Rail
An industry guide to enhancing resilience
ABOUT THE RESILIENCE SHIFT

The Resilience Shift exists to inspire and empower a global community to make the world safer through resilient infrastructure. More people than ever depend on the critical infrastructure systems that provide essential energy, water, transport and communications services, and underpin food, healthcare and education. When this infrastructure fails the consequences can be catastrophic.

Supported by Lloyd’s Register Foundation and Arup, the Resilience Shift provides knowledge and tools for those responsible for planning, financing, designing, delivering, operating and maintaining critical infrastructure systems. Our aim is to ensure infrastructure systems are able to withstand, adapt to, and recover quickly from anticipated or unexpected shocks and stresses - now and in the future.

DEFINING RESILIENCE

Resilience is the ability to withstand, adapt to changing conditions, and recover positively from shocks and stresses. Resilient infrastructure will therefore be able to continue to provide essential services, due to its ability to withstand, adapt and recover positively from whatever shocks and stresses it may face now and in the future.

ACKNOWLEDGEMENTS

This primer is based mainly on a series of in-depth face-to-face and telephone interviews of practitioners and policy-makers working on improving resilience across the rail industry. The authors are grateful to all the stakeholders that provided their time and knowledge to provide input for this primer. These included representatives from Highways England, Transport Scotland, Department for Transport, Rijkwaterstaat, Norwegian Public Road Authority, John Dora Consulting/Infrastructure Operators Adaptation Forum, UK Roads Board, Local Government Technical Advisory Group, Transport Focus and other organisations which prefer to remain anonymous. We would like to thank Juliet Mian, Technical Director of the Resilience Shift. Any errors or omissions are solely the responsibility of the authors, not the contributors.
Foreword

Building resilience of critical infrastructure requires decision-makers working in different industry sectors to understand ‘what’ can be done, ‘why’ it should be done, and ‘how’ to put it into practice. Our work to date has told us that key stakeholders are often either unaware of the value that resilience can bring or are constrained by a lack of resources or support in terms of how to embed and enhance resilience.

This primer is a brief document introducing the elementary principles of resilience relevant to the rail sector and is part of a body of knowledge, tools and approaches that the Resilience Shift is producing, funding, and curating, intended to help those responsible for the financing, planning, design, delivery, operation and maintenance of critical infrastructure systems to shift practice. Our vision is to contribute to a common understanding across critical infrastructure sectors of what contributes to resilience and how it can be achieved in practice.

Building resilience into your infrastructure systems, across your value chains, will allow you to prevent or mitigate against shocks and stresses that you identify, and to respond better to those events that you can’t predict or avoid.

We’re delighted to have supported the team at TRL in producing this primer.

The Resilience Shift team
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Executive summary

We all want a resilient transport system, but what does that actually mean and how does everyone in the industry work together to make it happen? There is no simple solution to this complex problem, but the application of carefully considered levers at different points in the value chain can make a real difference.

Effective transport underpins the economic and social functions of society, and disruption can cause a cascade of impacts including limiting or preventing access to jobs, education and leisure, and essential services such as healthcare. In severe cases, transport disruptions can even affect the GDP of a country. Many transport organisations are working to improve resilience, however, consistently including it throughout the value chain is challenging.

This primer identifies a number of different areas where consideration of resilience can help to create a safer, more reliable and robust rail network. Based on a series of interviews with practitioners and policy-makers, examples of good practice are presented highlighting what can be done to incentivise improvements to resilience. It is hoped that this primer enables sharing of knowledge between similar organisations to encourage increased resilience in practice.

The primer was produced as part of the Resilience Shift initiative funded by the Lloyds Register Foundation and managed by Arup. In producing this document, we saw common problems across many stakeholders, and identified a number of innovative solutions being used in practice.

No one organisation has all the answers, but each has addressed different aspects of resilience in different ways.

Resilience needs to be considered across different activities, project stages and organisations, with many different stakeholders working together to embed it in to everyday practice. Infrastructure owners, government, regulators, suppliers and users of the network each have a role in applying levers to increase resilience. Such levers might include the provision of specific requirements in planning documents, design standards, procurement processes and other regulatory and influencing documents, and employing political and media pressure to promote awareness.
Our recommendations

Six areas of action are identified:

- Changing mind-sets
- Embedding resilience in organisational processes and procedures
- Providing leadership and accountability
- Encouraging systems-thinking and collaboration
- Disaster management
- Risk management

Recommendations and examples of levers are provided under each of these areas in section 6. If rail transport is to become more resilient, each area has to be addressed. Learning from the experiences of other organisations that face similar challenges is a vital part of this.
Introduction

Railway bridge in Cầu Long Biên, Hanoi, Vietnam
The purpose of this primer is to equip practitioners in the rail industry with knowledge that will help you embed resilience in your organisations, by having access to examples and case studies from your sector, and by understanding what drives changes in practice.

WHY READ IT?

Are you already championing resilience within your organisation and looking for information to demonstrate its value and importance to your colleagues?

Are you seeking to champion resilience within an organisation or industry, and looking for information to support your case?

Do you simply want to gain knowledge about the benefits, incentives, obstacles, and trade-offs involved with embedding resilience in this particular industry sector?

CONTEXT

While a common understanding of resilience across industry sectors is essential, and it is well understood that we need to move away from ‘silo’ thinking in the way we approach resilience of critical infrastructure, it is also clear that for individual organisations, working in particular geographies to do things differently, tailored guidance is needed.

The focus of this series of primers is to provide a context specific to a particular industry sector, in this case rail, based on structured interviews and research. The examples are drawn from the UK, but the knowledge and information presented is practical, tangible, and directly relevant to those working in rail, beyond the geographic focus of the study.

APPROACH TO PRIMER DEVELOPMENT

A series of interviews were carried out with stakeholders within the rail industry, including infrastructure owners, policy makers and regulators. They were selected partly as these countries are active in the area of resilience and also because they provide examples of different organisational structures and therefore have different levers. The interviewees provided examples of incentivisation of resilience from their respective countries which are used to illustrate the described levers, but the general principles described are transferable to any country.

A list of questions (one for practitioners and one for policy-makers) was prepared and circulated to the interviewees before the interview along with some introductory information. The interviewers used these questions as a prompt, but were also flexible tailoring the questions to the individual interviewees. The majority of interviewees were carried out by telephone, but a few were carried out face-to-face. On average the interviews took around 90 minutes and all interviews were recorded. Some interviewees provided written documents and the interviews were supplemented by literature review and the teams experience of the industry.

The TRL project team also prepared the road resilience primer, carrying out the road and rail interviews concurrently. Some interviewees’ roles covered the organisational structure and the levers are different. Therefore it was decided to produce separate primers. There are transferable approaches and so some duplication across the two primers where appropriate, but with different examples of implementation.

Although road and rail are discussed in separate primers so as to reach different sets of decision-makers, it is important to consider the transport system as a whole and the interdependencies between modes.

For the purpose of this primer we did not speak to metro organisations, however most of the information captured here, in terms of levers to incentivise resilience, would apply to any type of rail.

Urban rail is specifically covered in the World Bank Urban Rail Development Handbook, particularly Chapter 17: Climate and natural hazard resilience in urban rail projects, that includes information equally applicable to urban overground, metro, inter-urban or high speed rail.
Defining resilience in the rail industry
Why a resilient rail network is important

Transport plays a vital role in society, and its effectiveness directly influences a country’s economic and social success as highlighted by the Eddington Study (2006) in the UK. The railway provides access to jobs, supports tourism and enables goods to reach consumers and manufacturers. Mobility is something the majority of us take for granted until something occurs to limit it.

Multiple natural and anthropogenic hazards can damage infrastructure and impede travel. In the absence of serious injuries and fatalities, the real impacts of these events are economic and social. These include the cost of transport delays and the severance of access to and from communities for services and markets for goods; employment, health and educational opportunities; and social activities.

Widespread, long-term disruption to travel can have a significant economic impact. For example when a section of railway near Dawlish in the UK was damaged by coastal flooding and closed for two months, the cost to the local economy was estimated to be £1.2 billion (BBC News, 2015).
What does the term ‘resilience’ mean to the rail industry?

There is agreement within the rail industry that improving resilience constitutes both increasing the ability of infrastructure to withstand potential threats and also the capability of the system to rapidly recover from disruptive events. When communicating about resilience it is necessary to be sure that everyone has the same understanding of what is trying to be achieved. In this primer resilience is taken to mean a long-term holistic perspective of any threat to the functionality of the transport system.

EXAMPLE RESILIENCE DEFINITIONS

**UK Cabinet Office (2011)** - “Resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to, and/or rapidly recover from a disruptive event.”

**Network Rail** - “Weather resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to, and/or recover from disruptive weather events. Climate change adaptation is action taken to improve the resilience of assets, networks and systems to future weather conditions, avoiding, minimising or mitigating the impact of more severe or frequent adverse and extreme weather events and gradual or erratic changes in weather patterns due to climate change.”

**Resilience Shift** - see definition used by on p.3
Quantifying resilience

The direct benefits of improving resilience include:

- an improvement in safety
- a reduction in travel disruption
- reduced infrastructure damage

Indirect benefits include the ability of individuals, communities, businesses and other physical and social infrastructure that depends on transportation to continue to function. Education, healthcare, food, and other supply chains are all vulnerable to cascading failures in the event of disruption to a critical transportation link.

Quantifying these benefits in economic terms can help to make the business case for improving resilience. Importantly, the benefits of increased resilience are an avoidance of future costs, which is difficult for some to accept as an economic incentive for action especially as it is difficult to prove the cost would have been incurred if no action had been taken. Cost-benefit analysis (CBA) can help to make the case for preventative action. CBA is structured to monetise the avoidance of future costs, define these as benefits, and compare these benefits against costs of specific actions. Where benefits outweigh costs, decision-makers should be incentivised to invest. It is important to note, however, that the boundaries and appraisal period of the CBA are particularly important when evaluating actions to improve rail resilience.

The main costs of improving resilience are typically borne by the infrastructure owners, who are most interested in the future costs and benefits affecting their own budget. However, the wider socio-economic costs of travel disruption are far larger than the economic costs borne by the infrastructure owners, and payback times for preventative action can be long-term (i.e. outside budgetary timeframes or traditional appraisal periods). Limiting the analysis to direct costs and short appraisal periods can fail to take into account the full benefit of an action. Also risks are not always fully incorporated into economic appraisal, and are often underestimated.

Whilst CBA can help to highlight the benefits of greater resilience, it is often not sufficient to change behaviour. In the construction industry concepts such as value engineering can be misapplied to reduce initial costs by removing aspects of a project which may be required only rarely (i.e. to address low frequency, high impact events). More direct incentives need to be created to counteract this, and the purpose of this primer is to highlight some of the ways this can be done.

The market will never provide resilience because the market always goes for efficiency.

Source: Anonymous
Embedding resilience in rail infrastructure and its management

To effectively increase the resilience of rail transport, consideration of resilience needs to be embedded in the industry. The primer’s focus is on the resilience of rail infrastructure, which includes a wide range of asset types such as track, bridges, tunnels, earthworks and slopes, stations, signalling, depots and so on. The physical infrastructure cannot be separated from the other aspects of the operation and governance of the rail network and the interdependencies with other sectors. It is the resilience of the system as a whole which is important to the user. Therefore these aspects are also discussed within the primer.

Figure 1 depicts a typical value chain of a large infrastructure project, showing the different project stages from proposal to delivery. At each stage decisions are made that influence the resilience of the infrastructure, often involving different stakeholders working in collaboration.

**Initial proposal stage** - decision-making is centred on the policy need and how best to meet this. This includes the case for investment, the objectives (i.e. the benefits expected from the project), and the major design options available e.g. bridge or tunnel. These types of high-level decisions are normally made by national government, and are influenced by local communities groups and businesses. It is more effective if resilience is fully integrated in a project from the start, for example by inclusion in the project objectives and being considered in major design options, so this is an important stage in the value chain.

**Planning and appraisal stage** - options are further developed and then evaluated in terms of their economic, social and environmental impacts. This is normally carried out by the infrastructure owner in conjunction with government, and follows national appraisal guidelines. The resilience of both the infrastructure being built/ upgraded and the impact the project has on the resilience of other infrastructure and communities should be considered. Planning consent often involves public consultation, so any group or individual is able to influence the project.

**Detailed design** - is carried out after an option is selected, with decisions being made on design and materials by the infrastructure owner and (depending on the type of procurement) supplier. Procurement decisions are also made by the infrastructure owner in terms of procurement type, supplier requirements and supplier selection. Resilience can be embedded by using more robust materials and design better able to withstand different hazards, by incorporating features which make it easier to repair if damaged or update if conditions change and by including it in procurement processes.

**During construction** - the planned design and materials may need to be adjusted by supplier, with the agreement of the infrastructure owner, to fit the actual conditions. When complete, the infrastructure owner signs-off the new asset and it enters into use. Although, most major decisions have been made by this phase of the project there are still opportunities for modifying designs to increase resilience. Also care needs to be taken that aspects included in the design to increase resilience are not eroded due to pressures on time and budget.

**Maintenance and operation** - decisions relating to existing assets relate to maintenance of deteriorated infrastructure and the operation of the network, these are made by the infrastructure owner and their supplier. Resilience can be included in prioritisation of maintenance and improving response to incidents.
Improving resilience of rail networks requires integration into decision-making at all points of the infrastructure lifecycle, and there are a range of different types of organisations and individuals that contribute to these decisions (see Table 1). The interactions between these stakeholders are particularly important for determining resilience.

<table>
<thead>
<tr>
<th>STAKEHOLDER TYPE</th>
<th>DESCRIPTION/EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>USERS OF THE INFRASTRUCTURE</td>
<td>Train and freight operating companies are the direct customers, but ultimately it is the general public and a multitude of different businesses.</td>
</tr>
<tr>
<td>OWNERS/OPERATORS OF THE INFRASTRUCTURE</td>
<td>The majority of rail infrastructure is owned by the state, for example through publicly-owned companies. There is a limited number of privately or community owned railways, usually heritage railways for tourists.</td>
</tr>
<tr>
<td>GOVERNMENT DEPARTMENTS/MINISTRIES</td>
<td>Most countries have a central government department/ministry responsible for transport. The level of influence they have depends on the organisational structure, e.g. if the infrastructure organisations is an arms’ length company.</td>
</tr>
<tr>
<td>REGULATORS/MONITORS</td>
<td>There may be one or more regulators or watchdogs. For example the Office of Road and Rail is the independent statutory body responsible for the safety and economic regulation of British railways. Transport Focus is a public body which acts as a watchdog for railway users in England, Scotland and Wales.</td>
</tr>
<tr>
<td>EMERGENCY SERVICES</td>
<td>In the case of an incident often transport police, ambulance and fire services would be involved in its management.</td>
</tr>
<tr>
<td>OTHER GOVERNMENT AGENCIES</td>
<td>Depending on the type of hazard other government agencies may be involved. For example for large scale flooding in England the Environment Agency would be a key stakeholder. Meteological organisations, national health service, government departments involved in civil protection could also be involved. For severe incidents government ministers would play a role.</td>
</tr>
<tr>
<td>LOCAL GOVERNMENT/MUNICIPALITIES</td>
<td>Local government is a key stakeholder for any incident that occurs within its boundary. It is also often the planning authority, so able to influence new construction.</td>
</tr>
<tr>
<td>CONTRACTORS/SUPPLIERS/OPERATING COMPANIES</td>
<td>Private companies are often contacted by the infrastructure owner to manage, maintain, construct and design infrastructure on their behalf. Their responsibilities depend on the type of contract.</td>
</tr>
<tr>
<td>COMMUNITIES AND LOCAL BUSINESSES</td>
<td>Local communities and businesses are affected by travel disruption. They can exert pressure for improvements in resilience.</td>
</tr>
<tr>
<td>TECHNICAL ADVISORY BODIES</td>
<td>Some countries have publicly-owned organisations which offer technical advice for example the Rail, Safety and Standards Board (RSSB) in the UK. These organisations may not have direct control over the industry but their advice and guidelines influence government and industry decision-making.</td>
</tr>
<tr>
<td>ROLLING STOCK MANUFACTURERS AND OPERATORS</td>
<td>A rolling stock operating company (ROSCO) leases the rolling stock to the train and freight operating companies. The design and condition of the rolling stock affects the resilience of the railway.</td>
</tr>
<tr>
<td>EXTERNAL FUNDERS</td>
<td>Whilst the majority of rail infrastructure construction is funded by government and users of the infrastructure, in low and middle income countries there may be investment from external funding organisations such as international development banks or foreign governments. Provision of funding may have resilience requirements associated with them.</td>
</tr>
</tbody>
</table>

Table 1: Types of rail stakeholders
3 Vulnerabilities in the rail industry
Rail infrastructure has always been subject to a wide range of threats to its physical condition, safety of users and level of service. However, in today’s society the number of threats and the potential level of impact are greater than ever. Increasing travel demand, terrorism, climate change and ageing infrastructure combine to make the impacts of transport disruption felt throughout society.

As discussed in Section 2.1, rail transport is a vital enabling sector, and disruption can produce a cascade of impacts across different sectors:

- Disruption of major commuter routes, especially long term or repeated disruption can have significant economic impacts as result of lost working time. There are also social implications for passengers such as loss of employment, difficulties with child care, reduction of personal time, increased stress etc.
- Widespread power outages may occur as it is not possible to deliver fuel (e.g. coal) to power stations, affecting businesses and industry as well as private residences.
- Freight train delays affecting ‘just-in-time’ industry supply chains and causing a shortage of some materials, for example building materials such as aggregates are often transported by rail and disruption could impact on the construction industry.
- Freight and passenger transport may be unable to reach major transport hubs, such as ports and airports, blocking imports/exports and international travel.
- It could cause a shift to road transport causing congestion and increased environmental impact.

The types of threat to the functionality of railway can be divided into three types:

<table>
<thead>
<tr>
<th>Planned events</th>
<th>Such as major sporting events, political visits, maintenance work and known times of high demand such as Christmas and bank holidays.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unplanned events</td>
<td>Such as those due to severe weather flooding, landslides, avalanche, etc. (some warning of severe weather may be given by forecasts), earthquakes, fire, accidents, terrorism, pandemics, industrial action, trespass, infrastructure or rolling stock failure.</td>
</tr>
<tr>
<td>Changes</td>
<td>In climate, technology, transport demand, mobility trends, political environment, public expectations and government requirements over time.</td>
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Each category of threat can create shocks (sudden events of short duration) and stresses (more gradual onset and longer duration) to the rail system. The stresses may be short-term e.g. a week of standing water as a result of flooding or high demand due to a sporting event, or long-term such as higher summer average temperatures or establishment of a new technology.

Dealing with accidents, infrastructure failures, periods of high demand, adverse weather etc. effectively is a routine part of rail network operations, but less frequent, large scale events can cause enormous disruption and damage. Often problems are caused by a combination of events, e.g. heavy snow and infrastructure failure. Disruptions can also cascade with delays in one location creating a cascading impact across the network. Rail timetables are often at capacity, so any small delay can have a large impact affect large proportion of the network, as demonstrated in the EPSRC project FUTURENET (2013).
Planned events

Major sporting, demonstrations and political events can cause transport disruption, through increased demand and security restrictions. These are normally short-term, but in some cases can last several weeks. As they are known in advance, mitigation actions can be put in place for the period of expected disruption.

EXAMPLES OF DISRUPTION FROM PLANNED EVENTS

Olympic Games in 2012, London

During the 2012 London Olympic Games an additional three million journeys were expected (25% more than normal). Actions to mitigate the impact included a campaign to dissuade unnecessary travel in the affected areas, suspension of engineering work, dedicated games lanes, exit only metro stops and extra staff to direct passengers.

G8 Summit in 2013, Northern Ireland

At the G8 summit in Northern Ireland in June 2013 protests and security precautions caused travel delay and disruption. Extra buses and trains were arranged to reduce the number of rail users and the public were warned to avoid the area if possible.
Unplanned events

The most disruptive events are the unplanned which could be due to severe weather, unexpected infrastructure failure or concern of failure, protests or strikes, terrorism and vandalism. Some examples of these are provided below. All the events described below were covered extensively in national and international press and discussed at the highest political levels. They also all led to improvements in the way the type of hazard is managed in the country concerned and in some cases internationally.

**EXAMPLES OF DISRUPTION FROM UNPLANNED EVENTS**

<table>
<thead>
<tr>
<th>TYPE OF HAZARD</th>
<th>EXAMPLE</th>
<th>IMPACT</th>
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</thead>
<tbody>
<tr>
<td>Terrorism</td>
<td>Madrid Train Bombings – 2004, Spain</td>
<td>Traffic disruption, Potential safety concern, Economic costs, Political repercussions</td>
</tr>
<tr>
<td></td>
<td>In March 2004, terrorists detonated bombs on four commuter trains in Madrid during the morning rush hour; claiming the lives of 193 people and injuring more than 2,000. The attack caused an estimated financial cost of 200 million Euros and disrupted travel for millions of passengers. Following this security of surface transport was tightened not just in Spain, but throughout Europe.</td>
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<tr>
<td>Infrastructure failure</td>
<td>Derailment at Grayrigg – 2007, UK</td>
<td>Loss of life, Travel disruption, Infrastructure damage, Financial implications (fine), Reputational damage</td>
</tr>
<tr>
<td></td>
<td>In 2007 a passenger train derailed near Grayrigg in Cumbria, killing one person and injuring 89, some seriously. The derailment also damaged the Overhead Line Equipment (OLE) resulting in a number of other trains coming to a halt and all signalling equipment immediately turning to danger (red) in accordance with the system’s fail safe design. The line was closed for two weeks to remove the train and replace the OLE. The cause of the accident was deterioration of points as a result of three factors; a mechanical failure, an incorrect set up of the points and a missed track inspection. Following the accident Network Rail checked all other points on the network (over 700), but no others had the same three factors. Network Rail was fined as a result of the safety failings and track inspection procedures were improved.</td>
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<tr>
<td>Extreme weather</td>
<td>Flooding – 2011, Thailand</td>
<td>Loss of life, Infrastructure damage, Economic impacts</td>
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<td>In 2011 Bangkok experienced severe monsoons causing over 800 deaths and direct costs estimated at USD 45 billion. Despite extensive flooding this the city metro and overground trains continued to function due to resilient design features, such as locating station entrances 12 metres above ground. (World Bank, 2018).</td>
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<tr>
<td>TYPE OF HAZARD</td>
<td>EXAMPLE</td>
<td>IMPACT</td>
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</tr>
<tr>
<td>Extreme weather</td>
<td>Hurricane Sandy - 2012, US</td>
<td>• Loss of life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Traffic disruption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Infrastructure damage</td>
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<td></td>
<td></td>
<td>• Economic impacts</td>
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<td>Hurricane Sandy was one of the most costly extreme weather events in US history, causing $70bn in damage and claiming hundreds of lives along its path. The 2012 event destroyed 650,000 homes, led to power outages for 8 million residents as substations flooded and falling trees struck power lines, flooded major cities, grounded more than 15,000 flights, submerged the New York subway system and shut down rail and road public transport operations, and led to the closure of major roads and bridges. The subway system was severely affected, although it has pumping systems in place which remove rain and ground water the power outages prevented these pumps from working. In preparation for the storm the Metropolitan Transportation Authority moved buses and trains to higher ground, blocked subway entrances and ventilation grates, deployed pump and drainage crews, prepared emergency response vehicles and staffed their Incident Command Control Centre to coordinate and manage response activities.</td>
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<tr>
<td>Extreme weather</td>
<td>Damage to coastal railway – 2014, UK</td>
<td>• Travel disruption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Repair costs</td>
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<td></td>
<td></td>
<td>• Economic impact</td>
</tr>
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<td></td>
<td>In 2014 a major storm led to sea wall failure which caused coastal railway track to be swept away, cutting off routes between Devon and Cornwall to the rest of the UK. This led to a two month route closure from February to April. The incident cost to Network Rail was at least £65m with disruption payments an additional £28m. The repairs included laying new tracks, cabling, debris removal, reinforced sea wall defences with a design life of 200 years. This event raised the national awareness and government recognition regarding the vulnerability of historical assets to extreme weather events, especially for coastal railways. The closure of the Dawlish section of track was estimated to cost up to £1.2 billion to the local economy.</td>
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<tr>
<td>Earthquake</td>
<td>Kaikoura Earthquake - 2016, New Zealand</td>
<td>• Loss of life</td>
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<td></td>
<td></td>
<td>• Costly infrastructure repairs</td>
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<tr>
<td></td>
<td></td>
<td>• Travel disruption</td>
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<td></td>
<td></td>
<td>• Economic impact</td>
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<td></td>
<td>In November 2016 a 7.8 magnitude earthquake struck the northeast region of New Zealand’s South Island, triggering 5000 landslides across 21 faults. The earthquake directly impacted the Main North Line railway and the State Highway 1, requiring the repair of 3300 road and rail assets. On top of the physical damage caused to property and businesses, local communities were isolated as all road and rail routes had been compromised. State Highway 1 took 13 months to recover and repair. The Main North Line railway took 10 months to repair to a point where limited freight services could resume operations; however it took until summer of 2018 before passenger services could resume. The costs of repairing the road and rail assets are estimated to have been $1.2bn.</td>
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<tr>
<td>Infrastructure failure of</td>
<td>Morandi Bridge Collapse - 2018, Italy</td>
<td>• Loss of life</td>
</tr>
<tr>
<td>third party asset</td>
<td></td>
<td>• Costly infrastructure repairs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Travel disruption</td>
</tr>
<tr>
<td></td>
<td>In August 2018 a large section of the Italian Morandi Bridge collapsed into the Polcevera River and onto underlying railway tracks after a period of heavy rainfall; claiming the lives of 43 people. Demolition and reconstruction works began in early 2019 and are estimated to take 12-15 months to complete. The collapse impacted two key railway lines which took seven weeks to return to service and significantly impacted the regional economy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Economic impact</td>
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</table>
Trends

Whilst new technology or mobility models emerging from the private sector can be beneficial, they can also be disruptive. It is not always easy to predict technology developments, how quickly they will be adopted and the impact they will have. They can also present new vulnerabilities, such as the opportunity of cyber-crime when digital technology such as European Railway Traffic Management System (a continuous communication-based signalling system) is installed.

Another important trend is climate change, which is expected to increase the frequency and magnitude of extreme weather events, cause sea level rise and changes in the timing of events such as snowfall. Whilst climate models provide an indication of the types of changes to be expected, there is still a high range of uncertainty in climate projections especially in the longer term. It is also unclear exactly how these climatic changes will impact on infrastructure. Many weather-related failures are complex, with multiple risk factors in addition to climate. More frequent extreme events can also mean there is less time for infrastructure owners to recover between events (see Figure 2).

An increase in demand as a result of sustainability policies to shift from road to rail is also an important trend.

"Technology is changing so rapidly you get a very big impact as a result of obsolescence in some areas. So you may have historic data and models, but looking back, the technology is different to what we're going to be expecting in the future. Just like smart phones – they just keep changing."

Source: anonymous
4 Potential levers for incentivising resilience
There are various levers that are available for different industry stakeholders to influence the resilience of rail infrastructure systems. The use and effectiveness of these levers depends on:

- Who funds and manages the infrastructure
- The degree of autonomy that owners have
- The flexibility of industry standards and client specifications
- Availability or otherwise of alternative routes (i.e. competition)
- Ability of end users to influence decision

Figure 3 depicts the key rail stakeholders and the levers available to them to influence resilience. Although there are some similarities between countries/organisations, the available levers to incentivise resilience and the level of influence of different types of stakeholder depend on the organisational structure. There are large variations in the way transport infrastructure is managed between countries, transport modes, regions within countries and different contract types. This results in differences in the available levers and the level of influence of different organisation types. This primer seeks to provide overarching insight and evaluation with specific examples of best practice from the interviewees from across different types of infrastructure management. Differences in organisational structures may mean that not every lever identified is applicable for all situations. It is also noted that some countries are going through major changes in the way their infrastructure is managed. This presents both challenges and opportunities in terms of improving resilience.
The levers open to various stakeholder types are summarised below. Examples of the levers being employed are given in Section 5.

**GOVERNMENT AND REGULATORS**

In general national or regional government own railway infrastructure whereas the companies operating rolling stock may be publicly or privately owned. For example Network Rail own and operate the railway infrastructure in England, Scotland and Wales (not Northern Ireland.) The UK Department for Transport provides rail policy for England and Wales, and Transport Scotland the rail policy for Scotland. Transport for London owns and manages the underground and overground rail services within London. The funding for Network Rail is from a mixture of UK and Scottish government grants, track charges and commercial income e.g. from station retail. The Office of Rail and Road (ORR) is the safety and economic regulator.

Government and regulators are the main incentivisers for rail infrastructure resilience and set the overall performance requirements. The levers open to them for influencing resilience include:

- **Legislation and regulation** – how specific these are varies by country. In the US, changes to transport legislation needs to be approved by congress (this means transport requirements can become political, e.g. when referring to climate change). The UK Climate Change Act 2008 provides the power for the government to ask key organisations to report on their climate change adaptation activities. UK Civil Contingencies Act 2004 sets out duties of category 1 and 2 responders. The Norwegian Planning and Building Act requires risk and vulnerability assessment to be carried out as part of the planning process. In the US, the Fixing America's Surface Transportation (FAST) Act requires resilience to be taken into account during transport planning.

- **Planning requirements** – Since 2014 in the EU Environmental Impact Assessments are required ‘to assess likely significant effects of a project on the environment, including vulnerability of the project to climate change and to major accidents and disasters’. Local planning authorities can also set planning requirements for infrastructure which can include resilience. In the UK a number of National Policy Statements include aspects of resilience, e.g. Planning Policy Statement 25 on development and flood risk.

- **Licence or service level agreements** – Depending on the type of organisation infrastructure owners can have statutory requirements included in their licence or service level agreements (see National Infrastructure Commission, 2019). These help those working on improving resilience to convince colleagues for the need for action.

- **Performance indicators and metrics** – Performance targets may be agreed with government e.g. as part of a licence agreement or published metrics may highlight areas of poor performance affecting reputation.

- **Financial incentives** – Access to certain government funding sources can depend on actions to improve resilience.

- **Fines** – Infrastructure owners can be fined for not meeting performance targets by regulators.

- **Political pressure** – Government can ask questions either publicly in parliament, audits or expert reviews or at an individual level regarding resilience. This can impact on the infrastructure owner’s reputation if this is taken up by the media. Ministerial and public/media pressure are usually in reaction to a specific event. In Scotland in 2010 the transport minister resigned over comments on the response to heavy snow. This ultimately led to a number of changes to improve resilience.
INFRASTRUCTURE OWNERS AND MANAGERS

Infrastructure owners and operators are influenced by Government and regulators, but also pass down requirements to supply chains. They also set policies and action plans regarding resilience. They influence suppliers via:

- **Design standards** – these may specify acceptable designs or be performance based
- **Procurement processes** – tender specifications, evaluation criteria and contract requirements for construction and term maintenance contractors.
- **Contractor performance indicators** – there may be financial penalties for not reaching these.
- **Refusal to take ownership** – (for the purposes of maintenance) of infrastructure built without taking resilience into account.
- **Awards** – recognition of good practice by contractors.

OTHER STAKEHOLDERS

Industry associations can influence resilience through:

- Code of practices and industry guidance
- Awards and recognition for good practice
- Training and awareness raising

SUPPLIERS

Contractors can improve resilience as a result of a desire to be ahead of the competition and enhance their reputation. Private organisations also have a legal obligation to disclosure risks to investors. A recent international initiative called the Task Force on Climate-related Financial Disclosures (TCFD) aims to increase transparency by encouraging companies to report on climate related risks. This includes both the impact of a changing climate on their business and also the effects of transitioning to a low carbon economy. This was not mentioned by any of the interviewees (which were representatives of infrastructure owners and government) as the risks to suppliers are outside their remit. However any industry-wide risks to their supply chain will inevitably affect them in the long-term.

USERS OF THE INFRASTRUCTURE

Customers to some extent rely on government to represent their interest, but can also exert influence via:

- Social media, political representatives, customer surveys, user watchdogs, community groups and industry associations
- Not using services (e.g. switching to road)
- Litigation if their legal rights have been violated

Customers can be influenced by educational campaigns, e.g. to take water with them during hot weather.
THE ROLE OF DEVELOPMENT FUNDING

Whereas the majority of rail infrastructure construction is funded by national government, in low and middle income countries (LMIC) external organisations such as the World Bank, European Bank of Reconstruction and Development (EBRD) and national aid agencies may provide development funding for rail infrastructure construction. Many LMIC suffer from frequent natural and anthropogenic disasters and are less equipped to deal with them than higher income countries, due to lack of resources and less mature government structures. Dealing with these risks is part of development banks’ remits, and they have allocated funds to addressing these including specific funds to help countries adapt to climate change. Development banks have funded technical support to help develop institutional capacity to better deal with disasters and also wish to protect the investments they make in physical assets such as transport infrastructure. For example World Bank projects are now screened for climate and disaster risk and it has created tools to make this assessment more consistent (World Bank, 2019). Other development banks e.g. the African Development Bank, Asian Development Bank and EBRD are in the processes of introducing similar requirements. Loan agreements financing infrastructure construction may include requirements designed to limit future risks.
Train in Rudra Nagar Colony, India (Photo by Belur Ashok, Flickr.com)
5 Current resilience practices in the rail industry
General overview of resilience penetration

Awareness of the concept of resilience within the rail industry has increased enormously over the last six or so years. Prior to this, enhancing resilience was implicit in actions to improve infrastructure robustness and reduce delay, but it was less explicitly highlighted as an area of focus. Over the last few years, roles and teams explicitly established to address resilience have appeared within both infrastructure owners and incentiviser organisations. The term has also changed from being used mainly in terms of addressing terrorism to become a universal term relevant to all types of threat. Reference to ‘climate resilience’ in particular has grown over the past few years and there are now numerous rail policies, organisational documents and research projects which highlight this topic. A quick search using a common research search engine for the terms transport and resilience shows the dramatic increase in use of the term since 2012 (Figure 4).

As recognition of the concept of resilience and its importance has grown, there has been a growth in actions to embed it in rail decision-making. Actions which improve resilience may not always be recognised as such and may instead be understood in terms of reducing delay and the likelihood of infrastructure failure. Although these isolated actions contribute to resilience, a more thorough understanding of resilience and the need to address the system as a whole and consider the long term produces a more consistent and holistic approach to resilience.

The following sub-sections highlight how resilience has been addressed consciously in the different business areas of the industry. It is difficult to truly benchmark organisations as the infrastructure owners are unique; there are no direct comparisons for organisations such as Network Rail for example, other countries have different infrastructure and organisational set-ups. However it is possible to identify areas where organisations have made some recent changes to improve resilience, and in many cases these are transferable to other organisations. The organisations interviewed are in general more aware and active than many of their peers.
Strategic/organisational

Examples of levers being used in practice to incentivise resilience at a strategic or organisational level include:

**HIGH LEVEL ACCOUNTABILITY FOR RESILIENCE**

Rail infrastructure is mainly owned by the public sector, and therefore there needs to be high level government accountability. For example the Deputy First Minister is responsible for resilience in Scotland. Government has several avenues open to it to ask questions regarding rail resilience.

**EXAMPLES OF GOVERNMENT OVERSIGHT FROM THE UK**

- In summer 2018, an Environmental Audit Committee questioned senior staff from several infrastructure owners on their response to heatwaves.
- The UK Climate Change Act 2008 gives the Secretary of State the power to direct reporting authorities (bodies with ‘functions of a public nature’ and ‘statutory undertakers’ which includes rail organisations) to produce reports on what they are doing to adapt to climate change.
- In 2014 there was a government review of transport resilience (the Brown Review) (Department for Transport, 2014).

**EXAMPLE OF HIGH LEVEL RESILIENCE TARGET FROM THE NETHERLANDS**

The Dutch Government has set a target in the Delta Programme for the country to become climate resilient by 2050. This means having the right policies in place by 2020 and then making sure critical infrastructure is less vulnerable to climate change. The Delta Programme was originally focused on flood management, but from 2018 has been expanded to include climate resilience in spatial planning. This expansion includes the MIRT (Multi-year Programme for Infrastructure, spatial planning and Transport); a series of collaborative projects on improving the physical environment, for example by adaptive planning.

Reputation was cited by many of the interviewees as one of the most powerful drivers for improving resilience, and having to answer to government (especially publicly) is an important incentive especially for public sector organisations. Therefore government has to be both accountable itself and challenges the industry on its performance.

*Nobody wants to be told they’re doing badly or not doing what they set out to do*

Source: Anonymous
“Having a defined performance specification with defined targets for performance is good as you can see trends. Having a separate organisation that is looking at the trend and is challenging you, focuses attention and rightly so.”

Source: Anonymous

INCLUSION OF RESILIENCE IN LICENCE/SERVICE AGREEMENTS

Resilience can be included in an infrastructure owner’s duties/role by including it in the legislation or licence agreement which establishes it as an organisation and sets out its statutory responsibilities. For example there is a clause in the High Level Output Specification (HLOS) for Network Rail in relation to threats.

ORR monitor Network Rail’s compliance with the HLOS and in the past has applied pressure to Network Rail on resilience issues, for example in its Network Rail Monitor document for Scotland Quarter 1 of Year 5 of CP4. It said that “Last year’s exceptionally wet autumn and winter weather exposed weaknesses in Network Rail’s management of earthworks and associated drainage. … Network Rail has now changed its management processes in the event of extreme wet weather” (see Wilcock et. al., 2013)

ORGANISATIONAL METRICS AND TARGETS

Organisational metrics and targets related to resilience can be set by governments to incentivise behaviour. It is difficult to develop one resilience metric, but there can be several metrics within a suite of measures which indirectly incentivise different aspects of resilience for example in terms of reducing travel delay, speed of dealing with incidents and taking action to increase the robustness of infrastructure. These proxy indicators do not fully encompass the true nature of resilience (particularly the long term aspects), but can be part of the approach to encouraging greater resilience.

Metrics focus an organisation on a particular aspect of performance and gathering the data to inform metrics can also reveal gaps in data and knowledge. This lack of asset information can impact resilience, for example a lack of knowledge of drainage condition can impede efforts to reduce flood risk. Therefore even if targets cannot be set, the very act of measuring different performance aspects, monitoring trends and publishing this information can incentivise behaviour.

EXAMPLE OF PERFORMANCE METRICS

Public Performance Measure and Cancellations and Significant Lateness are the two main performance metrics related to journey delay. There is a target set for England and Wales of 92.5% of journeys being within 5 minutes of their scheduled time (or 10 minutes for long distance). Also 2.2% trains which fail to run or stop and scheduled stops of arrive 30 minutes or more late than planned. (Targets are for 2011/12 to 2018/19 – control period 5). Both Network Rail and the train operating companies influence these targets as they are for the whole railway system. Many factors influence these metrics such as severe weather, industrial action, infrastructure failure etc.
INTERNATIONAL STANDARDS AND GOOD PRACTICE

At an organisational level, obtaining international standards such as ISO 31000 risk management, ISO 55000 asset management and ISO 14001 environmental management can incentivise improvements to resilience, for example ISO 55000 advocates a risk-based approach to managing assets. There is also a new international standard ISO14090 ‘Adaptation to climate change - principles, requirements and guidelines’ being introduced in summer 2019. In addition to reputation impact of obtaining these standards, the requirement to have them can also be stipulated by government.

“Asset management translates the organisation’s objectives into asset-related decisions, plans and activities, using a risk based approach.”

Source: ISO 55000

In addition to the organisational international standards there are project specific national and international award schemes, for example CEEQUAL which require elements of resilience to achieve a high award level. These help to highlight good practice, proving an incentive in terms of enhancing reputation and helping to spread good practice.

ESTABLISHING DEDICATED RESOURCES FOR ENCOURAGING AND COORDINATING RESILIENCE ACTIONS

Several organisations including government departments have a dedicated person or team to encourage and coordinate its internal resilience actions and liaise with external parties in relation to resilience. This also helps to establish accountability and develop a chain of responsibility. For example the UK Department for Transport recently established a cross-modal resilience team which provides more focus on resilience across the organisation and Network Rail has a dedicated weather resilience and climate change adaptation team. These individuals are not the only people responsible for resilience within the organisation, but act as coordinators and drivers of resilience improvements.

These resilience champions can also be involved in multi-organisation dialogues for example as part of the Rhine alpine corridor group where there are transnational discussions between neighbouring countries and in European groups e.g. UIC (International Union of Railways), ALICE (Alliance for Logistics Innovation through Collaboration in Europe). Benchmarking performance with other countries can create an incentive for improvement.

We’ve created a resilience team recently to give some special focus to that. It’s an opportunity to look at it properly and really spend some time on it.

Source: Anonymous
Rail infrastructure has multiple interdependencies with other sectors including electricity, telecommunications, water/drainage and adjacent landowners. Resilience requires systems thinking and a geographic approach rather than focusing solely on one type of asset, which is in contrast to the division of responsibilities across different organisations. Several countries have fora for cross-sector discussions on resilience including the Infrastructure Operators’ Adaptation Forum and local resilience fora in the UK and the National Hazard Forum in Norway. There are also transnational organisations such as UIC (an association of railway organisations) which have commissioned research on common challenges associate with resilience in the rail industry.

**USING RESEARCH, DATA AND TOOLS TO SUPPORT RESILIENCE**

Many public sector organisations have been carrying out research to provide the data and tools to support efforts to improve resilience. For example the Delta Programme in the Netherlands is a government-led collaboration which is focused on flood prevention and climate proofing spatial planning. UIC has commissioned two projects related to climate resilience (Adaptation of Railway Infrastructure to Climate Change and RailAdapt) and the UK rail industry has also commissioned its own research on resilience such as the RSSB funded Tomorrow’s Railway and Climate Change Adaptation projects, which produced recommendations in relation to a number of topics including metrics, economic appraisal, spatial tools, cross-organisation collaboration and future research.
Operational

Including resilience in operations is about prevention, preparedness, response and recovery. This is a cyclic processes and effective communication underpins all of these activities. Organisational responsibilities in relation to disaster/incident management may be set out in legislation (e.g. the duties of category 1 and 2 responders are defined in the UK Civil Contingencies Act), industry standards (e.g. the GB Railway Group Standard GO/RT3118 sets out requirements in respect of Incident Response Planning and Management) or individual contracts. There are also industry guidance documents that address specific issues such as the Rail Cyber Security Guidance to Industry. The following are examples of levers incentivising improved resilience in relation to rail operations.

**PREVENTION**

Preventative actions include raising signal boxes to minimise flood damage, painting parts of the rail white so they absorb less heat and attaching heaters to signal points to stop ice formation. These actions are driven by indirect incentives to reduce delay e.g. performance targets and reputation rather than direct requirements. Informing customers (see Figure 5) of actions taken can help to improve understanding and reputation.

![Figure 5: Trains use high-powered water jets to blast leaf mulch off the tracks (left) and informing customers of prevention actions (right) (Images from Network Rail)](Image from Network Rail)
PREPAREDNESS

Some examples of preparedness are: ensuring the appropriate equipment is available (e.g. inflatable temporary flood barriers, snow ploughs), installing severe weather warning systems and preparing action plans for different types of emergency.

Part of preparedness is ensuring that the right tools and resources are available during an event, for example access to real time data on weather. Training of staff is also part of preparedness and there is a requirement for category 1 and 2 responders to take part in training exercises in the UK Civil Contingencies Act (Network Rail is a category 2 responder).

If forecasts suggest adverse weather conditions are likely, specific actions such as clearing drains, precautionary de-icing or setting speed restrictions can be carried out. Thresholds may be set to trigger certain actions for example speed restrictions. Early-warning systems can be used to warn staff of risks, for example high track temperatures or high wind.

Railway maintenance training in Pretoria, South Africa. (Photo by David Brossard, Flickr)
**RESPONSE**

During an event a common challenge is defining responsibilities or jurisdictions particularly between different organisations. Establishing clear roles and contacts beforehand is key. Examples of good practice from Transport Scotland include formation of a multi-agency response team bringing together agencies and organisations that respond to events (planned and unplanned) on key transport links; establishment of a Resilience Room within the National Traffic Control Centre for liaison with government; communication with the public – clearer travel warnings e.g. Transport Scotland has four different advice stages depending on the severity of the weather; and use of technology such as variable message signs, social media to provide advice on travelling in snow, hot weather etc. Figure 12 shows how Transport Scotland sits within the emergency response structure.

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**Key:**

MART - Scottish Multi Agency Response team  
SGoRR - Scottish Government Resilience Room  
CSC - Cabinet Sub-Committee  
S-PICC - Scottish Police Information and Co-ordination Centre  
COBR - Cabinet Office Briefing Room  
CCC - Civil Contingencies Committee
RECOVERY
Rapid recovery from events may be incentivised by compensation for delays. For example train operating companies are entitled to payments from Network Rail as are customers from train operating companies. Reputation and the impact on delay metrics also promote improvements to speed recovery.

Integrating the concept of ‘build back better’ i.e. increasing resilience to future events rather than replacing damaged infrastructure like for like is important. However, this may at times be in conflict with the need for speedy recovery. Sometimes, as a solution to this, temporary solutions are employed until permanent new infrastructure can be built.

LESSONS LEARNED
An important part of improving resilience is learning lessons from past incidents. This could be through use of a template or database which can be reviewed by others within the organisation, workshops for the parties involved in the event or government reviews. One way of capturing and spreading good practice is through industry awards and case studies.

“We are good at responding and managing incidents, but we find ourselves responding to the same areas again and again. Lessons learned would be helpful.”
Source: Anonymous

EXAMPLE OF PERFORMANCE METRICS
In 2016 a 7.8 magnitude earthquake hit the south island of New Zealand. One of the most severe impacts was the damage to the transport infrastructure including railway lines. This caused wide spread disruption affecting local communities, businesses and tourism. One key aspect in dealing with the aftermath of the event and carrying out recovering activities was data management. The stakeholders involved used a variety of approaches to manage and share data (Blake et. al, 2019):

• They used different types of existing data. This included using some types of existing data in novel ways e.g. vehicle telematics to monitor the use of alternative routes.
• New mechanisms were created for sharing data between organisations e.g. on damage assessments and cost estimates.
• Common classification systems were used to provide information on aspects such as levels of service.
• Existing and new relationships and communication channels were utilised. It was suggested that single points of contact within each organisation would help.
Managing existing assets

Asset management is about managing existing assets based on strategic goals using inventory and condition data. The major decisions in relation to asset management are what maintenance or upgrades to carry out in which location and at what time. The majority of these decisions focus on prioritisation of limited resources in order for infrastructure to be maintained to an acceptable condition. Infrastructure in good condition is more resilient to hazards.

**PRIORITISING MAINTENANCE**

Key to including resilience in asset management decisions is assessing risk in order to prioritise improvements to infrastructure to increase robustness to different types of threats. Risk includes both the likelihood of an event occurring and its impact, so identifying the most critical assets is an important part of this. Network Rail has published a Guidance Note on carrying out weather and climate change risk assessments for those involved in delivering design, construction and maintenance projects. (Network Rail, 2018). Climate change risk assessments will become a mandatory part of project delivery from December 2019.

Risk assessment tools and methodologies provide a systematic and consistent method of assessing risk, enabling infrastructure owners to focus on the areas of highest risk when planning maintenance, for example Network Rail’s Washout and Earthflow Risk Mapping (WERM) tool is used to assess the risk of geotechnical assets failing due to flooding (Global Rail News, 2012). It enables identification of the earthworks at high risk, so they can be targeted for stabilisation measures.

Network Rail has produced Weather Resilience and Climate Change Adaptation Plans for each of its geographical regions (referred to as Routes) as part of its asset management plans (Network Rail, 2014). These plans are being updated in 2019 and set out the main weather hazards for each Route, the impact of climate change on these and the measures Network Rail intends to use to address these.

**MAINTENANCE CONTRACTOR REQUIREMENTS**

Requirements related to resilience can be included in maintenance contracts, either as specific actions or by requesting a resilience specialist be involved in the project.

*I think we need to place more requirements on contractors to have knowledge on resilience. Competency in this should be included in the tender specification.*

Source: Gordana Petkovic, Norwegian Public Roads Administration
USER COMPENSATION

Delay compensation payments (referred to as Schedule 8 payments) are made to the train and freight operators by the infrastructure owner depending on the cause of the delay. These mechanisms are included in the track access contracts to provide financial compensation to users of the network for performance below the agreed benchmark, and so in principle are an incentive for improving resilience. Figure 7 shows the weather related Schedule 8 minutes made by Network Rail from 2006 - 2018. The cost of these delays varies from £50-100m per year depending on the nature of the weather related impacts. The cost of wind is the highest followed by flooding but the impact of snow disruption and earthworks failures (subsidence) is also significant. It should be noted that a study that carried out analysis of Schedule 8 payments suggested they are not a strong incentive for changing behaviour, and that regulatory targets, reputational risk and loss of business are stronger incentives (ORR, 2012).

Figure 7: Network Rail weather attributed Schedule 8 costs 2006/7 to 2017/18 (Network Rail, 2019)
Network upgrades

The main decisions for new assets are where and what to build. This consists of the initial business case for the new infrastructure, planning and appraisal processes, preliminary and detailed design and procurement of the construction work. Some rail assets such as bridges have design lives of 100 to 150 years, so need to be designed for future conditions and with the ability to be adapted if required.

There are a number of methods used to embed resilience in new infrastructure.

INCLUDING RESILIENCE IN THE STRATEGIC BUSINESS CASE

A project proposal may include increasing the resilience of the transport system as one of its overall objectives at the start of a project. For example it could provide redundancy by providing an alternative route (e.g. a new river crossing), increase robustness (e.g. by replacing an old asset with a more robust design) or improve reliability by integrating measures such as raising the track height.

INCLUDING A RISK ASSESSMENT IN THE PLANNING PROCESSES

The location of infrastructure has a large influence on what type and level of threat it faces. Decisions on the optimal alignment needs to take into account multiple factors, including the future resilience of the asset. Preliminary design decisions such as whether to use a tunnel or bridge to transverse a river also impact on future resilience.

Examples of levers to incentivise the inclusion of resilience in planning include:

- Through Environmental Impact Assessment (EIA) – This is a common planning requirement used throughout the world, and has been expanded to include a risk assessment in some countries, e.g. the EIA European Directive was updated in 2014 to include an assessment of disaster prevention and climate change impacts. For example for High Speed 2 in the UK carried out a climate change resilience assessment as part of the Environmental Statement (HS2, 2017).
- The consideration of risks, including climate change, at the planning stage of a project has been a requirement of the Norwegian Planning and Building Act for the past five to six years.
- In the US the FAST (Fixing America’s Surface Transportation) Act 2015 requires that resilience is taken into account in transport planning. This includes recommending that infrastructure owners consult with agencies responsible for natural disaster risk reduction and the metropolitan transport plan assess investment to reduce the vulnerability of transport infrastructure to natural disaster.
- The UK National Policy Statement – National Networks states “4.40 New national networks infrastructure will be typically long-term investments which will need to remain operational over many decades, in the face of a changing climate. Consequently, applicants must consider the impacts of climate change when planning location, design, build and operation. Any accompanying environment statement should set out how the proposal will take account of the projected impacts of climate change.”

The planning process also provides an opportunity for external input via the public consultation processes. Local planning authorities, statutory consultees and the public
have a chance to raise any resilience concerns. For example in England the Environment Agency can highlight flood risk.

The planning processes include social and economic appraisal of the design which needs to follow government guidance (e.g. WebTAG in the UK (Treasury, 2018)). The current version of webTAG does not explicitly include resilience in the economic calculations, but does mention some aspects of resilience (e.g. flooding) in the qualitative evaluation. The Treasury (UK) Green Book: Central Government Guidance on Appraisal and Evaluation includes supplementary guidance on including climate change in economic appraisal (Treasury, 2009). This discusses appraisal options such as real options analysis and adaptive planning, and provides advice on selecting an appropriate discount rate.

**INCLUDING RESILIENCE IN DESIGN STANDARDS AND SPECIFICATIONS**

National, local and European (Eurocodes) design standards and individual project client specifications determine to a large extent what is built and to what standard. The review and updating of industry design standards is usually an ongoing cyclic process. There is always a balance between ensuring safety, durability etc. and affordability. Several infrastructure owners have recently reviewed and modified standards to account for climate change. The need for revising the Eurocodes to incorporate climate change has also been acknowledged (European Commission, 2014), but not yet carried out. Infrastructure owners can include resilience in other organisational documents and guidance for suppliers for example Weather Resilience and Climate Change Adaptation Policy (Network Rail, 2017).

Incorporating increased resilience into design standards can be considered a better approach than including it in the specification of individual projects as it provides overall consistency and it is not possible for it to be cut due to budget restrictions as easily. Formal derogations may be required to depart from standards (although exceeding standards to make a design more resilient should not require this). The downside of modifying standards is that it can take a long time to change these with often multiple approval stages.

Crew pumping water from flooded track bed after a water main broke in New York, USA (Photo by Metropolitan Transportation Authority of the State of New York)
INCLUSION OF RESILIENCE IN THE PROCUREMENT PROCESSES

Another method of including resilience in new assets is through the procurement process, i.e. client tender specifications, evaluation criteria, contract requirements, performance indicators and assurance of these. Most rail infrastructure is constructed via build or design and build contracts, so for long term resilience to be considered in the design and construction, it has to be specified in the contract.

INCLUSION OF RESILIENCE IN FUNDING REQUIREMENTS

International development banks such as the World Bank and European Bank for Reconstruction and Development are starting to require consideration of resilience including climate change impacts in the projects they fund. This could take the form of a resilience audit at the early planning stage of a project and include requirements related to resilience to be included in the funding requirements.

“The promise of future work is a good incentive for performing well

Source: James Bailey, Chair of the UK Roads Board

NETWORK RAIL ENVIRONMENT AND SOCIAL MINIMUM REQUIREMENTS

“The Designer shall:

- assess the impact of adverse and extreme weather and/or future climate change on the project/works and use the findings to influence design decisions and health and safety plans
- identify the potential for weather events to impact the area surrounding the project including direct/indirect impacts on rail infrastructure, neighbouring communities and/or the local environment.”

Railway maintenance by the workers in Lijiang Railway Station in Yunnan, People’s Republic of China (Photo by Asian Development Bank)
EXAMPLE OF INCLUDING RESILIENCE IN DEVELOPMENT FUNDED PROJECTS

The Asian Development Bank (ADB) climate risk management framework (ADB, 2014) comprises the following steps:

- context-sensitive climate risk screening at the concept development stage to identify projects that may be at medium or high risk
- climate change risk and vulnerability assessment during preparation of projects at risk
- technical and economic evaluation of adaptation options
- identification of adaptation options in project design
- monitoring and reporting of the level of risk and climate-proofing measures.

Uzbek workers build a culvert as part of the construction of the Hairatan to Mazar-e-Sharif Railway. The Asian Development Bank (ADB) funded a 76-kilometre railway from the Uzbekistan border to Mazar-e-Sharif. (Photo and caption by Asian Development Bank)
Opportunities for achieving critical mass
In this section the information gathered from the interviewees and literature review is used as a basis for recommendations on incentivising resilience. Opportunities for increasing consideration of resilience have been divided into six areas for action as shown in Figure 8. Potential actions to address these areas are discussed in turn.

**Figure 8**
Areas for action to improve resilience
Changing mind-sets

Increasing resilience requires changing mind-sets in a number of ways:

REINFORCING THE RIGHT BEHAVIOUR

There is often more recognition for dramatic efforts to deal with and recover from events than for effective planning so that events do not occur. As one interviewee put it, people like to be a superhero. To counteract this good practice in planning and preparation needs to be more widely recognised and rewarded, for example through case studies and industry awards. Where it is possible to estimate the cost savings as a result of a preventative action or comparing an event where there was no/minimal impact with a similar historic event where there was impact this is a good way of demonstrating the value of resilience action taken.

"People like to be a superhero which is great. But you need to sustain energy and effort over the long haul."

Source: John Lamb, President of the UK Local Government Technical Advisers Group

THINK LONG-TERM

When there are immediate problems to address finding the time and resources to consider the long-term can be difficult. This can lead to a reactive approach to managing disruptive events. An emphasis on reducing initial costs rather than considering whole life costs can also exacerbate this, favouring short-term solutions. Following good practice in asset management, by considering the infrastructure over its life cycle and identifying future risks will make an organisation more resilient.

"A good organisation thinks about all the possible things that can change the way they do things in the future. A weaker organisation would be one that envisages doing things in the same way they have always done forever."

Source: Anonymous
BEING PROACTIVE WHEN CONSIDERING POTENTIAL HAZARDS

Often it takes a disaster with large scale impacts such as public outcry, media attention, political ramifications or even deaths to trigger changes. When something catastrophic happens there is government money available to address that type of threat and a focus on instigating improvements. However, if repeat events do not occur within a relatively short timescale interest can wane and funding may dry up, sometimes before the identified improvements can be made. The inability to be certain what hazards infrastructure will face in the future and where these will occur can also be used as an excuse for inaction.

A more proactive approach where all potential hazards are considered and mitigation actions identified is more effective and less costly. This requires consistent long-term funding rather than funding that is only available for a short-time following a disaster.

CHALLENGING CURRENT PRACTICES

There is a tendency to become complacent when an event has not occurred for a period of time. People often follow what has always been done, rather than thinking of future considerations. There is also too much emphasis/trust on the ability of people on the ground to deal with anything that occurs rather than investing in better preparation and more robust infrastructure. Current practices need to be challenged and constantly questioned in order to be improved, for example through stress testing current practice with different scenarios and asking more customer-focused questions.

“I think the knee jerk reaction following the event in that community is the single biggest driver.”

Source: John Lamb, President of the UK Local Government Technical Advisers Group

“If we ask the right questions in advance it would avert a lot of cost.”

Source: John Lamb, President of the UK Local Government Technical Advisers Group
Leadership and accountability

Resilience has to compete with other priorities for resources and attention. Reducing the risk of travel disruption is less headline grabbing than for example the introduction of new types of vehicle technology or the construction of a new bridge. As one interviewee put it “resilience isn’t sexy”. Greater political and high-level organisational leadership on resilience could help to address this and provide powerful incentives to move resilience up the agenda. Some actions which can help to do this are:

ASSIGN A CHAMPION
There should be someone in a high-level position both politically and within infrastructure owner organisations to champion resilience and be accountable for improvements. For example in Scotland there is a government minister responsible for resilience and the UK’s Department for Transport has a cross-modal team responsible for transport resilience. Cross-sector resilience champions such as Chief Resilience Officers within city governments can help to embed resilience into all city departments including transport.

I think it comes down to individuals showing leadership, people who understand that there is an expectation placed upon them and that they personally are required to undertake that leadership. If trained this can achieve great impact.

John Lamb, President of the Local Government Technical Advisers Group

IMPROVE AWARENESS AND UNDERSTANDING OF RESILIENCE
Whilst it is important that there is an individual accountable for resilience, there needs to be awareness and understanding of resilience throughout the organisation. People outside the team involved in resilience, also need to understand what resilience is, why it is important and their role in improving it. Actions to increase awareness include providing workshops, guidance, case studies, role specific training and including objectives in an individual’s appraisals. There are multiple sources of external case studies, but examples of good practice from within the organisation are particularly relatable.

For the individuals coordinating actions to increase resilience, high-level support and ‘hooks’ such as a clause in the licence agreement text or organisation metrics are useful in helping to get their points across to colleagues (see Section 5).

It’s everyone’s job and everyone’s responsibility. It shouldn’t be about having 1 or 2 key people going on a course; it needs to be broader that allows more people to become generally well informed.

John Lamb, President of the Local Government Technical Advisers Group
DEMONSTRATE THAT RESILIENCE IS IMPORTANT

Visibility of leaders in resilience discussions and actions demonstrates the value they place on resilience. For example speaking at external and internal events on resilience, asking staff questions on resilience and being involved during events as during severe winter weather in Scotland.

Part of demonstrating the importance of resilience is having the evidence to support the need for greater resilience, particularly in terms of economic benefit. In order to engage people and support funding request it is necessary to set out the business case for measures to improve resilience. This requires including risks within economic appraisal, and setting appropriate boundary conditions.

We had the Transport Minister replying to tweets in the Control Centre until 1am in the morning. It’s good to have the Government involved in high impact events.

Transport Scotland

PROVIDE RING-FENCED FUNDING FOR RESILIENCE

Every rail infrastructure owner and operator has a limited budget, which can be seen as a barrier to increasing resilience. To address competing priorities and prevent focus on the short-term issues funding specifically for actions to improve resilience may be required. For example the UK Department for Transport competition for technologies to improve railway resilience in 2019.

ASSURANCE

Often after an event recommendations to improve resilience are made, but it’s important that there is also a process in place to ensure these have been addressed. For example in 2012 there was a government review (DEFRA, 2012) of the implementation of the 92 recommendations of the Pitt Review of the 2007 flooding in the UK. This evaluated the progress in implementing the recommendations, explained which recommendations were not being taken forward and why and what work was still ongoing.

For example Transport Scotland stated that “by 2050, there will be less or no more disruption on the transport networks caused by flooding compared to 2010”.

ESTABLISH POLICY, TARGETS AND ACTION PLANS

Including resilience in organisational/government policy and developing appropriate action plans demonstrates internally and externally its importance to the organisation. It also allows people working on resilience within the organisation/industry to use this to engage their colleagues. Setting targets is difficult as resilience is not easy to measure, although this has been done in the Netherlands (see Section 5.2). Definition of what the expected level of resilience/performance is which then allows resilience measures to be developed and put forward for funding would be useful.
Systems thinking and collaboration

Resilience requires a cross-asset, cross-sector approach which involves collaboration between organisational business units and different organisations. Resilience needs to be addressed at the system level, rather than solely focusing on individual assets. There are opportunities to improve resilience through less siloed working and greater awareness of external interdependencies. Potential actions to encourage systems thinking and collaboration are:

**USE APPROPRIATE LANGUAGE AND ASKING THE RIGHT QUESTIONS**

One interviewee highlighted the importance of the language used when discussing resilience and the questions asked. This can encourage or limit systems thinking.

"I think it’s really important to recognise, when we talk about these things you’re actually constraining people’s imagination by the language you use and the questions you ask. I would like us to start thinking less about the individual asset, and more about the systems that they form part of and the functions that those systems fulfil."

*Source: Anonymous*

**ESTABLISH DISCUSSION FORUMS**

Regular resilience forums and resilience champions/coordinators can help bring staff from different business units and/or organisations together to discuss resilience of the system as a whole, for example the Natural Hazard Forum in Norway is cross sector.

"Discussions, talking and learning from each other is a powerful tool and just by talking we can get a lot of things done."

*Source: Tony Sawh, Resilience, Operations and Performance Manager, (UK) Department for Transport*

**CREATE MULTI-AGENCY RESPONSE TEAMS**

Multi-agency response teams, plans and training for different types of threats can also help organisations work together so that there is no miscommunication. There needs to be coordination between different infrastructure owners e.g. roads and rail. For example, Transport Scotland setup a Multi-Agency Response Control Centre, which brings together key partners from Transport Scotland, the Met Office, ScotRail, Operating Companies and Police Scotland. The control centre is staffed 24/7 and acts to share real-time accurate information with key stakeholders, issues advanced travel warning to logistics networks and the travelling public, and coordinates emergency response. The control centre not only allows event coordination, but also enables knowledge sharing and collaboration between all key stakeholders.
Understand and mitigate risk

To prioritise maintenance and upgrades to improve resilience, identification of the areas of highest risk is required. Data collection and analysis will support hazard and risk assessments, and decision-support tools and standardised methodologies provide a consistent methodology so that comparisons can be made between projects, areas of the network and hazards.

The requirement to carry out a risk assessment can be embedded in the planning process for new build and asset management processes for existing infrastructure. It should be reviewed regularly and appropriate requirements embedded within maintenance planning.

In order to make risk assessment more consistent and based on evidence as much as possible methodologies and tools are being developed by rail owners for example Network Rail’s WERM tool mentioned in Section 5. Other useful approaches to inform decision making are dynamic adaptive pathways and stress testing. It is important that decisions on resilience are based on robust research and evidence. For example collecting and analysing data on historic failures can provide information that enables better assessment of future risk.

We are moving more towards evidence based processes and away from the past when we had less science available.

Source: Anonymous

Construction of the Karsakpai railway station, Kazakhstan (Photo by Asian Development Bank)
Disaster management

Effective plans to deal with disruption, contingency, and recovery, set out the responsibilities clearly and are supported with sufficient resources and training of staff. Agreements of mutual aid for example and multi-agency practice events are helpful. Plans should include how to share information and data, before, during and after an event, and set out a process for a debrief after events to identify lessons learned.
Embedding resilience

No single lever can embed resilience within the rail industry. Multiple specific actions are set out in this primer to support resilience integrated in existing procedures at all major decision points and involving all industry stakeholders.

For example, by government and regulators:
- Include clauses relating to resilience in licence/service agreements
- develop supporting metrics / targets
- ask the right questions both publicly and in private.

For rail, infrastructure owners and managers:
- ensure an assessment of future risks to the infrastructure informs infrastructure designs and asset management policies
- improve response to events
- incentivise supply chains through contract requirements.

Other organisations such as local planning authorities, contractors, customer watchdogs and professional institutions also have roles to play in highlighting areas for improvement and influencing the industry. As several interviewees highlighted it is the application of all these levers together which are important.

“All of these things together align and give a consistent message and make clear the expectations.”

Source: James Bailey, Chair of the UK Roads Board
Conclusion

The interviews carried out as part of this project have provided useful insights into the challenges practitioners and policy makers in the rail industry face in embedding resilience within their organisations and the industry. This primer highlights examples of good practice, and provides recommendations on potential actions to increase resilience. Resilience is an increasingly important issue and learning from each other’s experiences is vital in order to keep making progress.

We hope these recommendations will contribute to the current thinking within the rail sector around how to embed resilience, and how to motivate its implementation from theory into practice.
ABOUT THE AUTHORS

TRL are delighted to be involved in the Resilience Shift initiative, which very much aligns with the work we are carrying out in the UK and internationally on resilience. Resilient rail transport underpins a successful society and we are very pleased to be able to contribute to highlighting the need for resilience and the types of actions that can be taken to incentivise it.

The following researchers were involved in developing the primer:

**Dr. Sarah Reeves** is a Senior Consultant, with 16 years’ experience of working on road and rail resilience and climate change adaptation. She is a member of the World Roads Association Technical Committee on climate change adaptation strategies and resilience. Her experience includes the use of climate projections to assess the risks of climate change impacts on transport, the development of risk assessment and management strategies, national and international policy analysis, the embedment of resilience and the provision of recommendations on adaptation actions.

**Prof. Mike Winter** is a Chartered Civil Engineer and a Chartered Geologist. He is the Regional Manager responsible for TRL’s infrastructure operations in Scotland and a visiting industrial Professor of Engineering Geology and Geotechnics at the University of Portsmouth. During the last 28 years he has acquired broad experience in research and specialist consultancy. His main area of expertise is in landslides; their forensic investigation, management and mitigation and the wider socio-economic impacts they cause.

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**Alison Hewitt** is a Senior Consultant with 22 years’ experience of working in the transport industry. She has an MSc in Highway Engineering and a BSc in Physics and has worked on a wide range of topics including investigating quiet concrete road surfaces, sustainability in pavement construction and air quality assessments for local authorities.
REFERENCES

ENDNOTES

1. The Act divides responders into Category 1 which are the major responders to emergencies such as police and local authorities, and Category 2 which are cooperating bodies. The duties of the two categories are different.

OTHER REFERENCES


BBC News, 2015. Dawlish rail line: Closure @costs economy up top £1.2bn! https://www.bbc.co.uk/news/uk-england-devon-31140192


