole) tends to manage risks from climate differently from other risks. When we conducted our initial case study interviews, the task was generally assigned to climate or environmental specialists, while staff elsewhere in the organisation managed operational, financial, and safety etc risks. NR have now appointed an Extreme Weather Mitigation Engineer to cut across these ‘silos’ and improve risk management.

NR's Asset Management

NR makes use of whole life costing principles and is charged with maintaining and renewing the infrastructure in a condition that existed in 1994. It has processes (e.g. the Company Standards) and systems (e.g. asset condition databases) that aid its asset management activities. Any addition to the asset base is an ‘enhancement’.

Civil Engineering has developed the Structures Annual Cost Profile (SACP) tool to carry out whole life costing of its assets. Using this it estimated a “bow wave” of funding for the 2004-2009 Control Period which was authorised by the ORR giving an annual budget of approximately £330 million. This recognises a need to bring its civils assets up to standard after which the costs would revert to a lower, ‘steady state’ figure.

What NR aims to do is to look beyond the next 20 years and ask what the weather conditions are likely to be and what it should be doing about it now (e.g. implement changes to its design and asset management standards).

In the medium term, it probably would not be too costly or onerous to make provision for extreme weather in assumptions that affect NR’s shorter lived assets (e.g. the signalling and track that have to be replaced over the next 15 years). These could be upgraded or renewed as they become life expired with updated extreme weather requirements being built into their design. An example of this type of provision being made now includes the inclusion of additional drainage capacity/larger diameter channels into track drainage systems when drainage renewals work are carried out. This is to allow for increased future volumes and rates of rainfall in the winter. However, there is a realisation within NR that changes should be made in an integrated way, and not in isolation, because there is a risk that a change in one asset discipline may have unforeseen knock on effects if a systematic perspective is not adopted.

A greater challenge is finding cost effective ways of building weather resilience (ensuring that the requirements are sustainable and allow the system to be upgraded in time) into very long lived assets (i.e. 50 years plus).

The Dawlish Case Study

Source: Peter Haigh, Structures Maintenance Engineer for the South-west region.

The Dawlish sea wall was built in the 1840s using techniques and methods which were appropriate at the time. The structure requires frequent attention to ensure its fitness for purpose for its current usage and demand. The line is partly in tunnel where there is sufficient headland.

This stretch of line is a Primary Route and an intensively used part of the network, passenger train companies include First Great Western, Virgin Trains and South West Trains, and there is a significant amount freight consisting of china clay, paper and nuclear fuel rods.
The structures, track, signalling and trains using the railway are susceptible to the following weather-related hazards:

- Sea spray, which can obscure signals;
- Waves, which can flood the track and cause impact damage both to the wall and to trains;
- Sand movements which can lead to erosion of the wall’s foundations;
- Persistent and heavy rainfall leads to groundwater percolation through the cliff face and through fissures causing hydrostatic pressure to build up behind the wall and can also make the cliffs prone to rock-fall;
- Salt water damaging signalling equipment;

Rail buckle risk is not of high concern because of sea breezes and the sheltered nature of the location.

There has been an estimated 450mm rise in sea levels since the wall was built. Presently about every 10 years there is a major disruption to the line caused by storms. Current predictions are that the sea level rise will accelerate and disruptions will become more frequent.

To ensure the continued safety of the line, there is a comprehensive inspection and reactive maintenance regime procedure in place. Emergency preparedness plans overlay the routine regimes in times of storm.

Network Rail’s routine works at Dawlish are justified on the basis of safety and performance and amount to £500k/year. This sum covers the whole of the Exe and Teign estuaries and the sea wall portion between Dawlish and Teignmuth. This is a dedicated maintenance budget for ongoing safety & operational requirements.

Examples of options available to NR for managing these coastal and estuarine defences assets are:

- Do nothing;
- Carry on as now but realising that there is an increasing investment requirement and the expectation of more disruptions over time;
- Rebuild the wall to more robust current standards;
- Reroute the line.

The last option is not one that Network Rail can progress itself, but the others are possibilities.

5 Industry Key Success Factors

The key success factors that climate change may affect differ according to which part of the industry is considered. However, taking the railway industry as a whole the overall key success factors can be summarised as follows:

- Punctuality/reducing train delays
- Train availability/reducing train cancellations
- Customer satisfaction (e.g. in regard to trains, stations, ticketing, ambience and other measures of quality)
- Safety and security (on trains and stations, for passengers and staff)
- Ride quality

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17 i.e. Those specific outcomes that the organisation must strive to get right, first time and every time.
• Profitability (primarily driven by keeping costs down and encouraging more passengers),
• Network capacity for passengers and freight – N.B. this is not mutually exclusive (achieved either through building new track, extending train and existing platform lengths, or optimising timetables)
• Asset management (for some types of assets, asset condition can deteriorate considerably and insidiously before performance is affected)

6 Climate Change Impacts

6.1 The Changing Climate

According to UKCIP, over the coming century it expects that in the UK:
• Temperatures will increase
• Winter rainfall will get heavier
• Summer rainfall may reduce considerably
• Sea levels will rise.

As well as changes in seasonal average climate, there will be changes in extremes, such as very hot days and intense downpours of rain. There may also be more storms, and possibly more violent storms crossing the UK, although there is still uncertainty about their frequency of occurrence. Extreme events are by definition rare, but they often have the most significant impacts and any changes in extremes have the potential to increase damage at the margins. They are also difficult to predict, so information on future climate extremes is still largely uncertain.

Climate varies naturally too – at any given point in time these natural variations could add to or act against the climate change effect.

In order to identify the impacts it is important to consider:
• Average climate, such as seasonal temperature and rainfall,
• The effects of extreme weather, such as heavy rainfall, coastal flooding, droughts, very hot days, and freak storms,
• The effects of combinations of variables, and
• Whether there are critical thresholds in a system that may be exceeded as climate changes, causing significant impacts.

We have identified the following threats and opportunities resulting from the impacts of climate change on the railway industry that could influence whether or not the key success factors listed in Section 5 are attainable.
6.2 Threats

Annually, ‘normal’ weather causes disruption to the railway because of its exposed nature. Extreme weather, however, causes severe disruptions. In the past, prolonged hot spells have required speed restrictions to be imposed; high winds have led to speed restrictions being imposed on lines with overhead line equipment (OHLE) and to the risk of debris and trees being blown on to the line. Rainfall has led to earthwork instability, to flooding and bridge foundations being undermined. Storms have caused breaches in the coastal defences owned by NR\textsuperscript{18}.

One or two extreme events tend to occur every year and these can cost the network significant sums. For example, the Ffestiniog to Llandudno junction line in central Wales has been lost twice to floods in the last decade; each time requiring over six weeks to reconstruct it. On the last occasion, areas that had been rebuilt withstood the floods. NR has also experienced similar events in Scotland – in 2002, causing about £20 million in delay costs and in engineering works after the event. The ‘at risk’ areas are to be identified and solutions put in place when appropriate.

The table below is based on research carried out for RSSB\textsuperscript{19} and gives a list of the types of infrastructure that are particularly vulnerable to extreme weather.

<table>
<thead>
<tr>
<th>Infrastructure Type/Asset Feature</th>
<th>Extreme Weather or Climate Change Event and Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures and earthworks (lineside and adjacent to watercourses)</td>
<td>Extreme precipitation (also links to vegetation) leading to soil instability, slips and scour and flood risk. It could also result in risk of track circuit failures.</td>
</tr>
</tbody>
</table>
| Vegetation | Changes in temperature and precipitation patterns leading to fallen leaves, particularly wet leaves in autumn, and shallow slope instability.  
Warmer and wetter summers may lead to increased vegetation and more difficult autumn leaf fall season, risking service disruption and safety. |
| Track | Extreme temperatures - these could be defined by the air temperature (for example the current intervention levels for imposing speed restrictions because of the risk from high rail temperatures). Large temperature ranges lead to higher risk of rail buckling and fractured rail lines. |

\textsuperscript{18} See the Dawlish sea defences case study

\textsuperscript{19} Safety Implications of Weather, Climate and Climate Change AEAT/RAIR/76148/R03/005
<table>
<thead>
<tr>
<th>Infrastructure Type/Asset Feature</th>
<th>Extreme Weather or Climate Change Event and Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage</td>
<td>Extreme precipitation - this could be defined both by considering a value by which rainfall exceeds the average over a comparatively long period (for example 30 days) to help manage the impact on earthworks, and by incidents where severe disruption has been caused by flash flooding. Other impacts include increased requirements to dewater tunnels, flooding in tunnels, cliff face percolation, shallow instability and wet beds.</td>
</tr>
</tbody>
</table>
| Overhead equipment               | Extreme winds - defined both by putting a value on a wind gust speed (for example intervention levels for imposing speed restrictions to protect the OHLE/pantograph interface) and from incidents when severe disruption has resulted. Storm intensity and direction - defined by incidents where severe disruption has taken place as a result of damage to coastal defences. Would need to take into account the effects of the predicted sea level rise and the north west/south east land tilt of the UK. There are still large uncertainties in prediction of storm intensities and directions. Warmer summers may lead to:  
  - OHLE expansion, causing service disruption,  
  - higher risk of rolling stock engines overheating (already an issue with current high temperatures) leading to cancellations, and  
  - overheating of lineside electrical equipment, causing service disruption. |
| Lightweight structures           |                                                  |
| Lineside trees                   |                                                  |
| Rolling Stock                    |                                                  |
| Coastal and estuarine infrastructure | Sea level rise, storm intensity, and storm direction lead to white and green water overtopping, flooding, foundation instability, train/traction damage, signals and communications damage, salt water degradation, poor sighting and visibility, and track washout. |

### 6.3 Opportunities

The main opportunities for the railway industry are:

- Warmer winters may reduce:
  - the risk of points freezing
  - the risk of rolling stock overrunning signals at low temperatures
  - the risk of heavy snowfalls disrupting services
  - ice formation on third-rail and OHLE conductors
- ice falls in tunnels

- Warmer summers, particularly in the south, may increase passenger demand for leisure travel (although it should be noted that this opportunity is currently severely constrained by capacity limitations), and

- Better understanding of weather impacts can lead to improved contingency planning and hence reductions in delays and improvements to services.

### 6.4 Influence Diagrams

#### 6.4.1 What are they?

Influence diagrams are pictorial representations of complex systems. They allow people to systematically describe a system and how the different aspects of the system interact with one another. In an influence diagram the key variables that are related to each other are represented by ‘nodes’. A node is related to other nodes by ‘links’. Where two nodes are linked, this indicates that the state of one node directly influences the state of the other node. An arrow shows which node acts on which. For example, in the figure below, there are four nodes, linked together:

![Influence Diagram](image)

The orange nodes in the figure represent climate variables. In the future, winter temperatures may become colder or warmer. Summer temperatures may become cooler or hotter. Both these nodes are linked to a yellow node, representing the effect of these climate change variables. In this case the combination of winter temperatures and summer temperatures will influence the likely temperature range experienced during the year. This in turn will affect the risk of rails buckling. Rails are designed to withstand a particular range of temperatures without buckling, standards are in place that require speed restrictions to be imposed at extremes of temperature to reduce the risk should buckling occur. If the normal temperature range alters, then these extremes may occur more frequently and eventually it may be necessary to change the rail design to meet the new temperature range, and to change the associated standards.

The value of representing the various factors, variables and influences on a diagram such as this is that it allows people to see and communicate how a complex web of influences, such as those associated with climate change, can either directly or indirectly impact on
their lives and businesses. The key influences can be followed through logically. An influence diagram can be used either qualitatively or quantitatively. In this study we have focused on qualitative values, although we have also explored how the diagrams could be used quantitatively.

It will be seen below that even the qualitative diagrams can quickly become very complex, and in the form shown here are probably likely to be of most use to risk management specialists who are familiar with this approach to laying out information. However, they can be used as the basis for developing simpler checklist based tools for application by non specialists.

6.4.2 Development of Influence Diagrams for the Rail Case Study

The influence diagram has been used during the case study to demonstrate how climate changes can impact:

1. rolling stock and infrastructure directly, and
2. passenger and freight demand.

The main impact of socioeconomic changes caused by climate change is expected to be changes to overall demand or to patterns of demand (for example more demand for services in the summer to seaside destinations in the UK). This would also be true of other asset or infrastructure intensive industries. We have not included the socioeconomic drivers on the diagram for clarity, but it is important to remember that in the medium to longer term these are expected to present the railway, which is currently operating close to capacity, with difficult challenges.

We were guided by the variables developed within the UKCIP02 scenarios to form the starting point for the case study influence diagrams. UKCIP02 does not address interactions between the socioeconomic and climate change scenarios but produces eight separate scenarios, four each for climate and socioeconomics, although clearly there will be interactions.

We have not generally represented in detail factors external to the system, for example electricity supply, which itself could be strongly influenced by the effects of climate change. Railway managers will need to be aware of these threats but such wider external impacts would deserve an entire study to themselves. Instead we have represented such factors through costs of production nodes, which will be influenced by the wider outside world.

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20 Figure 4 illustrates the principle of this tool, which has been produced using feedback from the Steering Group members. It is not intended to be a complete, comprehensive picture of the current system.

21 The diagram represents a so-called “steady state” in terms of these socio-economic drivers and therefore allows the impact of climate change in isolation of these other factors to be estimated. The major driver of the future economic and public health consequences of severe weather may well be the socio-economic factors that control the exposure of people and property to extreme events. For example, changing demographics, new geo-spatial plans, town construction, increased flexible working will all impact on passenger numbers and demand. Changing societal concerns may have a significant impact.
6.4.3 Interpreting the Rail Case Study Influence Diagram

Figure 4 shows the climate change influences, impacts, risks and opportunities. The very top orange node is a general ‘Global Climate Change’ node. This represents the four UKCIP02 climate change scenarios. Depending on which scenario is considered, this would influence the likely values for the climate change variables below. At the next level down in the diagram, the orange nodes represent the major climate change variables that are described by climate change models. These are: winter temperatures, summer temperatures, levels of precipitation, cloud cover, levels of wind (duration and speed), and sea level rises. In turn, these climate variables impact directly on weather and environmental variables (yellow nodes) that have an impact on risks to the rolling stock and infrastructure (green nodes). Demand side variables, relating primarily to passenger demands, are represented by blue nodes. At the bottom of the diagram, the purple nodes represent the key success factors for train operators and the infrastructure operator (Network Rail).

There are a number of weather factors that may be affected by climate change and are directly relevant to the railway. As described above, the temperature range can affect the risk of rail buckling, as well as the risk of overhead lines expanding, sagging and then failing. There are potential direct consequences of changes in average winter and summer temperatures. If winters become warmer, then risks associated with cold weather, for example points freezing, powers supply conductor rails icing and rails breaking, will be reduced. Hotter summers could increase the risks of carriages overheating, and engines failing. These impacts will have consequences for passenger comfort, for safety and for service delays. Reduction in cloud cover has the potential to lead to increased glare, with an impact on train drivers’ ability to see clearly. This might also be affected by fog, which might increase with warmer, more humid winters. Increases in summer temperatures, coupled with warmer winters (and higher atmospheric concentrations of CO$_2$) might encourage increased vegetation growth along the side of railway lines. This risk of extra growth might be offset by decreased precipitation. The amount of vegetation can affect not only the visibility afforded to train drivers, but also, with leaf fall in the autumn, create adhesion problems between wheels and rails. The lusher the vegetation, the more severe these adhesion problems may be.

The impacts of changes in precipitation levels and patterns are potentially very significant. Combinations of hot, dry summers followed by sudden storms or heavy winter rains can increase the risks of subsidence causing slumping of earthworks, or even sudden earthworks failures, with potential consequences of delays and temporary (or even relatively long term) loss of train paths, as well as increased safety risks. Flooding risks are increased by sudden storms, particularly if these follow long periods of drought when the earth becomes too dry to absorb the rain. Flooding can affect rail infrastructure in various ways, leading to line closures and loss of train paths. It can cause scour under bridges, with the potential to cause the bridge to collapse. Flooding of the tracks can result in signalling failures, washout of ballast, or damage to trains. In towns and cities, urban run-off can lead to station flooding and consequent closures at short notice.

The potential rise in sea levels and increase in storminess have the potential to increase the risks of storm surges along vulnerable coastal railway lines, with a consequent increase in coastal flooding and loss of train paths. Salt spray can affect track circuits, so if winds
increase, salt spray might increase and the risk of track circuit failures would be increased. This effect would be exacerbated by a rise in sea levels.

On the demand side, hotter summers might increase the demand for passenger services to coastal resorts, potentially boosting train operators’ revenues.

6.4.4 Adaptations on the Influence Diagram

Figure 5 shows a sub-set of the influence diagram, focusing on flood risks. In addition to the climate, weather, risk and key success factor variables, a series of potential adaptations has been added to the diagram (the brown nodes). These are shown on the diagram where they would influence the likely risks or outcomes of the weather-related flood risks.

The frequency of heavy rainfall events, the frequency of storm surges and the overall quantity of rainfall all influence the risk of flooding in tunnels. This in turn results in a change to the risk of tunnel closure. The risk could be mitigated by either enhancing existing gravity drainage systems or installing pumps.

The frequency of storm surges will influence the risk of coastal flooding. This could potentially be mitigated by rebuilding the coastal defences to an enhanced specification. Coastal flooding has the consequences of loss of train paths. A potential mitigation for this, rather than tackling the coastal flooding through improved defences, might be to divert the line or lines at risk. These two adaptation measures differ in terms of cost and in terms of their long term sustainability. For example, in the long term it might become more economic to divert (or close) the line rather than to keep investing in more and more extensive coastal defences.

Where bridges are at risk from increased flooding and scour, there are at least two adaptations available. Installing scour protection at the base of the bridge would eliminate any potential for scour and many structures have had this solution applied. Closing an at-risk bridge during a flood would mitigate against the safety risk of running services over a bridge with the potential to fail - this is the short term option that is often used in the day-to-day running of the railway.

6.4.5 Quantification of the Influence Diagram

Ultimately, influence diagrams can be quantified to allow modelling of ‘what ifs’ to be followed through a network of possibilities. For example one might quantify by how much precipitation levels are likely to differ, assigning different probabilities to different levels of rainfall. The same could be done for sea level rises and wind speeds. These probabilities would then be used to calculate the probabilities of different flood risks etc. Expert judgement would be required, for example to decide how changes in summer rainfall intensity might influence the risk of flooding.

We have made an attempt to quantify this particular influence diagram, using a Bayesian Belief Net tool called ‘Hugin’. The main difficulty with quantification is that data in a suitable state to inform such a model does not exist at the moment. Either the data is not captured, or if it is then it is not held in a readily accessible form. For example, if we want to link data on known historical rainfall in millimetres for a particular location and time (available from the Met Office) with data on flood incidents, the data on location and date of flood events, although captured by Network Rail, is not in an accessible form and would take considerable effort to process. This means that it is not possible to develop a
relationship between level of rainfall and risk of flooding, which we need in order to model how increased (or decreased) levels of rainfall will impact on flood risks and hence on railway operations.

However, for illustrative purposes only, we have coded up a model with dummy data. This enables us to show how changes in climate, at the top of the diagram, are passed down into changes in risks, and ultimately can impact on the railway’s key success factors.

Figure 2

Figure 2 shows a screenshot of the coded model. On the left-hand side are the variables, with the three climate change variables at the top expanded to show the individual states the variables have been allowed to take, and the initial probabilities assigned to those states. The ‘Global Climate’ variable can take four states, relating to the four UKCIP02 climate change scenarios. As we have no information about the relative likelihood of these scenarios, they have been assigned an equal probability of 25% each. The ‘Sea Level’ variable has been assigned to three possible states of sea level rise by the 2080’s. The ‘Wind Speed’ variable has been given three possible states of more high wind speed than now, the same as now and less than now.

On the right-hand side of the screen is a representation of the influence diagram. In the two boxes are the states for two of the risk variables, the risk of tunnel flood and the risk of bridge failure. The values for these states are estimated according to the states of the variables that lead into them, propagated through the model using Bayesian statistics. The values assigned should not be considered to represent an expert view - they are merely illustrative.
A Bayesian Belief Net model allows the user to carry out “what if” exercises, fixing individual variables in turn and seeing how the effects of this change propagate through the model. Figure 3 shows the same model, but this time the value for the ‘Global Climate’ variable has been fixed to show that the ‘High Emissions’ scenario is 100% certain to occur. The change in the probability of the different ‘Sea Levels’ and ‘Wind’ variable states can be seen below it, and compared with those shown in Figure 2. The states of the ‘Tunnel flood’ and ‘Bridge failure’ variables have also changed in response to the user change.

Figure 3

Although we do not have real data with which to populate this model, such a model is a powerful tool to help decision-makers explore the potential impacts of future scenarios, and identify:

- Which changes in climate variables and combinations of climate variables have most impact on the “bottom-line”
- Which asset and operations are most at risk, and why
- Which adaptation measures may best help offset these effects.

Quantification of such a model can be a time-consuming process, but can in the first instance be attempted through expert workshops.
6.5 Summary of Analysis

Capturing the impacts of climate change on an influence diagram has the following advantages:

- Weather interacts with the railway in many, often complex ways, the influence diagram illustrates clearly these interactions on one sheet providing a tool for communicating the impacts and to provide a checklist to help identify and assess the potential impact of climate change.

- The diagram can be quantified, or scored in various ways to help identify the most important variables in terms of their impact on industry key success factors over different time horizons to help inform planning, prioritise research and support more detailed business case development, identification of triggers etc.

These figures could be used by both the regulators and industry to understand the potential significance of climate change.

In its qualitative form the influence diagram:

- Illustrates the relationship between climate change and the bottom line
- Highlights the “at risk” assets and operations
- Helps identify potential responses, which can then be mapped on to it

Time horizons for decision-making can be illustrated by constructing a series of influence diagram successively eliminating nodes that have shorter planning time horizons than a certain threshold e.g. If the planned asset life of track does not exceed 15 years, then track related failures can be eliminated from the diagrams for anything in excess of 15 years in the future.

As such it can be used as a tool to help communicate the potential impact of climate change on assets and operations and to help people think through the issues for their specific areas of responsibility. Conversion into simpler diagrams or checklists may be necessary for the non-specialist.

The quantitative form can be used at the national or local level to

- Identify the most “at risk” operations and assets
- Identify the climate variables with most impact on the key success factors
- Estimate threshold levels for each of the climate variables above (or below) which will result in “unacceptable performance” levels against each of the key success factors. This requires that national or local unacceptable performance levels can be established for priority A, B and C routes.
- Enables estimation of probability distributions of weather related expenditure (assuming no special pre-emptive action) associated with:
  - the different climate change scenarios
  - different times in the future (e.g. 30, 50, 80 years)

Our initial attempts to quantify a diagram for flooding risks have shown that both climate change and railway industry data is not currently readily available in a form that supports
this process – and ultimately the more detailed process of business case development. Initial quantification of the diagram could be achieved through workshops/expert judgement. The benefit of this would be:

- It would allow initial estimation/prioritisation of the parameters listed above
- It would permit detailed data requirements specifications to be developed both for railway industry data and climate change data. In the former case this should enable current data collection systems to be modified at little extra costs to provide useful weather related data to inform business modelling and business case development.
Figure 4: Climate Change Rail Industry Influence Diagram – Steady state
Figure 5: Climate Change Rail Industry Influence Diagram - Flood Scenarios
7 Capability to Respond to Climate Change

7.1 The Sector

For some years, the fragmented nature of the industry has hampered strategic thinking and decision-making. The DfT/SRA and the ORR (and to some extent TfL and the PTEs) are now the main drivers for shaping the railway industry as part of a more integrated and systematic ‘publicly specified, privately operated and maintained’ railway.

The sector by its very nature will always be exposed to weather. However, because of underfunding and the significant changes that have occurred over the past few years, the companies working within the industry, are busy trying to address the many challenges to maintaining and running the network today. Managers and staff have to balance the network’s immediate needs against its medium to long-term requirements to ensure that it can continue to function reliably and safely. There are also severe resource constraints and cost cutting pressures imposed due to having to bear down on the recent years’ cost escalations. Therefore, currently there is not much time or resource on hand to look beyond the short-term at managing the asset’s needs.

Because the railway is highly influenced by the weather the industry already has many effective strategies for dealing with weather related challenges to assets and operations integrated into its overall maintenance and renewal strategy. Many of these strategies are however implicit in codes and standards, maintenance regimes etc that have been designed for today’s weather conditions.

In areas where weather and environmental challenges are already changing NR has responded to ensure that disruption to services is minimised. In some cases consideration is given to building in resilience where this can be achieved at marginal additional cost where new works, refurbishment or renewals are planned (e.g. providing extra drainage capacity). Widespread adoption of climate change resilient standards is however hampered because climate change data is not often provided in terms that can be easily adopted into standards and methods and data for appraising the available options (including maintenance and renewal options) and building business cases in the face of the high residual uncertainty are not commonly available.

Looking into the future, socio-economic changes are expected to present particular challenges to the railway (for example additional housing requirements in the south-east increasing demand on routes already running near capacity; the impact of congestion charging and tolls introduced onto the motorway network pushing more freight on to rail etc).

The challenge for the railway sector will be to manage climate change threats in an optimal way within the context of these other drivers, improving capacity to respond to extreme weather events in the short to medium term and building appropriate levels of resilience into the asset base for the longer term.
The risk for the railway sector more generally is that if climate change considerations are not built into strategy formulation, and into weather related decision-making, decision-making in the longer term could be sub-optimal\textsuperscript{22}.

We discuss the capabilities of the various key parts of the railway industry in more detail below.

### 7.2 Train Operators

In general the sector is not incentivised or well resourced to introduce innovations in rolling stock design. Although some scope for innovation exists, the complicated nature of regulation, franchising, rolling stock supply and ownership structure (i.e. the role of ROSCOs who own and lease the rolling stock to the TOCs), train manufacturers, etc. is a barrier to innovation.

For example, within this environment if a TOC wants to innovate to take account of climate change the DfT/SRA would have to agree to support any extra costs incurred up front, or to ensure that the TOC would receive a return on investment for items that have longer lives than franchise length. For example, if a TOC wants to specify new type of rolling stock (with a working life of 30-40 years) to be 'future-proof' against extreme temperatures in 25 years time, it may have no incentive to do so because it may only be able to use it for the next seven years before returning it to the ROSCO. In the current franchise regime, it is the job of the SRA/DfT to make this a requirement. However at present there is no awareness/mecchanism for SRA/DfT to take climate impacts into account explicitly.

The TOCs have access to some key pieces of information, such as likely numbers of days where ambient daytime temperatures are above a certain value (i.e. $25^\circ$C for air conditioning systems and $32^\circ$C for engine cooling systems). The industry needs to identify the critical pieces of data and any thresholds associated with these. UKCIP need to work with industry to understand how climate data can be best presented in terms of these critical data items so that the impact of climate change in the future can be fully appreciated.

### 7.3 Network Rail

At present it does not appear that NR has enough information to understand fully the risks of climate change impacts. The condition and behaviour of existing assets are not always fully understood, and the risks posed by extreme weather impacts are recognised but the effects are less well understood. Nevertheless, systems and processes exist that ensure that timely action is taken to ensure the safety of rail traffic. NR currently assume that the most significant issue is with the longest lived assets (bridges, embankments, tunnels), as these are capable of lasting many scores of years.

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\textsuperscript{22} Extreme weather and climate change risks can resemble security risks such as war and terrorism, in that they have no short-term upsides. Superior management of weather risk can, however, still be a source of long-term competitive advantage, because better risk management means better management of contingent costs.
The tools available to those responsible for maintaining the condition or health of railway assets are currently not well enough developed to enable the industry to plan for achieving an optimum mix between maintenance and renewals of assets in future environments and demands which are very uncertain.

The DfT are more concerned with the ability of NR to manage its asset under current conditions than with the risks associated with possible future climate change scenarios and admit to being focused more on the impact of rail on climate change rather than the impact of climate change on the rail industry.

ORR state that they will set aside provisions to fund climate change adaptation projects, provided that NR can make a robust case for such investment. However, making a strong business case to invest to optimise future costs, improve performance or to bring about social benefits that may not be realised for another forty years is very difficult within the current business case frameworks. Discount factors used are too high, the level of uncertainty about future extreme weather severities and frequencies is too great. In addition, data on the disruption caused by historic extreme weather incidents might not be valid for future climate change predictions because of the management and infrastructure improvements that have been implemented in the interim.

Currently, NR is able to make a reasonable case for projects and operational procedures that react to present day experiences of extreme weather on existing assets built to existing or even no standards and codes of practice (e.g. the Dawlish sea defences). What it may find much more difficult to do at present is to build into its investment decision-making assumptions about the patterns of extreme weather beyond 2050. To be able to do this it will require much more reliable and accurate information about climate change variables. Such information is inherently variable, and therefore, project sponsors within the sector will need available to them decision support tools that can cope with variability and uncertainty explicitly. Knowledge of how the asset is expected to respond to climate change and new design philosophies are not currently contained within NR or other design standards (these are mostly based on custom and practice and empirically derived prescription).

On the positive side, NR has recently created the post of Extreme Weather Mitigation Engineer, reporting to the Civil Engineer, who will be responsible for looking at engineering considerations associated with the actions of weather and water on infrastructure. Climate change considerations is part of the post’s portfolio, so there will be a mechanism in place for raising climate change impacts to the NR Civil Engineer and in turn to Chief Engineer and the NR board as well as to the ORR at future Periodic Review negotiations.

Current weather related initiatives are, in general, aimed at achieving improved weather forecasting and a faster reaction to extreme weather events, through the implementation of operational and emergency responses. The areas that are being addressed are the impact of snowfall and flooding, leaf fall and adhesion, the effects of ice on conductor rails, and the management of earthworks, (e.g. the current embankment stability research project, CRANIUM, which is aiming to quantify the future risks of lineside embankment instability based on a number of defined extreme weather related scenarios such as heavy rainfall and rising water tables.
7.4 Policy Makers

The benefits of investment in risk reduction are often highly uncertain and difficult to quantify, so risk aversion drives regulators (and business managers) toward rules deemed reasonably likely to protect against the largest or most obvious risks. The balancing of costs and benefits for each decision, particularly those involving weather risks is a challenging task given the level of uncertainty.

At present short regulatory and franchise review cycles discourage longer term planning by industry.

The DfT’s view of climate change is primarily focused on mitigation and to some extent on short-term infrastructure impacts. At present, climate change variables are not key considerations in their decision-making processes. They are, however, thinking about possible different rolling stock specification and procurement models (e.g. cheaper/shorter life) using a more ‘holistic and whole life based’ view of rolling stock assets. The principle being that more rapid rolling stock turnover (i.e. specify, design, build, operate, decommission) would reduce the risk that lock-ins to inappropriate rolling stock types. Although this principle is being driven more by the industry wanting to implement a more integrated, simplified and “modular” approach to system design, specification and procurement, it is also an important example of how adapting a design philosophy can make a very important contribution to building climate change adaptive capacity.

7.5 Strengths and Weaknesses

Our review of policy/strategy setting and decision-making processes and the impacts of future climate change on the sector has identified the following strengths and weaknesses within the sector. These have been used as a basis for deciding how the industry should respond to the challenges (i.e. the opportunities and threats) of having to adapt to the impacts of climate change.

The sector demonstrates many strengths in relation to climate change including:

Strengths

- Engineers and Operations managers are already used to building weather related assumptions into their day-to-day decision-making.

- A number of weather related initiatives have been and are being implemented. In NR, for example, these are in general aimed at achieving improved weather forecasting and a better reaction to extreme weather events through the improvement of operational and emergency responses, and a direct reporting line to the NR Board through the appointment of the Extreme Weather Mitigation Engineer.

- There are examples of medium to longer term asset based responses, for example:
  - taking the opportunity to install enhanced drainage whilst other planned track or civils related renewals or replacement works are being carried out
  - the possible move to cheaper/shorter life rollingstock using a more ‘holistic and whole life based’ view of rolling stock assets to reduce the risk of “lock-in” to inappropriate rolling stock types.
• They are, however, thinking about possible different rolling stock specification and procurement models (e.g. cheaper/shorter life) using a more ‘holistic and whole life based’ view of rolling stock assets. The principle being that more rapid rolling stock turnover (i.e. specify, design, build, operate, decommission) would reduce the risk that lock-ins to inappropriate rolling stock types. Although this principle is being driven more by the industry wanting to implement a more integrated, simplified and “modular” approach to system design, specification and procurement, it is also an important example of how adapting a design philosophy can make a very important contribution to building climate change adaptive capacity.

• While the heavily regulated nature of the industry may be seen to introduce barriers to innovation and effective response to climate change, there are levers in place to make change happen - if regulators ask for it, then it will be provided (for a price).

• NR is building capability in the short term to be more responsive in its asset maintenance

• Performance data needed to support understanding and planning for climate change, though currently not available in a useable format, could be obtained quite readily because of the quantity of information available to NR and the train operators

• Joint research aspirations

Weaknesses in terms of addressing climate change

• In general shorter term priorities dominate planning decisions within the industry and climate change in the longer term is not high on the list of priorities

• Climate change risks have to take their place alongside many other equally complex risks that also need to be understood in context

• There is a lack of understanding/focus on what the key long-term risk issues are, within the companies themselves but also within the regulators (especially DfT/SRA)

• There is generally a lack of incentive to take climate change impacts into account – the risk is not necessarily with the company (e.g. TOC only have short term interests) but resides with the DfT/SRA

• Asset planning tools exist – but do not currently support assessment of climate effects

• The industry collects a lot of performance data, but finds it difficult to associate events with a date, place or asset. Therefore, there are currently difficulties in associating performance with specific weather events or asset failures and the full cost to railway of incidents are not recorded. Therefore, estimating the business costs of climate change in terms of risk to safety and performance, and the benefit offered by different adaptation response is made difficult, although not impossible.

• Probabilised climate data is not currently available although these are currently being developed by UKCIP

• Railway culture is traditionally conservative and prescriptive and there is a lack of opportunity or realistic incentives for innovation

• Systems and standard present barriers to innovation – and are difficult to change. Design standards may also ‘lock-in’ assumptions based on past weather patterns
The building regulations, building codes and Eurocodes do not recognise future climate requirements.

Existing decision-making structures do not handle uncertainty well and bias against long-term thinking (e.g. discount rates, 5-yearly regulatory review or 7-10 yearly franchise review). The DfT does not currently see this as a concern, as they consider the shorter-term issues must be dealt with as a priority.  

Lack of leadership - who is responsible for the industry taking this issue seriously beyond the current planning horizons?

8 How can Adaptive Capacity be Improved?

A key concept developed by UKCIP is the development of ‘adaptive capacity’. This is the ability of an organisation to adapt to the variety of circumstances it might face in the future – tackling its current weaknesses and building on its perceived strengths. Building adaptive capacity is a way for organisations to safeguard themselves against major uncertainty, and could involve developing skills, reviewing decision-making systems and processes, and increasing organisational flexibility. A model for adaptive capacity is provided in Annex 1. The particular areas for consideration include:

- Awareness, understanding and commitment to tackling and adapting to the impacts from climate change
- Data and information (both related to climate change and the response of asset to weather related events)
- Decision-making tools (the systems and processes) to support a more detailed understanding of the nature and magnitude of climate related risks, time horizons for planning, and development of business cases for change in the face of high inherent uncertainty etc
- Skills development and resources needed to use and apply the tools and implement any adaptive responses identified.

The consequences of doing nothing or delaying adaptation to the impacts of climate change include:

- The potential to save on the wrong or unnecessary adaptation
- Permanent loss of network
- Loss of reputation and public confidence

However, the new arrangements for rail & rail strategy development result in DfT (the new Rail Group) now being responsible for setting the overall strategy for rail and specifying what will be delivered. This does not just involve considering rail on its own, but also other forms of transport and the wider agenda (including the likely impact of climate change policies, alongside other more short-term developments that impact on longer-term rail strategy, such as new housing and economic regeneration). It is unclear whether adaptation is now given priority under the new arrangements or whether the focus remains on mitigation of climate change.
• (Insidious) decline in performance and reliability and cost to UK plc
• Modal shift away from the railway
• Increased costs (emergency repair costs are generally ten times higher than planned maintenance costs)
• Failure to meet PSA targets (DfT)

While it may be too early for the Railway industry to take adaptive actions in most cases, the decision not to take action must be a positive one, based on a proper understanding of the risks, rather than a default position arrived at through lack of consideration. Recent history, and the current regulatory framework, is strongly constraining the industry so it has little incentive to take these decisions for itself. We discussed what railway industry players, the rail regulators and the other policy makers can do to build adaptive capacity and enable appropriate adaptation in the 13 May workshop and during the case study interviews and the results are summarised in the table below.

<table>
<thead>
<tr>
<th>CC requirement</th>
<th>Railway industry</th>
<th>Rail regulators and other policy makers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness and commitment (including resources)</td>
<td>Leadership and better incentives are needed to drive awareness of the issues throughout the sector. However, given the public nature of large parts of the industry this can only occur if there is a clear steer given from the Government downwards.</td>
<td>DfT working in coordination with other key government departments: the Treasury, Defra and the DTI (particularly in relation to government policy on energy) needs to provide a clear steer on priorities. Leadership should be provided by the DfT/SRA, and the ORR to make sure that climate change thinking and planning is taken on board within the railway industry. Given both the private and the quasi commercial nature of the industry there also needs to be clear definition of responsibilities to address climate change impacts within the industry (i.e. defined separately for NR, TOCs, Defra, UKCIP and others such as the ODPM and the Treasury to address, for example, capacity and transport planning).</td>
</tr>
</tbody>
</table>

<p>| Data, models and methods | At present there is insufficient knowledge to fully quantify the effects of climate change on business performance. Data should be collected in a format that supports development of this knowledge including: improved data on the condition of assets, their deterioration with use and weather, and the impact of this on performance. | Climate change data needs to be expressed probabilistically by UKCIP (this work is currently underway) and provided in a format that can be used by those who have to develop project business cases. |</p>
<table>
<thead>
<tr>
<th>CC requirement</th>
<th>Railway industry</th>
<th>Rail regulators and other policy makers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data, models and methods</td>
<td>Asset planning tools exist – but do not currently support assessment of climate effects.</td>
<td>There needs to be encouragement to carry out research and to integrate findings – particularly to develop a long term systems based model of the infrastructure and the impacts of weather climate change into the future – analogous to the security of energy supply model developed by Ofgem/DTI.</td>
</tr>
<tr>
<td>Data, models and methods</td>
<td>Better understanding of the future hydrological/ground water regime is needed. Rain on very dry earthworks has a different effect compared to on embankments with saturated soils. There is a need to map vulnerable areas (vulnerability maps/GIS coupled with weather forecasting)</td>
<td>Weather forecasting and prediction methods are needed that provide details on rainfall patterns, especially types of rainfall event and impacts on asset management - e.g. thunderstorms affect railway in a different way to frontal rainfall, saturation and ground water regime.</td>
</tr>
<tr>
<td>Systems, structures, people and processes</td>
<td>The industry needs to identify the critical pieces of data and any thresholds (triggers for action) associated with these and embed these in standards and procedures. To a large extent this requires the data and model development identified above. Climate change considerations should be embedded in routine risk management and decision-making processes to ensure, among other things, that opportunities to build resilience into the industry at marginal cost (win wins) are identified.</td>
<td>Relevant rail standards, e.g. rolling stock design standards and specifications, need reviewing to make reference to the challenges to design presented by climate change and provide explicit guidance to the designer, builder or maintainer. National, European or international standards also need reviewing and updating. We understand that UKCIP has started working with the professional institutions to address this.</td>
</tr>
<tr>
<td>Systems, structures, people and processes</td>
<td>Current investment case methodology and decision structures need to be re-evaluated to ensure that the impacts of very long-term, less tangible, uncertain or social benefits can be assessed realistically alongside more short term costs and benefits.</td>
<td></td>
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Annex A: A Model for Building Adaptive Capacity

Successful organisations are those that can create and adapt their strategies by:

- Recognising and acting on opportunities and threats from an early stage,
- Designing their organisation to meet the challenge, developing the necessary systems, structure, and skills within a set of norms or the culture within the organisation, and
- Supporting and maintaining change with appropriate resources.

A pictorial representation of strategy making within the industry and some of the key factors that go into the decision-making processes is given below.

The strategic change process allows the organisation to move from its current state to a future state where it is better positioned to manage its external threats and exploit its external opportunities. The prerequisite for this to happen is pressure (or preferably early recognition) at the top and throughout the organisation that change must happen if it is to perform successfully and satisfy the needs of its stakeholders.

The recognition of the need for change can often be identified through the early use of strategic analysis, by reviewing the organisation’s external environment and assessing how these could affect its values/purpose, service delivery goals or the expectations of its stakeholders. To be of value, strategic analysis needs to identify the areas where change is most needed. This should generate a number of options for how to align the organisation’s objectives with the resources, competencies and capabilities available to it. It is then the job of the leadership to choose from the strategic options.
External threats and opportunities characterised by major uncertainty, such as the potential impacts of climate change, should be considered within a risk-based framework. This should enable the organisation to identify key risks, and potential strategies and actions that would remain robust against the range of possible futures. Useful tools to help in such an exercise have been developed by UKCIP, specifically the “Climate adaptation: risk uncertainty and decision-making framework”, UKCIP, May 2003.

A key concept developed by UKCIP is the development of ‘adaptive capacity’. This is the ability of an organisation to adapt to the variety of circumstances it might be faced in the future. Building in adaptive capacity is a way for organisations to safeguard themselves against major uncertainty, and could involve developing skills, reviewing decision-making systems and processes and increasing organisational flexibility.

### Building adaptive capacity

**Resources**

- **Investment**
- **Design & management innovation:** facilities, materials, approaches
- **Skilled resources**

**Optimal strategy selection**

- **Systems, structures and processes**
- **Data, models and methods**
- **Awareness of climate change issues and commitment to address**

Organisations need to consider their assumptions with respect to:

- **Infrastructure and logistics:**
  - what does the organisation need in terms of infrastructure in order to successfully deliver its services?
  - are these threatened/improved?
  - facilities and asset management

- **Premises, people and other resources:**
  - where is the organisation located (offices, other buildings)?
  - what are the implications for these locations in terms of climate change?
— how flexible are these locations - can they be moved if necessary?
— how will this affect the people who work for the organisation (working conditions, journey to work, home locations)?
— management and staff competencies and capabilities.
— information systems and data.

• Investment and insurance:
  — what are the financial implications?
  — will major investment be required?
  — what are the timeframes?
  — can the risks be offset by insurance?

• Processes and operations:
  — what actions may be needed?
  — when will decisions need to be made?
  — are there identifiable triggers for future action?
  — what information is needed to inform decisions?
  — how does this fit in with wider strategy?

• Suppliers
  — materials
  — plant and equipment
  — services
  — logistics

• Innovation
  — ideas
  — designs
  — new products and new processes/systems

Once an organisation becomes aware that change is essential, the leaders of the organisation must be able to make the change happen. They will need to form a consensus amongst those who can best promote change by communicating a shared vision. Strong and effective leadership is a critical factor at these early stages.

For strategic choice to become operational reality the management need to set a course by articulating the future direction in some detail, creating the desire and will to change, planning for it (i.e. what has to be done and by whom) and communicating how it will be sustained and monitored.
# Annex B: People interviewed and information sources

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Interviewee and position</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail Safety and Standards Board</td>
<td>Andrew Sharpe, Head of Research Strategy</td>
<td>9 February</td>
</tr>
<tr>
<td>Network Rail</td>
<td>Julie Gregory</td>
<td>23 February</td>
</tr>
<tr>
<td>First Great Western</td>
<td>John Barker</td>
<td>23 February</td>
</tr>
<tr>
<td>National Express Group</td>
<td>Nick Coad, Head of Group Environmental Strategy</td>
<td>24 February</td>
</tr>
<tr>
<td>National Express Group</td>
<td>Jason Groombridge, UK Rail Fleet Executive</td>
<td>24 February</td>
</tr>
<tr>
<td>The Railway Forum</td>
<td>Adrian Lyons</td>
<td>24 February</td>
</tr>
<tr>
<td>Office of Rail Regulation</td>
<td>Colin Brading, Head of Infrastructure and Asset Management</td>
<td>25 February</td>
</tr>
<tr>
<td>Rail Safety and Standards Board</td>
<td>John Lane, Structures Specialist</td>
<td>28 February</td>
</tr>
<tr>
<td>Network Rail</td>
<td>John Dora, Standards and Assurance Engineer</td>
<td>28 February and 3 May</td>
</tr>
<tr>
<td>Department for Transport</td>
<td>Philip Killingly, Policy Advisor</td>
<td>2 March</td>
</tr>
<tr>
<td>Strategic Rail Authority</td>
<td>Jonathan Ellis, Technical Specialist</td>
<td>3 March</td>
</tr>
<tr>
<td>Strategic Rail Authority</td>
<td>Stephen Atkins, Assistant Director: Transport Planning, Policy &amp; Research</td>
<td>3 March</td>
</tr>
<tr>
<td>Department for Transport</td>
<td>Mark Lambirth, Director Railways (Finance and Strategy)</td>
<td>18 March</td>
</tr>
<tr>
<td>Network Rail</td>
<td>Peter Haigh, the Structures Maintenance Engineer, South West</td>
<td>15 April</td>
</tr>
<tr>
<td>Network Rail</td>
<td>Michelle Edney, Business Case Manager</td>
<td>19 April</td>
</tr>
</tbody>
</table>

The Competition Commission web site