

Safety, Technical and Engineering

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Weather Resilience and Climate Change Adaptation Strategy 2017-2019

27 January 2017

Foreword

Our vision for a weather resilient railway, now and in the future.



Network Rail exists to generate outstanding value for taxpayers and rail users by continually improving the railway. Our role is to develop, maintain and operate rail infrastructure in partnership with our customers, suppliers and other stakeholders.

Network Rail is focused on ensuring a safe and reliable railway network and key to this is managing the impact of weather on our operations. Climate change is projected to increase the frequency and severity of extreme weather and is likely to have significant impacts on our infrastructure in the future.

We are committed to transforming the way we work to ensure that, over time, Britain's railway becomes resilient to projected future climatic conditions at the same time as managing high risk assets which are currently disrupting operations during periods of adverse and/or extreme weather. Through this strategy we will:

- Adapt at construction and at asset renewal in order to provide resilience in the most cost effective manner. When weather events cause catastrophic asset failure such as collapse of a sea wall or scour damage to a bridge, we commit to replacing like for better rather than like for like.
- Update policy, procedures and standards so that future weather conditions are considered and appropriately captured and addressed within all the work that we do.
- See that all projects going through the GRIP (Governance for Railway Infrastructure Projects) process undertake a climate change risk assessment and design schemes to be resilient to future weather conditions and/or with a view to providing passive provision for future weather conditions.
- Identify high priority locations for proactive resilience interventions and will work to identify funding sources for those projects not included within business as usual asset policy compliance and capex investment.
- Work with train operating companies, emergency response authorities and others to identify opportunities to enhance the resilience of our preparation for, response to and recovery from extreme weather events.
- Aspire to close the gap between performance on adverse compared with normal weather days by 1% PPM by the end of Control Period 6.

This paper outlines the strategy for weather resilience and climate change adaptation at Network Rail as we head towards 2020. I look forward to leading this vision in the way we all do business.

A handwritten signature in blue ink, appearing to read 'G Hopkins', written over a horizontal line.

Graham Hopkins
Group Director, Safety, Technical and Engineering

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Executive Summary

This strategy has been developed in recognition of the need to provide long-term strategic focus to the activities relating to weather resilience and climate change adaptation (WRCCA) in Network Rail and to make a step change in the resilience of the railway.

Adverse weather conditions have resulted in an average 2-3% reduction in PPM (Public Performance Measure) across the railway network compared with normal weather conditions over the past decade. Weather related delays have cost Network Rail around £50-100m per year over the past decade with the cost to the railway and economy as a whole much higher when the impact of cancellations, timetable changes and damage are accounted for.

From a safety perspective, we have been fortunate that asset failures and fallen trees have not caused a serious accident in recent years. However, the landslide at Watford in September 2016 and bridge scour at Lamington in December 2015 are reminders of the potential consequences. The frequent and severe flooding in recent years – particularly 2015/2016 has increased focus and attention on the need for key infrastructure to be resilience to current and future weather extremes and government and regulators are seeking assurance that we understand the risk and are taking action to mitigate the impacts.

Climate change will affect our understanding of risk by shifting weather patterns and our historic records of likelihood and severity, thereby amplifying the impact of adverse and extreme weather on the railway. It will become increasingly more challenging to become resilient.

Network Rail's Weather Resilience and Climate Change Adaptation Programme was established in early 2014 following the serious weather impacts of winter 2013/2014 (including collapse of the Dawlish sea wall). Complemented by a series of recommendations from the [Transport Resilience Review](#) (2014) and the [Tomorrow's Railway and Climate Change Adaptation](#) project (TRaCCA: 2014-2016), progress has been made in recent years on enhancing operational weather management and our understanding of risk to our assets and infrastructure.

An internal audit of WRCCA activity, concluded in June 2016, raised a number of findings around ownership and governance. It identified the need for strategic targets and standardisation to articulate Network Rail's performance and subsequently to manage risk, inform decision making and prioritise work. The key recommendation for WRCCA activity concerned the development of a strategy, improved governance, and the establishment of a reporting framework.

This strategy looks to provide a framework within which all work relating to weather resilience and climate change adaptation is undertaken within Network Rail and to enable renewed energy, focus and investment in prioritised activities through engagement with the business in consultation with external stakeholders.

The overarching vision of the strategy is for ***a railway that is safe and more resilient to the effects of weather, now and in the future.*** By providing:

1. Infrastructure which is able to withstand the impact of future weather conditions; and
2. Rapid recovery from the impacts of adverse and extreme events;

And as a consequence:

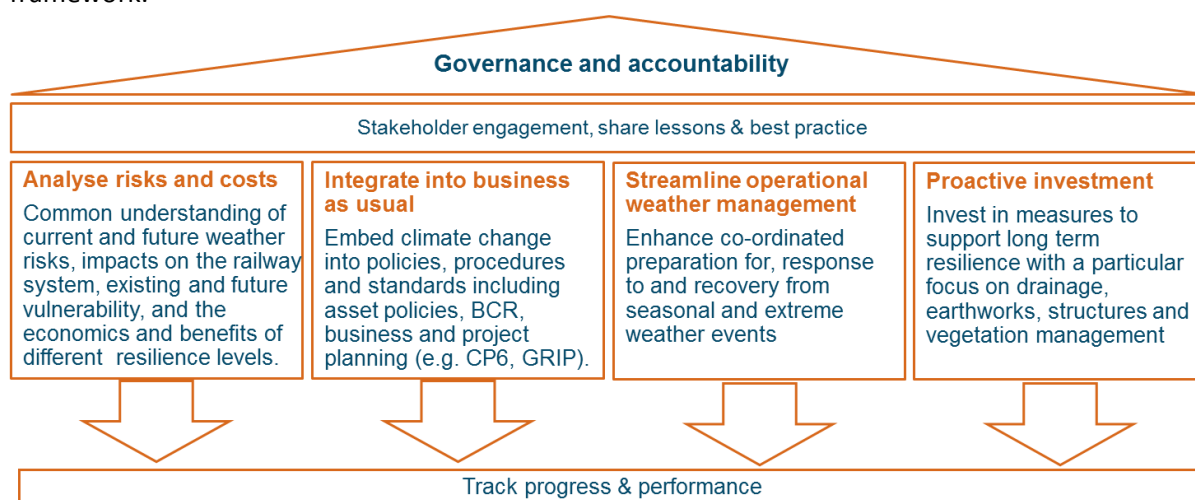
3. Improve performance and safety during adverse and extreme weather conditions; and
4. Leverage financial savings through reduced compensation payments and repair costs;
5. Enhance reputation and trust in the railway’s ability to manage weather events.

Whilst we understand the current risk of adverse and extreme weather to our infrastructure relatively well, it will take time to fully understand how climate change might amplify the risk and cost associated with impacts on the railway. The focus over the next three years is on getting the basics right and obtaining the evidence base for a comprehensive long term strategy in 2020.

This strategy has been developed in recognition of funding constraints and therefore aims to maximise opportunities for incorporating further activities to enhance weather resilience and adapt to future climate change within business as usual activities. However, we will only see a step change in resilience with focussed investment targeted at areas which will deliver the highest performance and safety improvements. Work over the next few years will enable us to gain a comprehensive understanding of the cost and benefits (including to the broader economy and society) of undertaking resilience activities and developing business cases and tools to support decision making and planning.

Network Rail is aspiring to a 1% PPM improvement in performance on adverse compared with normal weather days (i.e. reducing the performance gap) through improved weather resilience. This will be reviewed following the Control Period 6 settlement and further analysis into the causal factors affecting performance. The improvement would be achieved through the proposed increased national investment in drainage and vegetation management; proactive targeted investment in resilience measures; and through continuous improvement (e.g. reducing Delays per Incident) and innovative technologies and approaches.

A four pillared approach has been developed to help focus attention on the quick wins as the evidence base for future action is built. Tools and approaches will be tested through pilot projects to demonstrate the effectiveness and value in advance of rolling out to the business as a whole. Umbrella activities supporting this work include measuring and tracking progress and performance and a clear accountability and governance framework.



2020: Review and Revise Strategy



1. Analysis and reporting

Network Rail has come a long way in understanding the impact of weather events on the railway, however, we are still in the early stages of our journey to understand and quantify the impact of climate change and the cost associated with a changing risk profile. A common and more comprehensive understanding of future risk and vulnerability will be developed and appropriate interventions for reducing this risk, to agreed tolerance levels, will be identified.

The above will be supported by work to improve asset data and decision support for these assets including, Drainage, Ellipse and Whole Life Cost tools to support maintenance, renewal and enhancement decisions.

Progress with implementing this strategy and improvements in resilience, performance and safety associated with the activities undertaken will be measured through a series of performance and capability metrics. Regular reports to internal and external stakeholders will enable progress to be tracked and for the implementation plan associated with this strategy to be updated to maximise the benefit associated with work in this area.

2. Integration into business as usual

Resilience to existing weather conditions is integrated within existing policy and standards through improvements in vegetation and drainage management, making earthworks more resilient and understanding the most vulnerable structural assets.

Network Rail will continue to drive policy compliance but where possible will design to future rather than historic weather conditions. Consideration of future climate changes will be embedded within asset policies (such as through specifying future temperature or precipitation envelopes) and project development processes (e.g. GRIP) which will enable action to be taken through business as usual enhancements to increase infrastructure resilience and improve performance and safety in the longer term.

We will adapt at construction and at asset renewal in order to provide resilience in the most cost effective manner. When weather events cause catastrophic asset failure such as collapse of a sea wall or scour damage to a bridge, we commit to replacing *like for better* rather than like for like.

Network Rail will assess the capability and overall cost benefit of different levels of resilience of reducing risk with a priority in the short term being development of the Whole Life Cost investment tools to understand the cost of this change in asset policy.

3. Streamlining operational weather management

Improvements have been made to Network Rail's operational weather management systems and processes over the past few years and review of effectiveness and lessons learned from incidents will enable us to further enhance this process. We will work with train operating companies, emergency response authorities and others to identify opportunities to enhance the resilience of our preparation for, response to and recovery from extreme weather events.

Maintenance of assets, particularly vegetation and drainage, is of key importance to reducing the number and duration of weather related incidents. Regular, targeted, maintenance is required in high risk areas and those with a history of impacts in order that the impact be minimised.

4. Proactive Investment

A step change is required to ensure continuous improvements in resilience, particularly given the challenges climate change brings. Building on analysis under pillar 1 and working with external infrastructure managers where appropriate, Routes will identify high priority locations for resilience interventions with a focus on critical infrastructure. This will enable prioritisation of critical lines or assets where weather events could have a significant impact on safety and/or performance - it might, for example, be more appropriate to accept intermittent flooding on a rural route than on a suburban one.

Investment, over and above core Network Rail funding anticipated over the five to ten years, will be required in order to enable this step change. Tools will be developed to support robust cost:benefit analysis to support planning for future Network Rail funding cycles. External funding sources will be identified through engagement with government, regulators and others as well as opportunities to leverage additional capital investment through collaboration with stakeholders with an interest in the resilience of the railway (e.g. local flood authorities).

Accountability and Governance

Routes are responsible for day to day operational control of the railway and for planning, prioritising and implementing renewals and enhancements to infrastructure. However, the centre has a role to play in providing strategic direction, subject matter expertise and coordinating activities at a national level such as processing, analysis and reporting of data. This strategy places clear accountability and responsibility for activities relating to weather resilience and climate change adaptation with those best positioned to make change within the organisation.

Implementation

Actions, timeframes, accountability and responsibilities in relation to implementing the work outlined in this strategy will be set out in a detailed implementation plan. Routes will be responsible for developing their own plans for embedding the activities outlined in this strategy into their current and future work and for feeding back on progress to the Weather Resilience Group. The WRCCA team will provide expert guidance, analysis, tools and support as required

The Weather Resilience Group will sign off the plan and will monitor progress against agreed milestones. The plan will be reviewed every six months and updated as required in response to Network Rail priorities and lessons learned.

1 Introduction

Network Rail owns and operates Great Britain's rail infrastructure including tracks, signalling, bridges, tunnels, level crossings and many key stations. Network Rail's vision is a [better railway for a better Britain](#). This means delivering a railway that is safer, more reliable and more efficient than ever before, and that will support a thriving, and sustainable economy. Our [Sustainable Development Strategy](#) has a vision of *A Railway Fit for the Future* and looks to *make our network and our operations resilient to **future changes in the climate***.

Network Rail has a focus on continuous improvement and 'must win' priorities over the next few years and improving our resilience and response to weather-related incidents will have impacts across these activities. With the primary impact on performance and **delays per incident**, effective forecast and alerts for adverse and extreme weather events will help **planning and delivering safe work**. **Enhancements** and **renewals recovery** will enable implementation of some delayed resilience projects thereby improving performance and safety. Learning lessons and sharing best practice from responding to incidents will support **continuous improvement** and a **LEAN** approach to doing business.

Following the serious weather impacts of winter 2013/2014, the Weather Resilience and Climate Change Adaptation (WRCCA) Programme was established in early 2014. Complemented by a series of recommendations from the [Transport Resilience Review](#) and the [Tomorrow's Railway and Climate Change Adaptation](#) project (known as TRaCCA), progress has been made in recent years in enhancing operational weather management and understanding risk to assets and infrastructure. Some key results include:

- Enhancing the centralised [weather forecasting system](#), providing more granular forecasting capabilities and incorporating better alerts for adverse and extreme weather conditions across critical infrastructure;
- Better incident management through the Extreme Weather Management Process (EWAT - NR/L2/OCS/021)
- Improved liaison with operators and Rail Delivery Group through regular reporting to the National Task Force on weather resilience activity and seasonal preparedness/delivery;
- Enhanced understanding of weather impacts through detailed data analysis and risk modelling and decision tools to support the development of management plans;
- Lessons learned from incidents such as Dawlish, Lamington and Watford feeding into policy and process; and
- Strengthened Route Control and Operational Standards to provide better clarity on roles and responsibilities.

Network Rail produced an overarching [Climate Change Adaptation Report](#) in early 2015 following publication of [Route Climate Change Adaptation Plans](#). These plans summarise progress in understanding the potential impacts of climate change on performance and safety of the rail network, and what is being done to increase resilience. Routes are making progress in implementing the actions identified although a number of challenges have been experienced in relation to funding and some initiatives have been deferred.

An internal audit of the WRCCA activity, concluded in June 2016, raised a number of findings around the lack of ownership and governance. It identified the need for strategic targets and standardisation to articulate Network Rail's performance and subsequently to manage risk, inform decision making and prioritise work. One of the key recommendations was development of a strategy, governance and reporting framework.

In recognition of the need to provide long-term strategic focus to managing the current and future weather resilience of the railway, this WRCCA Strategy looks to draw together activities across Network Rail to provide a complete picture of where we are, and direction for the next three years in order to guide and energise activity and create forward momentum. It will be supported by a detailed reporting framework and implementation plan to provide clarity on actions, responsibilities and timeframes.

2 How does weather and climate change impact the railway?

2.1 Weather events significantly impact the railway

Adverse and extreme weather conditions have a significant impact on the reliability of assets and on the performance and safety of the railway (See Box 1). Weather impacts cost Network Rail £50-£100m per year in delays and cancellations alone with the overall cost being higher when the costs of weather-specific maintenance and repairs are included. Adverse weather conditions have resulted in an average 2-3% reduction in PPM performance across the railway network compared with normal weather conditions over the past decade. The impact of extreme weather can vary significantly year-by-year.

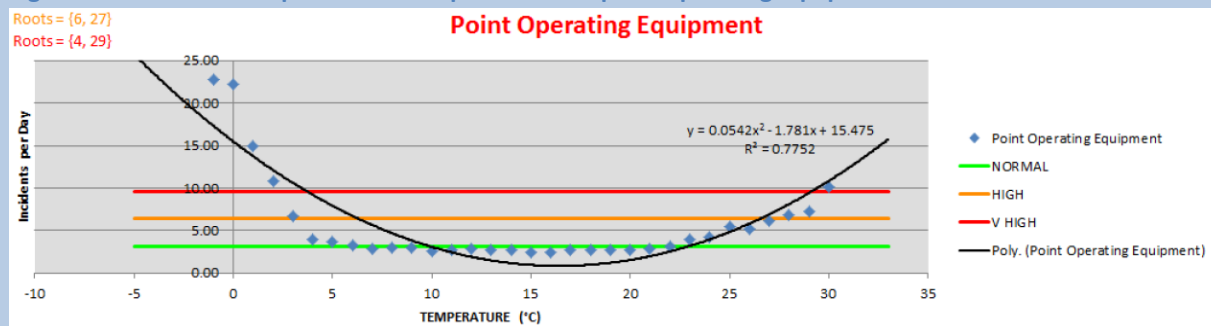
Snow incidents between 2008 and 2010 produced widespread disruption; however since then, we have had milder winters and there has been limited delay due to snow. Over the last 5 years, high winds have resulted in numerous train delays and localised storms and coastal surges resulted in a number of particularly disruptive incidents incurring wide spread damage to railway infrastructure and extended cancellation of services. Key events include: Damage to coastal infrastructure at Dawlish, the Cambrian Coast and Dover; closures from Settle to Carlisle, Banbury, Botley and Watford due to landslip; structural damage from river scour at the Lamington Viaduct and extensive track flooding across the Western Route, London North West (LNW), London North East (LNE), Scotland and Wessex.

Box 1 Defining adverse and extreme weather conditions

In order to understand how weather impacts performance, Network Rail has defined what we consider to be a 'Normal', 'Adverse', and 'Extreme' weather day. These definitions are based on analysis of the relationship between weather conditions and asset reliability...

Detailed asset analysis supports our understanding of root causes of failure and thresholds at which failure rates significantly change. For example, *Figure 1* illustrates how, as daily maximum temperatures increase above 25°C and decrease below 3°C, the frequency of points-operating-equipment incidents doubles (orange line) and triples (red line). This is usually a consequence of older assets that are vulnerable to weather extremes. The analysis has supported the definition of 'normal, adverse, extreme' operational weather days for rail infrastructure, approved by the rail industry's National Task Force in September 2014. These thresholds are used to alert Routes when weather forecasts suggest increased risk of asset failure and the alerts help preparations for the event.

Figure 1 The relationship between temperature and point operating equipment failure



Source: Network Rail analysis

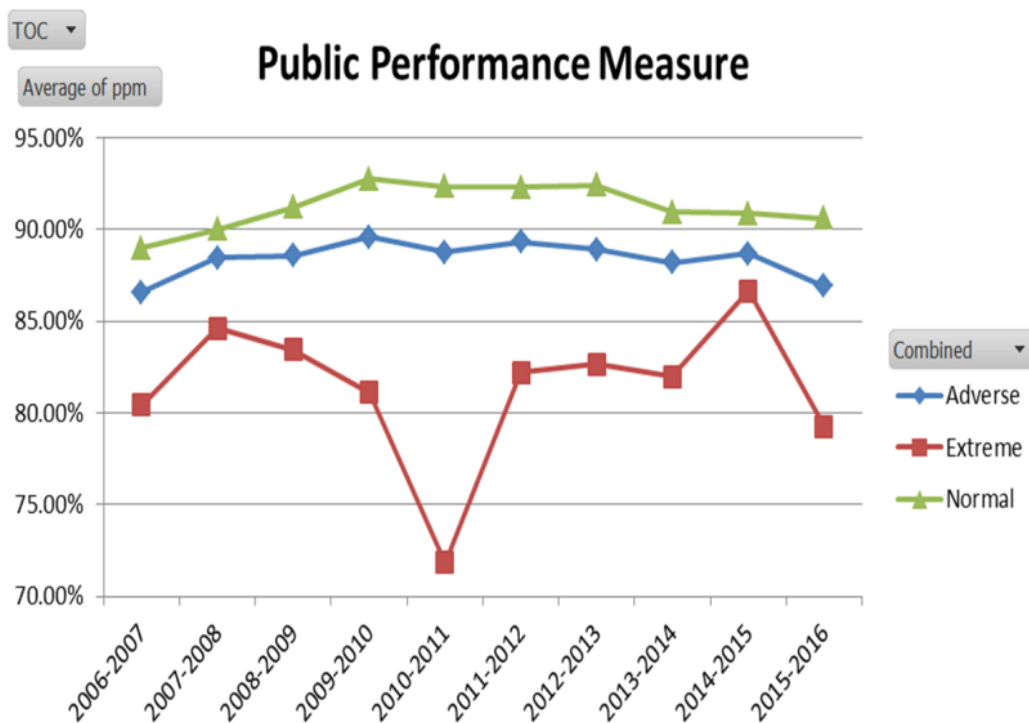
From the perspective of the travelling public, an 'extreme' weather day is when the railway is not expected to operate without disruption and delay given the nature of the weather experienced (e.g. a storm, prolonged rainfall/flooding). An 'adverse' weather day, on the other hand, is when the public would expect normal service to be maintained during poor weather (e.g. frost/light snow, warm or windy days) yet the conditions impact reliability and cause delays.

2.2 Performance drops during adverse and extreme weather conditions

Many rail assets are vulnerable to weather, a reflection of the characteristics of a nationwide transport system. Controls are in place to mitigate the impacts from weather-related events, ranging from speed restrictions during high temperatures and high winds to investments in improving the condition of high risk assets. However, the nature of weather, the scale and age of the rail network mean that impacts are still experienced.

The concept of adverse and extreme weather outlined in *Box 1* is used to determine the impact on railway performance¹. *Figure 2* illustrates the drop in performance due to weather with a consistent reduction of 2-3% PPM on adverse weather days compared with normal conditions. The drop in PPM on extreme weather days can be much more significant with extreme cold and snow conditions in 2010 causing around 20% drop and flooding in 2006/2007 and 2015/2016 around 10% drop compared with normal conditions.

Figure 2 The impact of Adverse and Extreme Weather on Performance since 2006



Source: Network Rail analysis

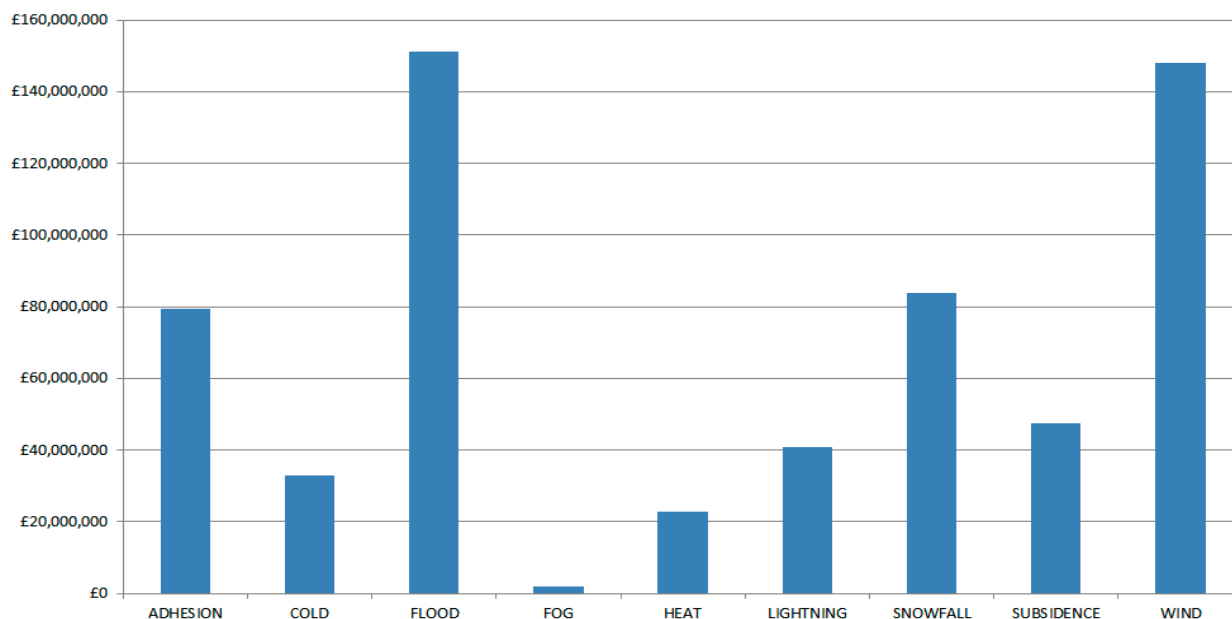
2.3 The cost of weather related delay and compensation payments is high

Network Rail pays train and freight operating companies compensation when railway infrastructure is not available and caused delays and interruption to services. Schedule 8 payments relate to delays and Schedule 4 to cancellations/timetable amendments.

¹ The public performance measure (PPM) is the industry standard, measuring the performance of individual trains combining figures for punctuality and reliability. PPM is the percentage of trains which arrive at their terminating station 'on time' compared to the total number of trains planned. A train is defined as on time if it arrives at the destination within five minutes (i.e. 4 minutes 59 seconds or less) of the planned arrival time for London and South East or regional services, or 10 minutes (i.e. 9 minutes 59 seconds or less) for long distance services. (from www.networkrail.co.uk)

Analysis of Schedule 8 costs provides an indication of the type of weather event causing delays and the associated cost of compensation. This provides a minimum indication of the cost of weather impacts as the cost of Schedule 4 compensations, cancellations, repairs and maintenance add to the cost of impacts – work is planned to understand the nature of these costs in more detail. *Figure 3* presents the cost associated with different weather events over the past 10 years. The cost increases significantly when cancellation costs are added – these have been in the order of £100m over the past three years. Wind and adhesion are the most costly with many small incidents occurring over the course of the year. Flood and subsidence events occur less frequently but create the highest cost per incident.

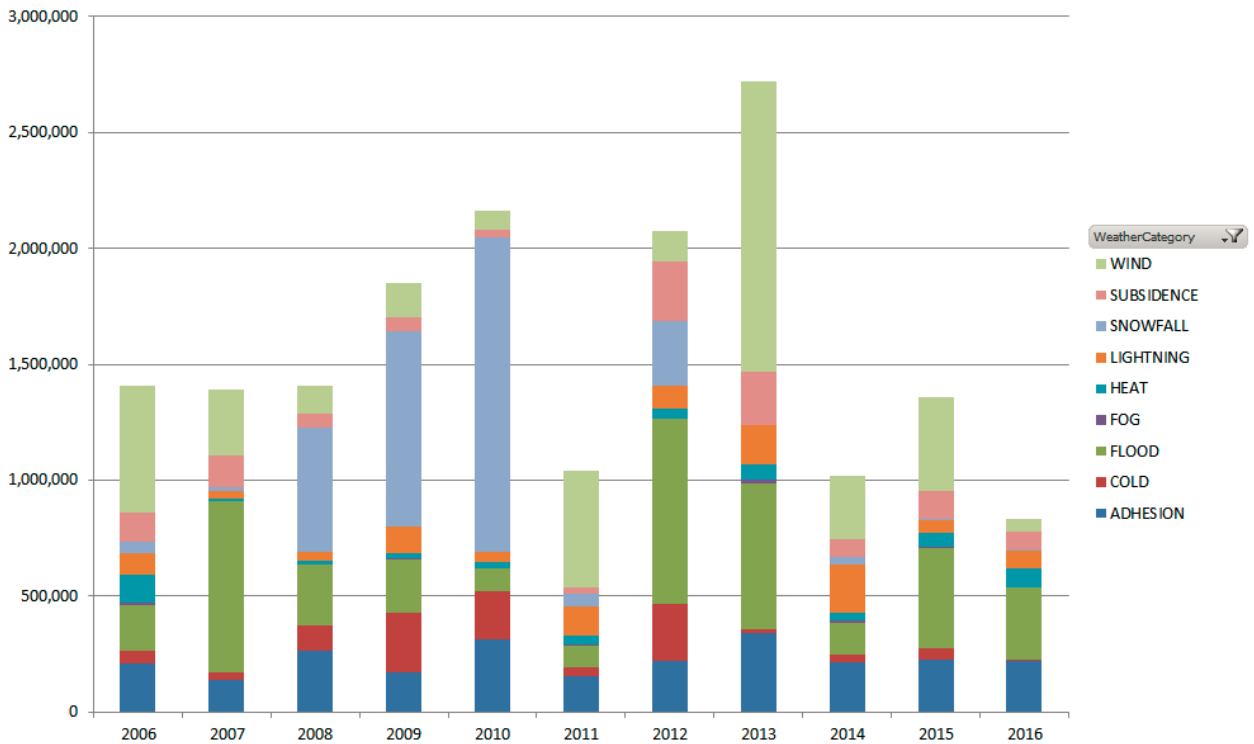
Figure 3 Schedule 8 cost of weather related events 2006 – 2016



Source: Network Rail analysis

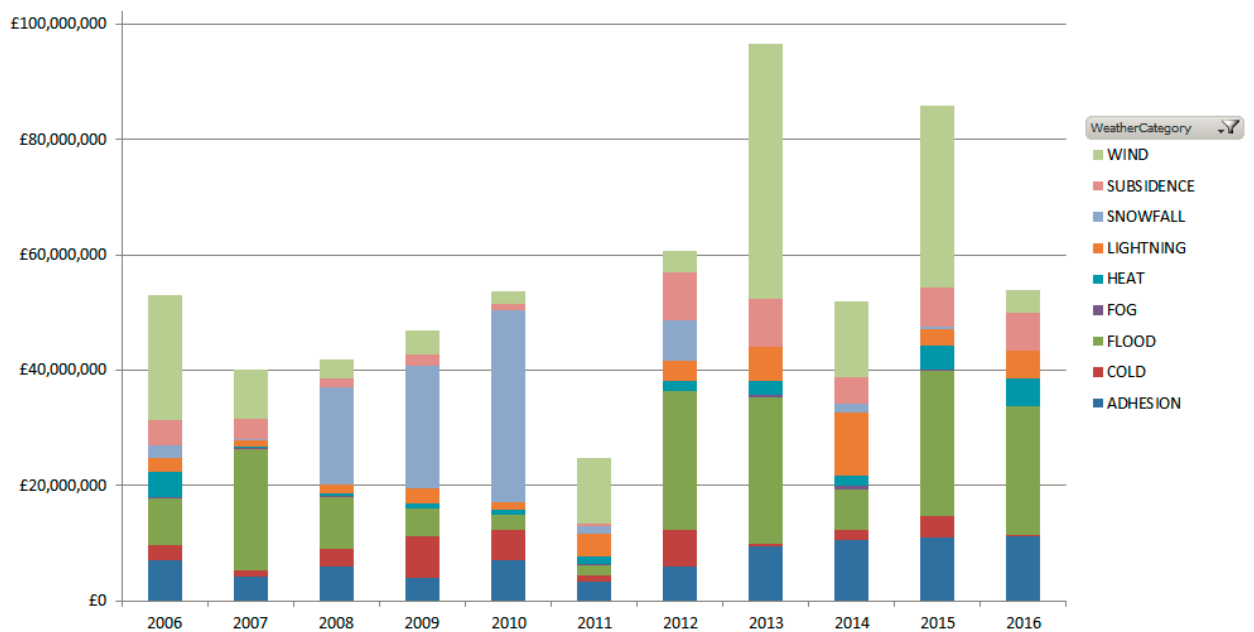
Figure 4 and *Figure 5* show the delay minutes and Schedule 8 costs attributable to weather events over the past 10 years. Note that Schedule 8 payment costs increased in 2015 explaining the comparatively higher cost vs delay impact since 2015. 2016 data covers 9 months of the 2016/2017 financial year from March – December.

Figure 4 Total delay minutes attributable to weather related events 2006 – 2016



Source: Network Rail analysis

Figure 5 Total Schedule 8 cost attributable to weather related events 2006 – 2016



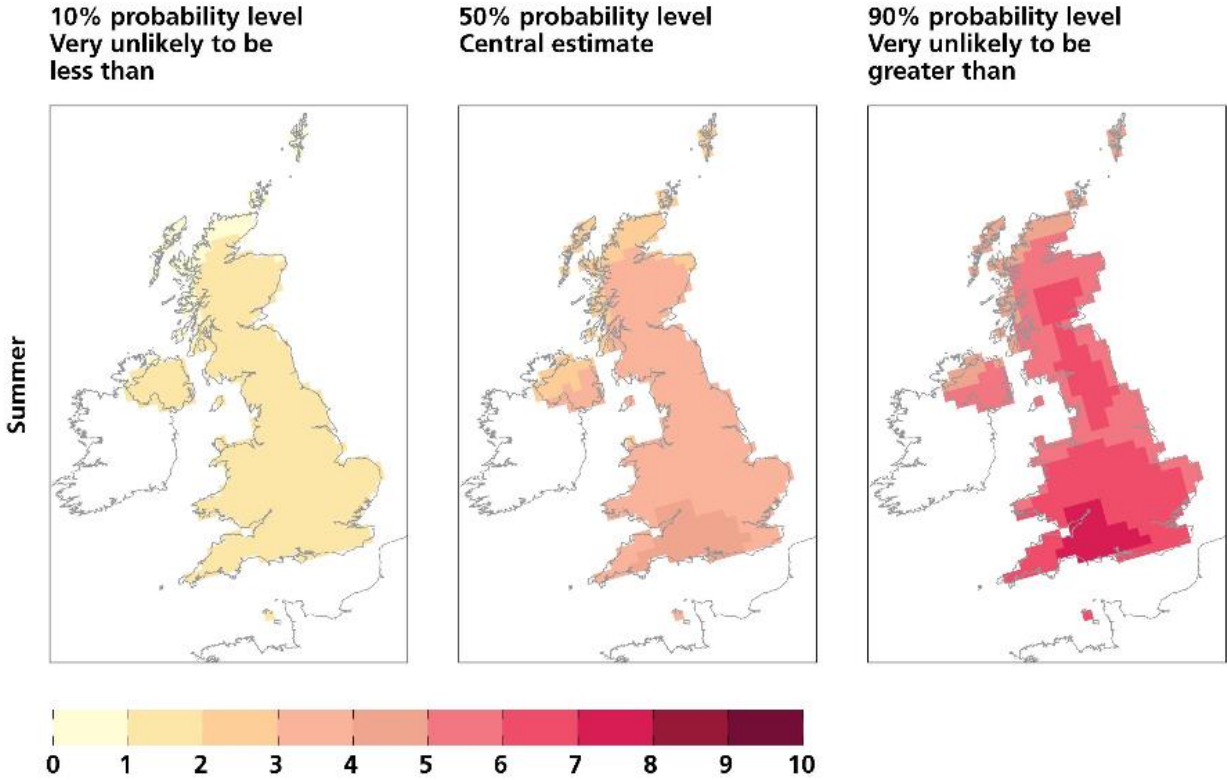
Source: Network Rail analysis

2.4 Climate change will amplify the risk

Climate change is projected to alter temperature and precipitation and associated weather events such as storms. It will affect our understanding of risk by shifting historic patterns of likelihood and severity, thereby amplifying the impact of weather on the railway and making it more challenging to become resilient.

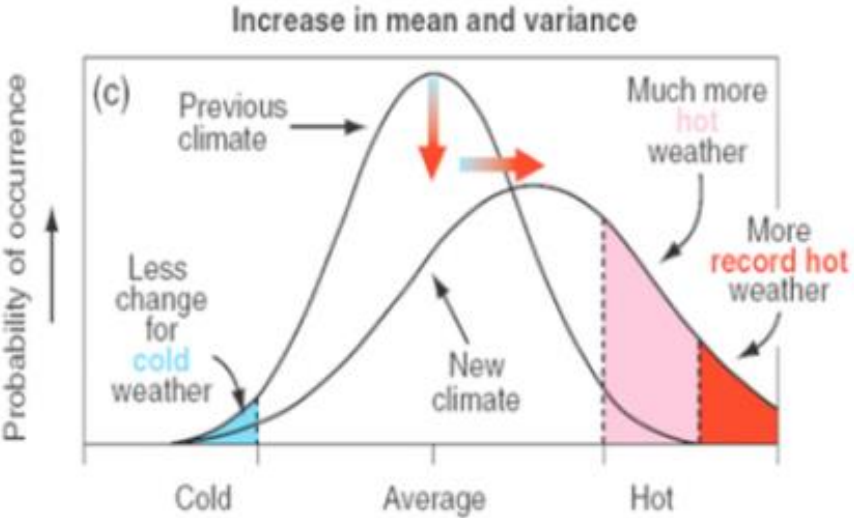
The future climate for the UK is outlined in the [UK Climate Change Projections 2009](#) (UKCP09) where a range of scenarios based on different emissions and probability estimates are presented as illustrated in *Figure 6* for maximum mean summer temperature in 2050. *Figure 7* shows how an increase in mean temperature could shift the distribution of probable events resulting in significantly more hot and extreme hot weather. For example, the chance of a very hot summer similar to the 2003 European heatwave is now 10 times more likely than 15 years ago (risen from once in 50 years to once in five 5 years) and this will increase further in the future².

Figure 6 Change in summer mean maximum temperature (°C) for the 2050s, high emissions scenario



Source: [UK Climate Projections 2009](#)

Figure 7 Climate change impacts on average and extreme temperatures



Source: [IPCC \(2012\) Managing the risks of extreme events and disasters to advance climate change adaptation](#)

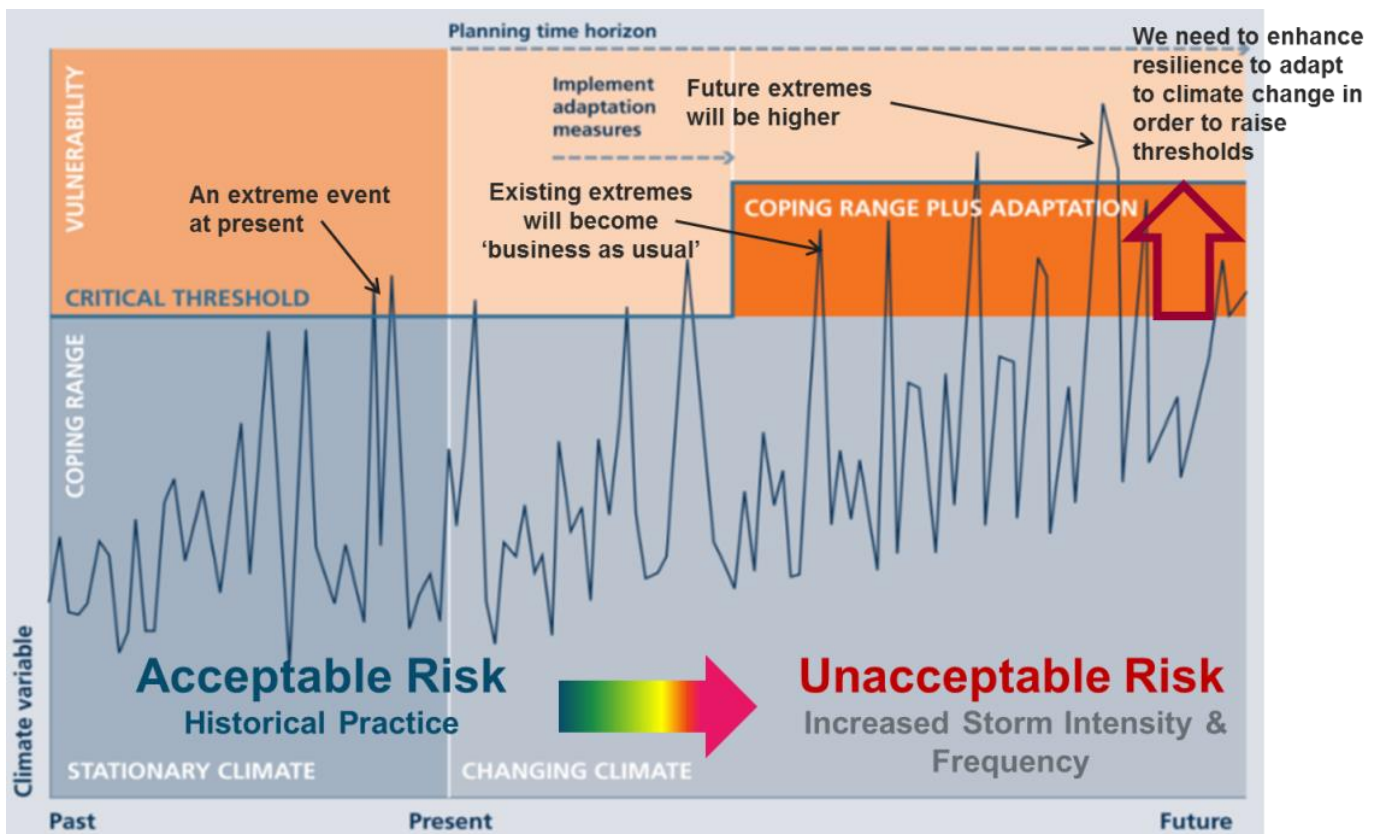
² See: <https://www.carbonbrief.org/european-summer-heatwaves-ten-times-more-likely-with-climate-change>

Weather fluctuates around long-term averages and has always included occasional extreme events such as flooding, heat waves, drought and storms. The frequency and severity of such events has been relatively predictable within critical coping thresholds as illustrated in *Figure 8*. The critical threshold is the point beyond which the consequences are considered to be unacceptable. Thresholds may be natural, such as the water level at which a river overtops its banks or a temperature above/below which points operating equipment fails, or based on risk attitude, such as the frequency of coastal flooding or technical specification in a standard. Climate change is expected to increase extremes and breach coping thresholds more frequently thereby shifting acceptable risk into the unacceptable category.

Figure 8 is an illustrative example of this concept. There have been and always will be events which are so extreme that they will impact operations and Network Rail would not be expected to keep trains running (e.g. when a whole region including access roads and stations are flooded).

Climate change is causing more frequent and more severe extreme weather events, increasing the likelihood of critical coping thresholds being exceeded. Climate change is likely to increase the frequency of experiencing conditions above the coping thresholds.

Figure 8 Coping thresholds and the need to manage unacceptable risk



Source: Adapted from Figure 3.1 in the [UK Climate Impacts Programme 2003 Technical Report](#)

2.5 Understanding and managing climate change risk – what is adaptation?

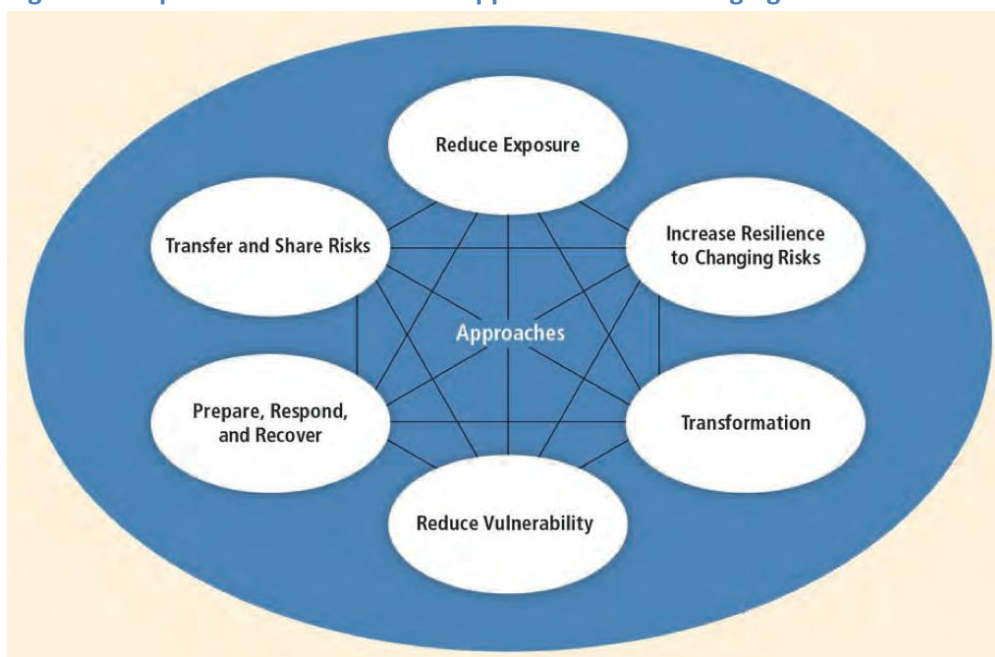
Network Rail conducted a climate change risk assessment in 2009 following publication of UKCP09 in order to understand potential changes in current risks and the effectiveness of controls. Extensive knowledge of assets and awareness of weather vulnerabilities at that time, and the long-life nature of the majority of assets means that we know broadly how climate change is likely to impact the railway. The challenge is to understand the extent of those impacts in particular locations and the associated risk and cost to our activities and the railway as a whole.

Climate change adaptation refers to the process by which Network Rail controls risks arising from changes in extreme weather events (e.g. storms) and gradual changes in the climate (e.g. temperature, water availability) to an acceptable level. Adaptation measures include altering physical design of the assets, implementing business procedures, and altering operating patterns. *Figure 9* provides an overview of different approaches to adaptation. It is widely recognised that investing in climate adaptation now will avoid potentially significant costs in the future.

At a local level, climate change adaptation measures could include:

- ‘Hard’/engineering adaptation controls that are incorporated into the design. For example, raising track/signalling equipment and enhancing drainage in flood-prone areas; strengthening coastal defences, raising temperature stressing of track, etc. These measures are already considered to a certain extent in policies, but the aim is to ensure that the technical designs are stress tested in relation to potential risk amplification by future climate changes.
- ‘Soft’/administrative adaptation controls are incorporated into operational procedures or processes. For example, streamlining emergency response procedures, implementing health and safety measures to manage heat wave events such as changing shift patterns to avoid employees or contractors working during the hottest part of the day.

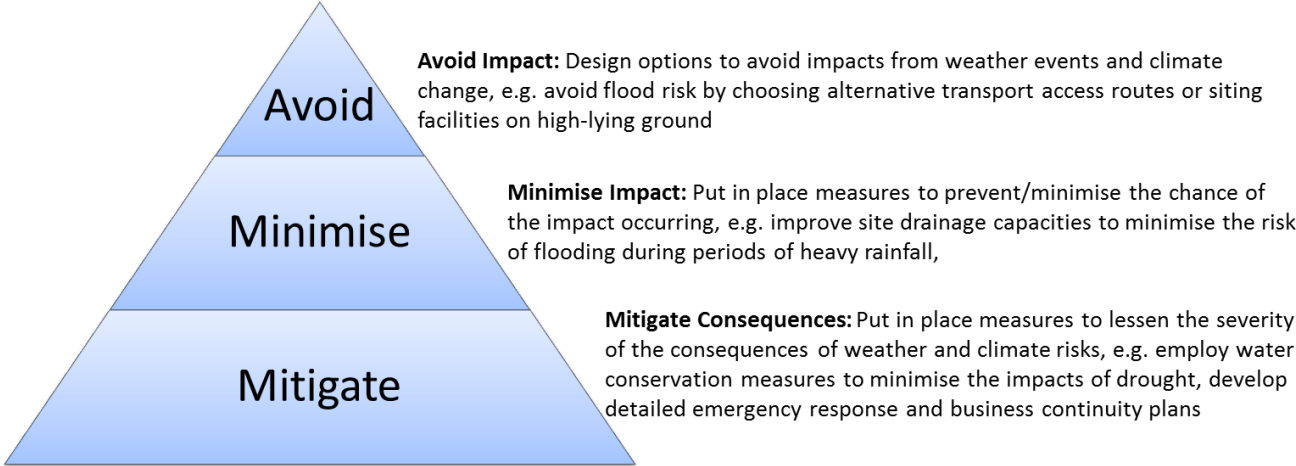
Figure 9 Adaptation and disaster risk approaches for a changing climate



Source: [IPCC \(2012\) Managing the risks of extreme events and disasters to advance climate change adaptation](#)

Adaptation measures should be selected to manage the climate change risk in accordance with the risk mitigation hierarchy, which prioritises avoiding the risk, then minimising the impact, and finally mitigating the consequences *Figure 10*.

Figure 10 Risk mitigation hierarchy



3 Communicating and engaging with stakeholders

The success of this strategy relies on collaboration with a wide range of internal and external stakeholders. Co-ordinated and effective communication and engagement will enable us to leverage mutual benefits and manage risks in a holistic manner with best advantage for the railway and country as a whole.

Table 1 provides an overview of the key stakeholders with an interest and/or role in implementing elements of this strategy – this list is not exhaustive. Section 6 outlines roles and responsibilities for the key players including the governance framework. Key elements of communications and engagement with internal and external stakeholders include:

- Developing a shared understanding of current and future risk, vulnerability and cost associated with weather impacts on the railway;
- Facilitating sharing of knowledge, lessons learned and best practice between Routes;
- Providing updates and engaging with government and regulators including regular meetings with the Department for Transport (DfT), Office of Road and Rail (ORR), and the National Task Force (NTF);
- Reporting to Defra on Adaptation under Climate Change Act (2008);
- Engaging with Environment Agency/ SEPA and Natural Resources Wales to collaborate on designing and implementing resilience measures and to co-ordinate and enhance the operational response to incidents;
- Participating in the National Infrastructure Resilience Council, National Flood Resilience Forum, Infrastructure Operators Adaptation Forum; TRaCCA Implementation Group and other discussions; and
- Engage with RSSB, CIRIA, NERC and others to support research and analysis.

Table 1 WRCCA Stakeholder Groups

Government and Regulators	Internal Network Rail Stakeholders	External Stakeholder Groups
<ul style="list-style-type: none"> • Department for Transport (DfT) • Transport Scotland • Transport for Wales • Department for Environment, Food and Rural Affairs (Defra) • Office of Road and Rail (ORR) • Environment Agency (EA) • Scottish Environmental Protection Agency (SEPA) • Natural Resources Wales (NRW) 	<p>Routes</p> <ul style="list-style-type: none"> • Route Asset Management • Seasonal Delivery Specialists • Maintenance and Delivery Units • Project Sponsor and managers <p>Project Developers (IP/WD)</p> <ul style="list-style-type: none"> • Project Sponsors • Design Engineers <p>STE/NOC</p> <ul style="list-style-type: none"> • Weather Resilience Group • Safety Technical and Engineering (WRCCA team, analysts, risk managers, R&D etc.) • Chief Engineers Group (Heads of Asset Functions and Strategy) • National Weather Client • NR Weather Forecast Service • Business Continuity and Emergency Preparedness 	<ul style="list-style-type: none"> • National Task Force • Rail Delivery Group • Infrastructure Operators Adaptation Forum • RSSB – Rail Safety Standards Board • TRaCCA³ Implementation Group • National Flood Resilience Forum • Transport for London • CIRIA - Construction Industry Research and Information Association • CIWEM, IEMA and other professional groups • NERC – National Environment Research Council • Various academic and research groups

³ TRaCCA – Tomorrow’s Railway and Climate Change Adaptation – is an RSSB funded research project which provided information on the vulnerabilities of the GB railway to projected climate change. A group has been set up to track implementation of the recommendations in order to support adaptation of the railway as a whole.

4 What does resilience look like for Network Rail?

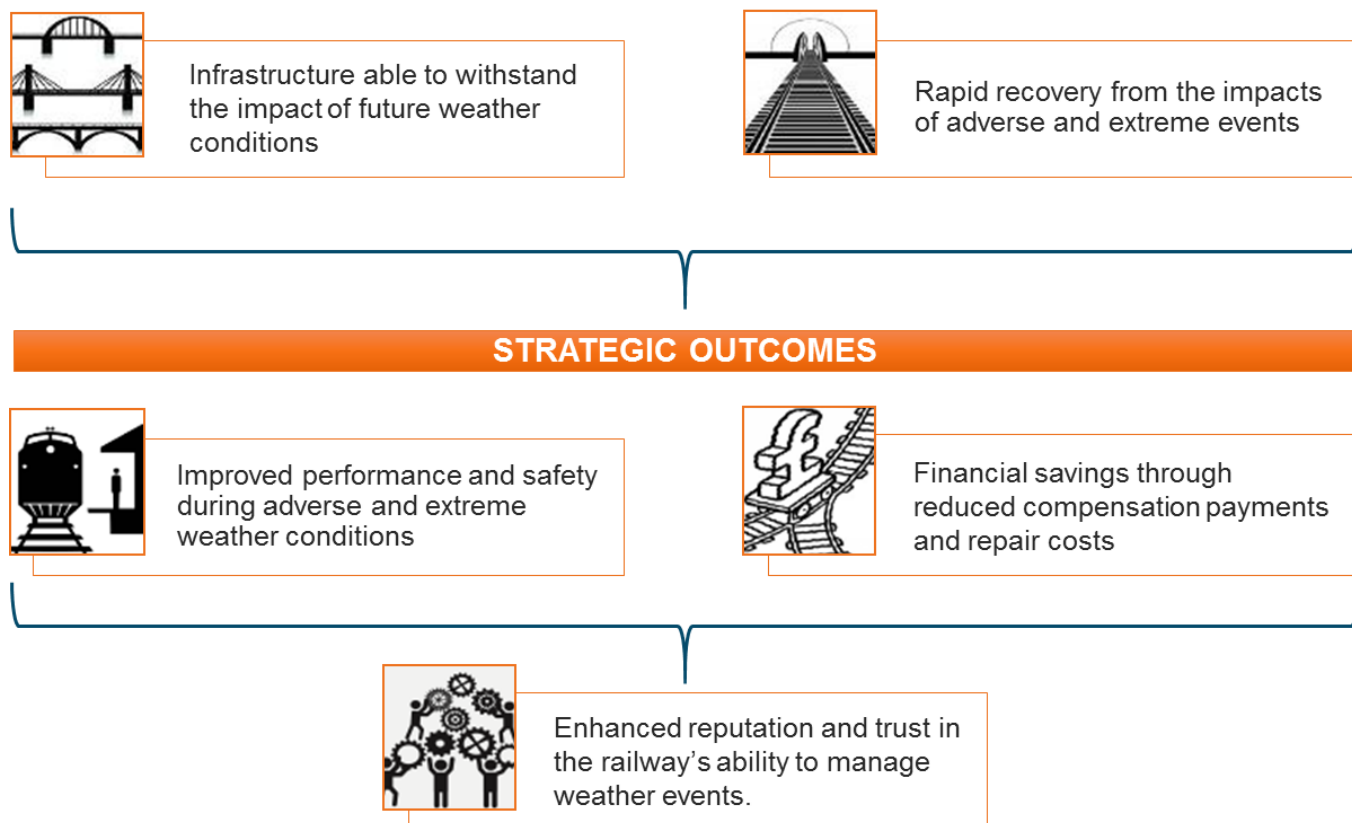
4.1 A vision for a weather resilient railway

Resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to and/or rapidly recover from a disruptive event. In its broader sense, resilience is more than an ability to bounce back and recover from adversity and extends to the broader adaptive capacity gained from an understanding of the risks and uncertainties in our environment.⁴

Our vision is for a railway that is safe and more resilient to the effects of weather now and in the future with the desired outcome for Network Rail’s journey to resilience is presented in *Figure 11*.

Figure 11 Strategic vision and outcomes for enhancing resilience of the railway

A railway that is safe and more resilient to the effects of weather, now and in the future



Working collaboratively with the rail industry as a whole, Network Rail aspires to improve performance on adverse weather days by 1% PPM compared with normal weather days by 2024 (end Control Period 6 – CP6) from an end CP5 (2019) baseline. This seeks a reduction in the gap between PPM on normal and adverse days as illustrated in *Figure 2* (rather than increasing overall PPM although by implication this would also present an

⁴ Cabinet Office (2011) [Keeping the Country Running: Natural Hazards and Infrastructure](#)

associated improvement). This ambition will be reviewed in light of the CP6 settlement, any resultant changes to future performance metrics and further analysis into the causal factors affecting performance – such as the reliability of the infrastructure, timetabling during adverse weather situations etc.

It is anticipated that this improvement will be delivered by:

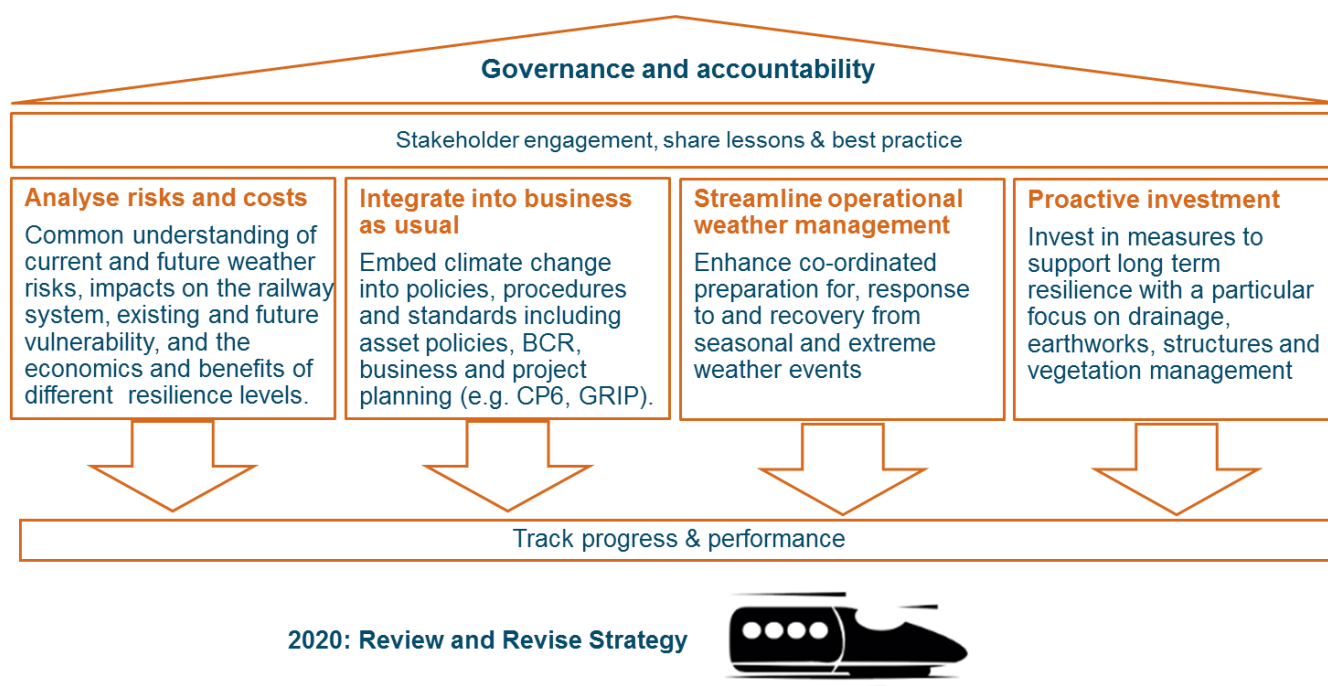
- 0.6% through proposed increased investment in drainage and vegetation management in compliance with policy and standards (included in core CP6 plans);
- 0.2% through proactive investment in resilience measures funded through the WRCCA fund (*Section 7*); and
- 0.2% stretch target to be achieved through continuous improvement (e.g. reducing Delays per Incident) and innovative approaches.

This is a national target and the relative contribution of individual Routes to achieving it will be agreed as part of the review in advance of the start of CP6.

5 The four pillars of resilience

Whilst we understand the current risk of adverse and extreme weather to our infrastructure relatively well, it will take time to fully understand how climate change might amplify the risk and cost associated with impacts on the railway. The focus for enhancing resilience to weather impacts over the next three years is on getting the basics right, integrating and streamlining procedures and standards and obtaining the evidence base for a comprehensive long term strategy in 2020. The plan for achieving this is presented in *Figure 12* and discussed in further detail in the remainder of this section.

Figure 12 Four pillars of resilience



5.1 Analyse risks and costs

Network Rail has come a long way in understanding the impact of weather events on the railway, however, we are still in the early stages of our journey to understand and quantify the impact of climate change and the cost associated with a changing risk profile. We will build a common and more comprehensive understanding of future risk and vulnerability and will identify appropriate interventions for reducing this risk. This will be supported by work to improve asset data and decision support for these assets including, Drainage, Ellipse and Whole Life Cost (WLC) tools to support maintenance, renewal and enhancement decisions.

A detailed programme of work will be developed posing clearly defined research questions and challenges with a view to obtaining actionable insights which will support decision making, identification and prioritisation of interventions and further work.

The programme will enable us to:

- Map existing and future risk across the network for all weather related events initially focussing on flooding;
- Investigate the causal factors affecting performance such as the reliability of the infrastructure, timetabling during adverse weather situations etc;

- Understand our level of resilience now, where we need to be in the future (based on UK climate change projections) and where we should be prioritising action to reduce the gap;
- Investigate the whole life cost of weather related impacts and resilience measures including socio-economic impacts to the country as a whole;
- Understand the cost of different levels of resilience;
- Explore adaptation pathways/scenarios to map out flexible options for enhancing resilience over the long term based on time of emergence of climate change signals;
- Develop decision support tools to analyse (socio)-economic benefits and to support whole life cost (WLC) planning; and
- Create and refine a suite of metrics that define and measure resilience.

Work will be undertaken by our internal team of analysts, expert academics/consultants and collaboration with other infrastructure companies and stakeholders including the Infrastructure Operators Adaptation Forum (IOAF) and RSSB.

Analytical techniques, decision support tools and innovative resilience measures and approaches will be identified, trialled and tested through pilot projects in Routes. The results of the pilot projects will aim to support updates to policies and procedures and provide tools for use across the country to facilitate work in adapting to future weather conditions and managing the impacts of adverse and extreme events.

Progress with implementing this strategy and improvements in resilience, performance and safety associated with the activities undertaken will be measured through a series of performance and capability metrics. Regular reports to internal and external stakeholders will enable progress to be tracked and for the implementation plan associated with this strategy to be updated to maximise the benefit associated with work in this area.

5.2 *Integration into business as usual*

Resilience to existing weather conditions is integrated within current policy and standards through improvements in vegetation and drainage management, making earthworks more resilient and understanding the most vulnerable structural assets. Network Rail will continue to drive policy compliance but where possible will design to future rather than historic weather conditions.

Network Rail will ***adapt at construction and at asset renewal*** in order to provide resilience in the most cost effective manner. When weather events cause catastrophic asset failure such as collapse of a sea wall or scour damage to a bridge, we commit to replacing ***like for better*** rather than like for like.

Network Rail will assess the capability and overall cost benefit of different levels of resilience in reducing risk with a priority in the short term being development of the Whole Life Cost investment tools to enable the cost of this change in asset policy.

Integration into business as usual will involve embedding within asset management, project development and Route strategies as discussed further below.

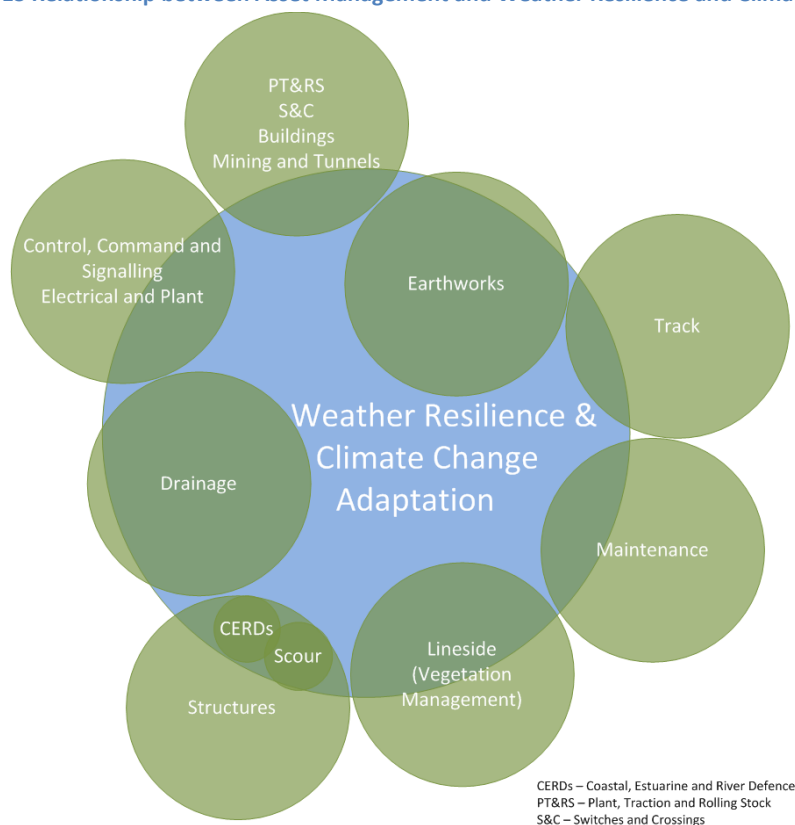
Asset management

Weather resilience (now and in the future) relies heavily on effective asset management. Core management activities within all asset functions add resilience to weather impacts to a greater or lesser extent and *Figure 13* illustrates how the broad activities under the weather resilience and climate change adaptation umbrella

overlap with the role of asset functions in managing weather impacts on the railway. The Civils functions of Drainage, Earthworks and Structures have the most important role to play from an infrastructure perspective and compliance with updated policies, standards and Business Critical Rules which incorporate consideration of future climate change will drive resilience going forward. Effective lineside management of vegetation is also important as wind impacts have the highest weather related cost implications for the railway (see *Figure 3*) in addition to safety concerns from fallen trees.

We will update policy, procedures and standards so that the consideration of future weather conditions is appropriately captured and addressed within all the work that we do.

Figure 13 Relationship between Asset Management and Weather Resilience and Climate Change Adaptation



Project development – Infrastructure Projects and Works Delivery

Infrastructure Projects (IP) and Works Delivery are responsible for designing and implementing renewals, enhancements and new infrastructure across the network. All projects going through the GRIP (Governance for Railway Infrastructure Projects) process will be required to undertake a climate change risk assessment and schemes will be designed to be resilient to future weather conditions and/or with a view to providing passive provision for future weather conditions (e.g. additional drainage capacity, space accommodate future track lift etc.). The comprehensiveness of the assessment will be proportionate to the size of the project and the resilience measures implemented appropriate to the risk appetite at the particular location. Major projects such as CrossRail2 will undertake detailed modelling to understand changing flood risk and to locate and design infrastructure accordingly. Smaller enhancements and/or more urgent work such as replacing failed assets would look to provide greater resilience than that of the asset it is replacing in line with the climate change specifications in updated asset standards/controls.

The sponsorship community and design engineers will specify the need to include resilience at construction/renewal/enhancement in projects. Guidance, training and support will be provided to facilitate this process.

Integrating Route Climate Change Adaptation Plans in Route strategies

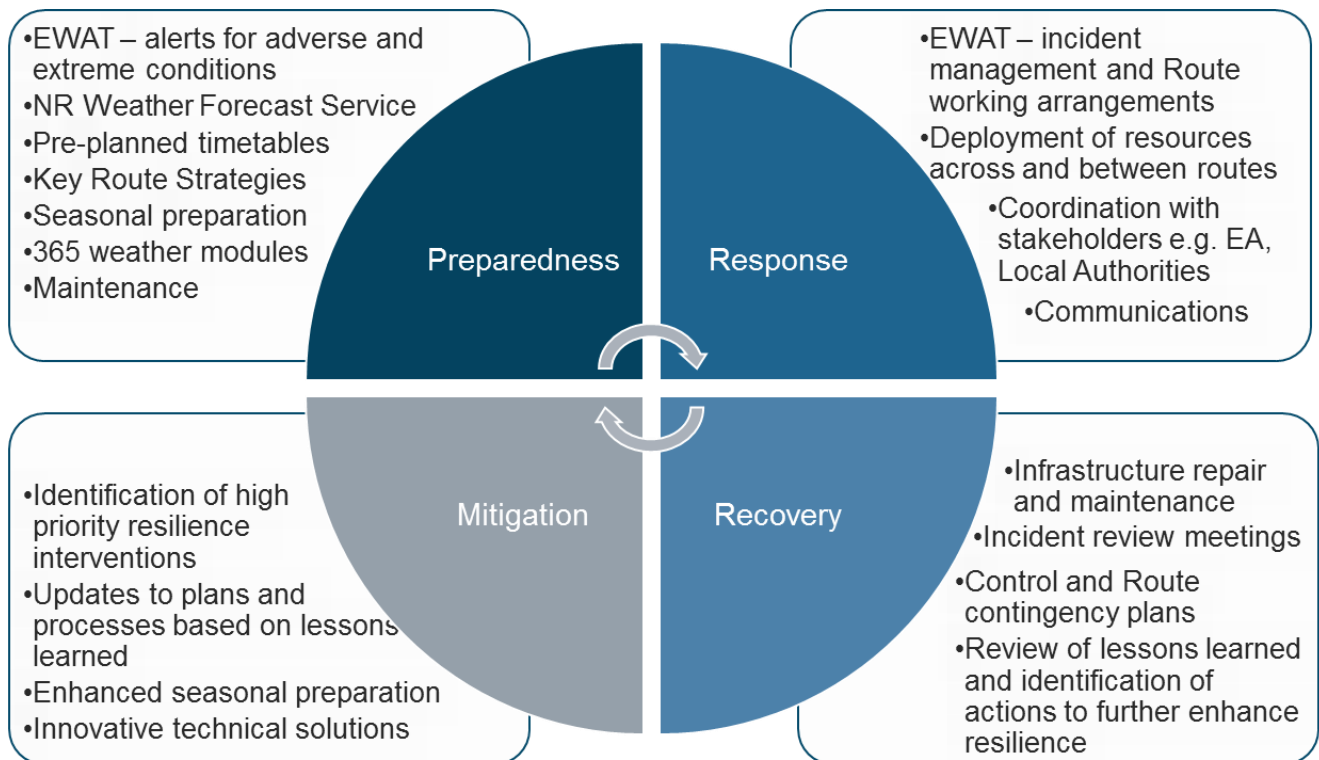
Route Climate Change Adaptation Plans will be updated based on the findings from analysis on risk and vulnerability of the network as well as the 2018 UK Climate Change Projections. These plans will set out priorities and investment requirements within the route over the short (5 years), medium (10-15 years) and long term (2030 and beyond).

In order to see that the activities set out in the Adaptation Plans are fully embedded within Route activities and receive the appropriate level of priority and funding, the detail will be incorporated within Route Strategic Asset Management Plans and other Route Strategies. In this way, managing weather resilience and climate change will become part of business as usual.

5.3 Streamlining Operational Weather Management

Operational weather management involves planning for seasonal variability, preparation for, response to, and recovery from adverse and extreme weather events as well as activities to mitigate the impact of events occurring as illustrated in *Figure 14*. Mitigation is linked to other areas of this strategy in that it needs to consider how events will differ in the future as a result of climate change.

Figure 14 The elements of operational weather management



Maintenance of assets, particularly vegetation and drainage, is of key importance to reducing the number and duration of weather related incidents. *Regular, targeted, maintenance* is required in high risk areas and those with a history of impacts in order that the impact be minimised. When events do inevitably occur, *rapid response to and recovery* from incidents helps to limit impacts on performance and safety. Streamlining the process, to make it as effective as possible now, will enable us to manage more frequent and severe events in the future.

Network Rail has made progress in improving our operational weather management in recent years. We will continue to enhance current systems and processes through review of effectiveness and lessons learned from incidents. Activities will include:

- Targeted inspections and maintenance activity for vegetation clearance and drainage management to reduce the number and duration of associated incidents.
- Increase collaboration with authorities involved in managing and responding to weather events (e.g. Local Flood Resilience Forums) to enhance coordination before, during and after events. Building on successes in Western and Wessex Routes, we will explore the possibility of having additional jointly funded liaison officers to facilitate working between Network Rail and the Environment Agency in England and other relevant organisations in Scotland and Wales.
- Identifying key locations nationally which could be affected by flooding (now and in the future) and develop contingency plans including availability of workforce in an emergency, access to emergency equipment such as barriers or pumps, and alternative arrangements in case sections of the railway are put out of action.
- Working with analysts, train and freight operating companies and other stakeholders to identify new and innovative approaches to managing the seasonal impact of leaf fall and ice on the conductor rail and future changes in seasonality in order to improve safety and performance.

5.4 Proactive investment

A step change is required to ensure continuous improvements in resilience, particularly given the challenges climate change brings. Investment, over and above core Network Rail funding anticipated over the five to ten years, will be required in order to enable this step change.

Through implementation of Route Climate Change Adaptation Plans and a number of external funding sources, proactive investment in managing flood risk and various other weather impacts such as high and low temperatures, wind and lightning has been made in recent years. Routes will continuously identify high priority locations for resilience interventions and will work to identify funding sources for those projects not included within business as usual asset policy compliance and capex investment.

Given the long term nature of climate change, the benefits associated with enhancements in resilience may not be seen for a number of years making the business case for investment in the short term difficult to justify. One of the key elements of the analytical work discussed above will be better understanding the risk and vulnerability of the network to current and future weather impacts and the cost associated with different options for maintaining or enhancing resilience. Tools will be developed to support robust cost:benefit analysis to support planning for future Network Rail funding cycles. External funding sources will be identified through engagement with government, regulators and others as well as opportunities to leverage additional capital investment through collaboration with stakeholders with an interest in the resilience of the railway (e.g. local flood authorities).

5.5 Track, share and revise

A reporting framework will be developed to enable monitoring of changes in the resilience of the network as well as progress in implementing this strategy. The findings will be shared through regular reporting internally as well as with external stakeholders such as ORR and NTF. Activities will be reviewed and revised in light of trends identified as well as experience and lessons learned in order to course correct as necessary - as decided by the Weather Resilience Group governing activities in this area (discussed in *Section 6*).

Metrics

Existing KPIs and performance metrics reported across the organisation and industry will be drawn on to track those that are affected by adverse and extreme weather conditions. We will work to draw out the weather indicator from metrics as required and will work to improve data completeness, consistency and quality to enable us to rely on the information provided.

Metrics will be used to track adverse and severe weather related changes in the following:

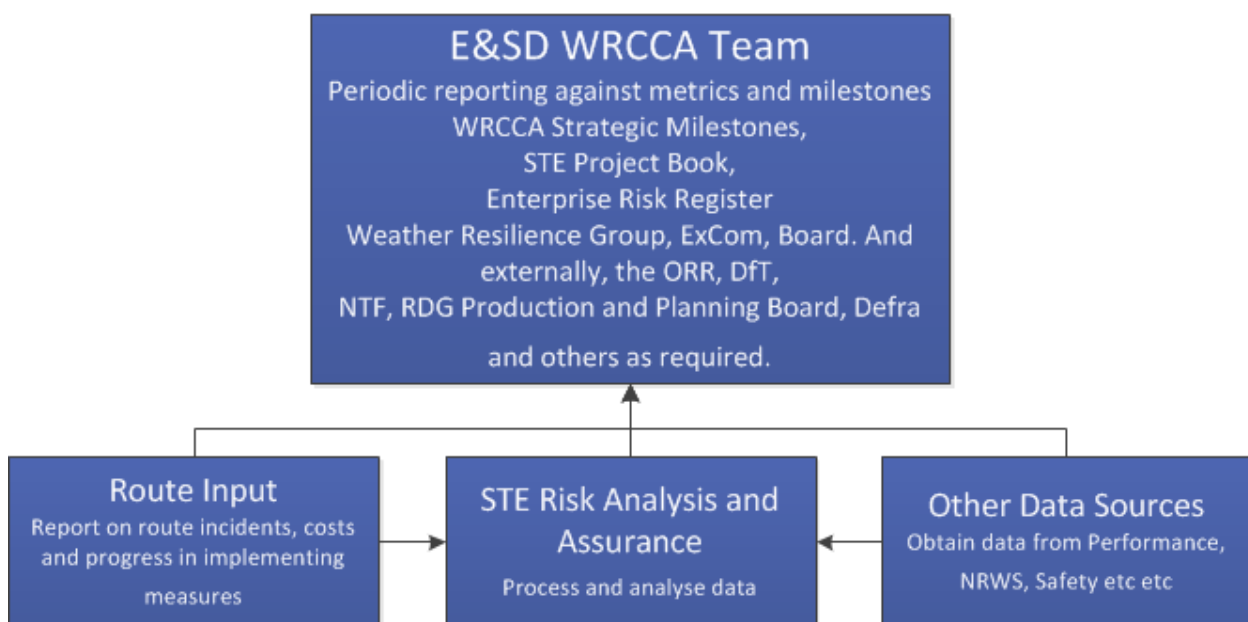
- Performance;
- Delays and cancellations;
- Cost;
- Number and type of incident;
- Health and safety impacts;
- Asset reliability and capability;
- Preparedness; and
- Early warning indicators linked to the enterprise risk register.

Reporting

A reporting framework including the appropriate frequency of reporting (periodic/quarterly/annual) for different metrics based on when trends are observed will be developed as part of implementation of this strategy.

The reporting process will produce a single set of data which will feed into regular reports for the Environment and Sustainable Development (E&SD) team, Safety, Technical and Engineering Directorate, Weather Resilience Group, various Route reports and to external stakeholders such as the National Task Force as illustrated in *Figure 15*. Updates will be provided to the Executive Committee and Board regularly.

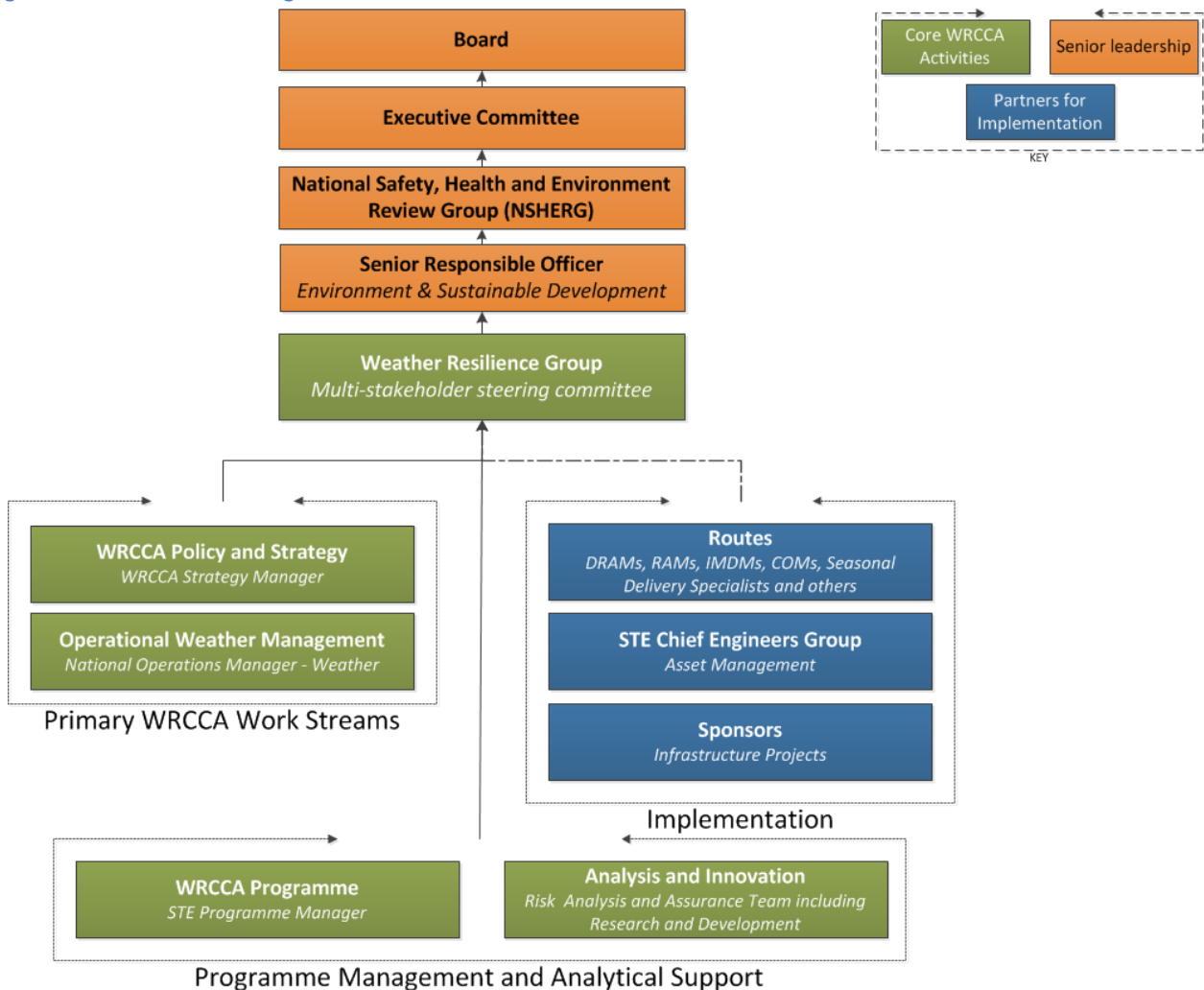
Figure 15 Overview of lines of reporting



6 Responsibility & Accountability

Routes are responsible for day to day operational control of the railway and for planning, prioritising and implementing renewals and enhancements to infrastructure. The centre has a role to play in providing strategic direction, subject matter expertise and coordinating activities at a national level such as processing, analysing and reporting of data. This strategy places clear accountability and responsibility for activities relating to weather resilience and climate change adaptation with those best positioned to make change within the organisation. An overview of the different individuals and groups involved in this work is presented in *Figure 16* with roles discussed further below.

Figure 16 Overview of internal governance framework



6.1 Governance

The Senior Responsible Officer for Weather Resilience and Climate Change Adaptation within Network Rail is the Head of Environment and Sustainable Development (E&SD) within the Safety, Technical and Engineering (STE) Directorate.

Work in this area is governed by the multi-stakeholder Weather Resilience Group (WRG) which provides guidance and direction and a technical sign off before seeking decisions from the National Safety, Health and Environment Review Group (NSHERG), the Executive Committee and the Board.

The WRG is chaired by the Weather Resilience and Climate Change Adaptation Strategy Manager (in the E&SD Team) and comprises members from across the Network Rail including the Chief Engineer Group, Risk Analysis and Assurance, STE Business Management, Network Operations, Infrastructure Projects, Route Asset Management, Planning and Regulation, Strategy and Capacity Planning and others.

Input from government (primarily DfT), regulators (ORR) and from the rail industry (National Task Force and/or Rail Delivery Group Production and Planning Board) will be through quarterly meetings providing updates on the outcome of WRG meetings and other activities and seeking input on proposed work going forward.

6.2 Strategic support

Core activities to facilitate implementation of this strategy will be undertaken by individuals within Safety, Technical and Engineering Directorate and the National Operations Centre.

WRCCA Policy and Strategy – WRCCA Strategy Manager

The Weather Resilience and Climate Change Strategy Manager and their team within the E&SD Team are responsible for:

- Maintaining high-level oversight and providing a central point of contact in Network Rail;
- Co-ordinating activities at strategic level through the WRG;
- Providing expert input to facilitate embedding climate change in policies, procedures and controls;
- Communications and engagement within centre and the routes;
- Engaging with government, regulators and other external stakeholders; and
- Development of competence framework and training materials.

Operational Weather Management – National Operations Manager - Weather

The National Operations Manager for Weather, working with others within the Network Operations Centre and Routes is responsible for:

- Planning and review of processes for operational weather and seasons management through engagement with Routes and train operating companies and the Rail Delivery Group; and
- Facilitating trialling of new technologies, products and materials both train and non-train borne through RSSB and Rail Delivery Group.

Analysis and Innovation

Taking its remit from the Weather Resilience Group, the Risk Analysis and Assurance Team is responsible for:

- Analysis and development of tools to support understanding of risk, impact and economics of weather resilience and climate change adaptation for Network Rail;
- Collating data and reporting on KPIs and metrics on periodic/quarterly/annual basis; and
- Engagement with external research organisations to benefit from multi-agency projects.

WRCCA Programme

Taking its remit from the Weather Resilience Group, the WRCCA Programme Manager is responsible for:

- Managing the programme of projects identified by WRG to support work across all WRCCA activities; Managing the delivery of actions identified in the WRCCA Enterprise Risk Register; and
- Reporting programme and project progress to WRG and SRO.

6.3 *On the ground implementation*

Routes, Asset Heads and Sponsors are responsible for implementing the aspects of this strategy which relate to their area of work as summarised below.

Routes

There are three core areas of Route activity covered by this strategy. Directors of Route Asset Management (DRAM) are accountable for Route implementation of Climate Change Adaptation Plans and this strategy supported by Infrastructure Maintenance Delivery Managers, Current Operations Managers. Responsibilities include:

- Identification and implementation of proactive resilience measures;
- Design for future resilience in line with policies, procedures and controls;
- Regular maintenance and inspection of drainage, vegetation and other assets;
- Operational management of weather including incident response and seasonal preparation; and
- Identify lessons learned and implementing LEAN to improve performance and safety,

STE Chief Engineers Group

Professional Heads of Asset Functions are accountable for assets that are resilient to future weather conditions. Responsibilities include:

- Embedding consideration of future weather conditions within asset policies and controls;
- Supporting analysis of risk, benefits and resilience priorities across the network; and
- Identifying opportunities for enhancing resilience outside business as usual Route activity.

Sponsorship and Project Development Community

Sponsors guide the overarching requirements for Infrastructure Projects and therefore have an important role to play so designs are sustainable and resilient to future weather conditions. Route Asset Managers may act as sponsors for projects developed by Works Delivery. Responsibilities include seeing that:

- A climate change risk assessment is carried out during the early stages of assessment to inform option selection and design; and
- A design is resilient to future weather conditions and incorporates passive provision for future enhancements as required.

6.4 *Information, Education & Building capability*

Given the usually localised nature of the impacts of weather events on the railway, Routes approach their work on enhancing resilience based on past experiences. Climate change is a technically complex subject area and is likely to throw up challenges which have not previously been experienced in certain regions and amplify those that already occur.

Key to effective management of these issues is sharing the latest research and analysis as well as lessons learned in order for the people responsible for implementing resilience measures to benefit from the experience of others and apply best practice on a day to day basis.

A communications plan will be developed to:

- Disseminate the latest analysis providing insights into risks, vulnerability and costs within individual Routes;
- Provide updates on the latest climate change projections and guidance and what this means for work in

different parts of the country;

- Provide regular updates at existing meetings including Directors of Route Asset Management; Integration Group, Periodic Business Review etc.;
- Provide a platform for discussion and information sharing between responsible and interested parties across Routes through web-conferencing and conferences/workshops; and
- Engage with external stakeholders and groups to support and enhance work in this area.

7 Influencing Investment Decisions

This strategy has been developed in recognition of the funding constraints over the next five to ten years and therefore aims to maximise opportunities for enhancing resilience through business as usual activities. However, we will only see a step change in resilience with focussed investment targeted at areas which will deliver the highest performance and safety improvements. Work in the analysis work stream will enable:

- A comprehensive understanding of the cost and benefits (including to the broader economy and society) of undertaking resilience activities;
- Development of the business case clearly demonstrating return on investment aligned with when benefits are likely to be realised; and
- Development of tools to support decision making and prioritisation within Route planning processes.

Collaboration with others could leverage alternative/additional funding sources such as working with environmental regulators, local authorities, and internal drainage boards etc. Having a complete understanding of the business case and investment priorities will facilitate access to grants from DfT and other sources as and when money becomes available.

Network Rail is aspiring to reduce the gap between performance on adverse compared with normal weather days by 1% PPM through improved weather resilience. This will be delivered through increased investment in drainage and vegetation management (0.6% - included within core CP6 asset plans), 0.2% from proactive investment in resilience measures and 0.2% through continuous improvement (e.g. reducing Delays per Incident) and innovative technologies and approaches. This ambition will be reviewed in light of the CP6 settlement, any resultant changes to future performance metrics and further analysis into the causal factors affecting performance – such as the reliability of the infrastructure, timetabling during adverse weather situations etc.

Recognising that climate change brings additional pressure to the railway and in order to achieve the additional 0.4% PPM improvement, a WRCCA Fund is proposed for CP6 to support implementation of this strategy which would be focused on:

- Projects that fall outside the day to day functioning of the railway in order to provide additional resilience (e.g. flood retention ponds; raising low lying embankments susceptible to storm surges / flooding etc.);
- Supporting detailed analysis of climate change risk and vulnerability;
- Developing decision support tools; and
- Identifying innovative resilience technologies and approaches and testing through pilot projects.

This fund is not for any work that should be driven by normal policy or standards. It is not for drainage or vegetation maintenance, asset inventories, emergency response/repairs *post* an event, improving reliability of existing assets against current requirements or enabling new infrastructure to meet future climate change requirements. 10-15% of the total fund will be used to develop the required decision support and pilot projects.

It is anticipated that investment of £150m through the fund will lead to the following direct benefits over 10 years with savings recurring into the future:

- Additional ~0.2% PPM improvement (~£17.6m saving - 0.4% PPM (~£35m) stretch target);
- £40m reduction in cost due to delays and clean-up costs;
- £80m reduction in cancellation and cost of structural repairs; and
- Maintaining weather-related safety risk in spite of increased extreme storm events.

The fund will be managed by the WRCCA Programme and governed by the Weather Resilience Group. Ring-fenced funds will be allocated to individual schemes based on a multi-criteria assessment ensuring that money is focused on projects delivering maximum ***additional*** benefit to Network Rail and to the future resilience of the railway as a whole.

8 Implementation

Actions, timeframes, accountability and responsibilities in relation to implementing the work outlined in this strategy will be set out in a detailed implementation plan. The primary focus will be on work from the WRCCA team in the centre including the following:

- Reporting Framework for tracking progress, resilience and performance
- Data analysis and research requirements
- Pilot studies and other projects under the WRCCA Programme
- Communication framework between Routes and with Centre

The implementation plan will identify specific requirements stemming from this strategy which Routes will be responsible for integrating into their current and future work. The WRCCA team will provide expert guidance, analysis and support as required.

The Weather Resilience Group will sign off the plan and will monitor progress against agreed milestones. The plan will be reviewed every six months and updated as required in response to Network Rail priorities and lessons learned.