CReDo

CATAPULT Connected Places

THE CASE FOR EXTENDING CREDO TO TRANSPORT

Future Expansions to CReDo

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Delivered in partnership with: UKRI Innovate UK

OVERVIEW

Background

Due to climate change, extreme weather events are occurring on an increasingly frequent basis and to greater severity. The UK's infrastructure is not prepared. There is insufficient awareness of the impact of climate change on critical national infrastructure, as agreed by Climate Change Committee and National Infrastructure Commission. More intense and frequent weather extremes are predicted by the Met Office, with winter storms causing flooding, and intense summers causing extreme heat. Weather leads to disruption with storms causing power cuts and communications outages, landslides blocking roads, heatwaves disrupting rail services, and flooding contaminating water supplies.

The interconnected nature of UK's infrastructure means that disruptions or impacts in one sector can cascade into other sectors. If one piece of infrastructure fails, this can cause a domino effect with power cuts leading to hospitals being without water, homes without means for communication, or communities without means of transport. In emergency situations, the effect is devastating. Flooded transport networks can restrict access to critical assets, further delaying the restoration of assets to service once they have failed.

CReDo

CReDo (Climate Resilient Demonstrator) is an innovation-funded programme led by Connected Places Catapult (CPC) to develop a climate change adaptation digital twin of connected infrastructure to better understand cascading climate risk. The risk modelling framework cascades asset failures from flooding and extreme heat through individual networks, between networks, and across sectors. The programme is building out the strategic resilience investment planning use case to provide cross-sector insights to network operators on criticality and vulnerability to maximise the socioeconomic impact of investment – keeping the lights on at the lowest economic, social, and environmental cost.

Extending to transport

Whilst CReDo has made progress in demonstrating the benefits of modelling the interdependencies of energy, water, and telecoms networks, it has not yet reached the vision of economy and sector wide connectivity.

This document makes the case for transport as the next sector to be connected into CReDo. What follows is an exploration of the economic, environmental, and societal impacts to Road and Rail. It is an extension of the Strategic Outline Case[1] for CReDo published in 2023 and highlights the critical dependencies between the transport and wider infrastructure sectors.

Stakeholder priorities

In considering expansions to CReDo, views were sought from a wide variety of public and private organisations to understand their strategic areas of interest. This was supplemented by desk-based research and the knowledge of Catapult transport experts.

Stakeholders in other sectors felt that road networks were the highest priority. 'We are currently more dependent on the road compared to rail. Daily operations use roads, and whilst suppliers may use rail, this is seen more as a second order dependency.' Engineers access sites via road for repairs. Additionally, there are strong interdependencies, as road networks rely on power for signage, traffic signals, and communications. They also equally rely on the telecoms network to collect data for controlling traffic signals.

Whilst CReDo sees roads, rail, and other parts of transport as crucial to a system-wide digital twin, this finding led to road networks being investigated in greater detail within this report.

Consulted stakeholders prioritised flooding due to the increasing threat of floods in the UK caused by climate change, and the imminent danger this presents to infrastructure. In comparison, extreme heat was considered as a nationally emerging issue. Additionally, the better data availability of flooding allows for more accurate modelling. This primarily focused the scope of this report to flooding.

Next Steps

CReDo is in the process of prototyping the inclusion of transport with open data to demonstrate the art of the possible. This will be used to further engage with transport sector stakeholders.

1 https://digitaltwinhub.co.uk/download/credo-phase-2-strategic-outline-case/

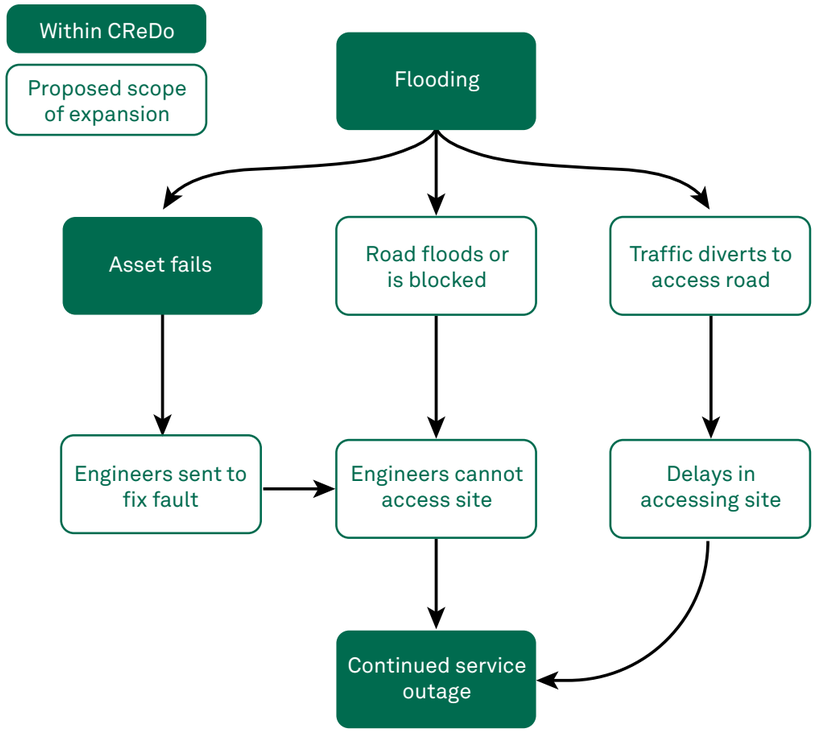
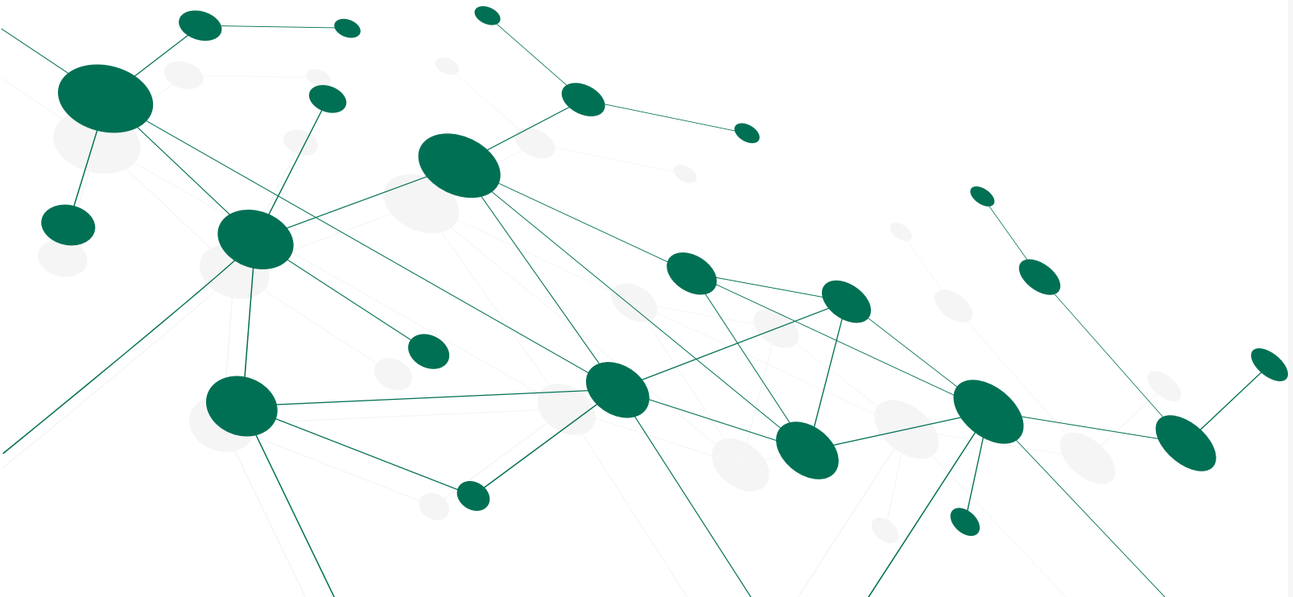


Figure 1. Dependencies on the Road Network



ROAD NETWORK

Flooding on roads and highways creates a complex set of social, economic, and environmental challenges. Socially, it isolates communities, disrupts essential services, and increases mental health issues. Economically, it imposes significant costs on businesses, individuals, and governments, including lost revenue, increased transportation costs, and expensive infrastructure repairs. Environmentally, flooding leads to pollution, habitat destruction, and erosion, while contributing to a feedback loop of climate change and future flooding risks.

Economic impacts

Storm Ciara led to extensive road flooding across the North of England resulting in the failure of flood protection installed at a cost of £30m[2]. The government response involved allocating emergency funds to repair bridges, culverts, and roads, diverting resources from planned infrastructure improvements. Delayed deliveries, employee absenteeism, and reduced customer footfall can result in substantial revenue loss for businesses, both large and small. When major roads are flooded, traffic is diverted onto minor, less efficient routes, leading to increased fuel consumption and transport costs for businesses and individuals.
The increased wear and tear on these minor roads also requires more frequent repairs, adding to the financial burden on local councils. During the 2014 floods in Somerset[3], road closures led to higher transportation costs for businesses that relied on trucking goods. Detours added significant travel time, resulting in fuel costs that were 20-30% higher for local hauliers.

Flooded roads reduce access to key tourist destinations, impacting local economies that rely on tourism as a primary income source. This can lead to cancellations of bookings, closures of hotels and restaurants, and a decline in visitor numbers, with long-term economic consequences for local communities. The 2014 floods in Cumbria[4] led to road closures around popular destinations such as the Lake District, resulting in a sharp decline in visitor numbers during the peak tourist season. The local economy, which relies heavily on tourism, saw an estimated £50 million in lost revenue over the course of the flooding event. Higher frequency of floods is also driving up insurance premiums, adding financial strain to affected communities.

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2 https://www.mirror.co.uk/news/uk-news/storm-ciara-leaves-towns-under-21467411
3 https://www.internetgeography.net/topics/the-somerset-levels-flood-case-study/
4 https://cumbria.gov.uk/elibrary/Content/

Environmental impacts

The environmental impacts of flooding on roads and highways are both direct and indirect, affecting ecosystems, pollution levels, and contributing to long-term environmental degradation.

Floodwaters often carry pollutants from roads, including oil, gasoline, chemicals, and debris, into rivers, lakes, and other natural water bodies. This runoff can lead to water contamination, affecting aquatic ecosystems and the quality of water supplies for communities. In 2021, floods along the River Severn caused extensive road runoff, contaminating water supplies and harming local ecosystems. The Environment Agency reported high levels of pollutants, including heavy metals and hydrocarbons, entering the river system from roads, exacerbating the degradation of water quality in the region.

Floodwaters can also cause significant erosion along roadsides, leading to the destruction of natural habitats for plants and animals. The loss of vegetation weakens the soil structure, making future floods more likely and exacerbating the cycle of environmental damage. During the 2019 floods in South Wales, the Brecon Beacons National Park saw extensive erosion along roads that border the park. This resulted in habitat loss for local wildlife, including protected species, and led to long-term environmental degradation that affected the park's biodiversity.

Flood-related road closures and traffic diversions lead to longer travel times, increased congestion, and higher fuel consumption. The increased emissions from diverted traffic contribute to air pollution and carbon dioxide (CO_2) levels, exacerbating climate change, which in turn increases the frequency and severity of flooding. Following the 2020 floods in West Yorkshire[5], traffic diversions added significant delays to regional transportation, with estimates suggesting that emissions from vehicles increased by 15-20% due to the longer routes and congestion.

5 https://yorkshire.guide/content.pl?action=stormciara

Societal Impacts

Flooding on roads and highways affects society in numerous ways, disrupting daily life and imposing significant stress on individuals and communities. The social implications are often long-lasting, particularly in areas that are repeatedly affected by flooding.

Consequences of flooded roads include often restricted or cut off access to essential services, including healthcare, education, and emergency services. In rural areas, where transport options are limited, communities can be left isolated, unable to access hospitals, schools, or food supplies. During the 2019 floods in Doncaster, road closures prevented residents from accessing local hospitals, leading to delays in emergency care. Schools were forced to close, disrupting education for thousands of children. The stress on the community was exacerbated by long-term road closures that extended isolation.

Daily commuters may face significant delays and disruptions when roads are flooded. The stress of navigating detours, longer journey times, or the inability to commute at all can lead to mental health issues, especially in areas where flooding is frequent. In 2014, during the flooding of the Somerset Levels, thousands of daily commuters were forced to find alternative routes, often resulting in journeys that were two to three times longer.

Importantly, severe road flooding can displace residents, particularly in areas where access roads to homes and communities are submerged or damaged. This displacement often forces families to relocate temporarily, leading to social disconnection and trauma.

When assets fail

Flooding often overwhelms drainage systems, pipes, and other infrastructure assets that are meant to manage stormwater. When these systems fail, it can lead to more severe road damage and extended flooding, with water remaining on road surfaces for longer periods, further eroding the road structure

Drainage system overload:

- **How it happens:** Inadequate or old drainage systems, unable to handle extreme volumes of water, are overwhelmed during flooding events. This leads to backups, causing water to pool on road surfaces. The lack of effective drainage accelerates the degradation of road surfaces, contributes to flooding in surrounding areas, and increases pressure on nearby bridges and pipes, which can collapse.
- **Who it impacts:** Local councils, homeowners, businesses, and commuters. The failure of drainage systems causes extensive road closures, home flooding, and infrastructure breakdowns.
- **Example:** In 2007, the floods in Gloucestershire caused the Severn Trent Water system to fail[5], with drainage and sewage pipes overwhelmed. This resulted in 10,000 homes being flooded, damaging property, and leading to £3 billion in insurance claims. Roads were damaged due to standing water, which further delayed repairs to utilities.

Bridge and road foundation collapse:

- **How it happens:** Flooding can erode the earth supporting bridges and roads, especially when floodwaters carry debris that further undermines structural integrity. Water can seep into cracks and degrade the concrete and steel reinforcements of roads and bridges.
- **Who it impacts:** Local councils (responsible for road and bridge maintenance), businesses relying on road access, and emergency services. Long-term road closures may isolate communities and significantly disrupt regional economies.
- **Example:** During Storm Desmond in 2015, the Eamont Bridge in Cumbria was washed away by floodwaters, causing major disruption. The cost to repair the bridge was estimated at £5 million[7], with the local economy losing millions more due to the extended closure of key roads.

6 https://www.cirenscience.org.uk/images/members-papers/Newbould_CNFC_Proc_Jan2009.pdf
7 https://www.bbc.co.uk/news/uk-england-cumbria-48408722#:~:text=Work%20has%20begun%20to%20replace,stone%20bridge%20was%20washed%20away.

Blocked roads

Flooding directly impacts roads by submerging them under water, washing away the road surface, and making them impassable. When roads become flooded, they either need to be closed for safety reasons or they suffer long-term damage from the erosion of the road surface and the infrastructure beneath it.

Road surface damage:

- **How it happens:** Floodwaters, especially if they carry sediment and debris, can cause erosion of the road surface, making it unsafe for vehicles. Water can infiltrate cracks in the road, leading to potholes and structural weakening.
- **Who it impacts:** Commuters, freight companies, emergency services, and local authorities. The immediate costs include emergency closures and diversions, while long-term repair costs can burden local governments and taxpayers.
- **Example:** In 2019, during Storm Ciara, the roads in Yorkshire were severely flooded, with many areas submerged for days. The A684, a major road, had sections washed away, leading to £2.5 million in repair costs. Many local businesses were impacted as supply chains were disrupted, leading to further losses.

Blocked roads from debris:

- **How it happens:** Floodwaters often carry debris, such as fallen trees, stones, and other materials, which can block roads even after the water has receded. These obstructions need to be cleared by local authorities before roads can reopen.
- **Who it impacts:** Businesses and services that rely on just-in-time deliveries, public transportation, and individuals needing to travel. Local councils bear the cost of cleanup, while businesses face delays in operations.
- **Example:** After the 2014 floods in the Somerset Levels, roads were blocked for days due to debris, requiring an extensive cleanup operation that cost Somerset County Council over £10 million[8]. The longer-term economic impact, including agricultural losses and business interruptions, was estimated at £150 million.

8 https://www.tutor2u.net/geography/reference/aqa-gcse-geography-weather-hazards-somerset-levels-flooding-case-study#:~:text=In%20terms%20of%20economic%20impacts,livestock%20had%20to%20be%20evacuated.

Traffic diversion

When major roads are flooded, traffic is often diverted to minor, less robust access roads. These roads are not designed to handle the volume and weight of diverted traffic, leading to their degradation and further traffic delays. This has a knock-on effect, exacerbating congestion and damaging both the access roads and the infrastructure that supports them.

Overuse of minor roads:

- **How it happens:** When a primary road is closed, traffic is rerouted through smaller, less well-maintained roads. These roads often can't support high volumes of traffic or heavy vehicles, leading to quicker wear and tear, potholes, and damage to road surfaces.
- **Who it impacts:** Rural communities and businesses that rely on these access roads for transport. The local councils responsible for these roads incur unexpected maintenance costs, while businesses face delays in deliveries and lost productivity.
- **Example:** During the 2019 floods in South Yorkshire, the closure of the A1(M) motorway due to flooding forced traffic onto smaller, rural roads. This caused severe congestion, leading to delays in the distribution of goods from Doncaster. Local businesses faced higher transport costs and delivery delays, while Doncaster Council spent over £1 million repairing damage to rural roads that were not designed for heavy traffic.[9]

Traffic accidents and increased congestion:

- **How it happens:** Diverted traffic leads to congestion on narrower, less maintained roads, increasing the likelihood of accidents. Inadequate signage or road surfaces can also exacerbate these risks, leading to more frequent and severe accidents.
- **Who it impacts:** Emergency services, road users, local businesses, and insurance companies. Increased accidents due to congestion raise costs for insurers and slow emergency response times.
- **Example:** In the aftermath of the 2019 Wainfleet floods, traffic was diverted from the A52 onto smaller local roads. The congestion and narrow lanes led to several accidents, delaying emergency services and increasing local insurance claims. The cost of road maintenance and clearing the damaged vehicles was borne by local authorities, adding to the £30 million cost of repairing flood-damaged roads in the region.

9 https://committees.parliament.uk/writtenevidence/9714/pdf/

RAIL NETWORK

> **"In 2006 heat damage to road surfaces was reported from Cornwall to Cumbria, with the cost of repairs estimated at £3.6m in Oxfordshire alone. Speed restrictions were introduced on many rail lines, because of the risk of buckling with the west coast main line particularly affected with delays and cancellations."**
>
> **Met Office[10]**

The rail network is socioeconomically important and is integral to the expansion of CReDo. The impact of flooding and heat waves on rail services extends deeply into the daily lives of people, affecting not only commuters but also the broader social fabric, economic stability, and psychological well-being of individuals and communities.

Rail networks also rely on power for traction, signalling, and buildings, and on telecoms infrastructure for operations and controls. Signalling and train control systems are conducted over a proprietary telecoms network. However, all other communications – such as emergency communications, station and staff communications, and surveillance monitoring – are handled over the standard mobile network.

Flooding has caused significant damage to the UK's rail network over the past 20 years, leading to widespread disruption and costly repairs. This type of damage occurs in several ways, affecting the physical rail infrastructure, signalling systems, and operational capacity.

10 https://www.metoffice.gov.uk/weather/warnings-and-advice/seasonal-advice/health-wellbeing/hot-weather-and-its-impacts

Track flooding and erosion

Heavy rainfall or rising river levels can submerge rail tracks, making them impassable for trains. Prolonged exposure to floodwater erodes the ballast (the stone layer supporting the track), weakening the structural integrity of the tracks. Flooded or eroded tracks lead to widespread cancellations or delays, affecting passengers, freight transport, and businesses relying on rail connectivity. In 2014, flooding caused by Storm Frank disrupted rail freight services between Scotland and the rest of the UK. The Scotch whisky industry, which heavily relies on rail freight for exports, faced significant delays, leading to millions of pounds in lost revenue. This prompted the industry to lobby for improved flood defences around key freight corridors.

Damaged tracks require costly and time-consuming repairs, often disrupting services for weeks or months. In extreme cases, flooding can wash away tracks entirely, causing long-term closures. During Storm Dennis in 2019[11], major flooding caused several sections of the South Wales mainline to be submerged, disrupting both passenger and freight services. Rail lines were washed out, causing significant delays. Repairs were estimated to cost Network Rail £20 million[12], with long-term disruptions impacting local businesses that relied on the line for freight transport.

Embankment Failures

Embankments, which support rail tracks, are particularly vulnerable to erosion during floods. When heavy rains saturate the ground, embankments can collapse, undermining the track's foundation and making it unsafe for trains. Embankment failures are among the most severe types of rail damage caused by flooding. Rebuilding embankments requires heavy machinery and specialized engineering, leading to prolonged rail closures. This impacts not only rail operators but also commuters and industries relying on rail services for the movement of goods. During Storm Desmond, the West Coast Main Line near Carlisle suffered an embankment collapse. The damage closed a key route between England and Scotland for several weeks. The economic loss due to this closure was substantial, with Network Rail spending over £40 million on emergency repairs and compensation for disrupted services.

Damage to Signalling and Electrical Systems

Floodwaters can damage essential signalling equipment, electrical lines, and control systems that manage train movements. This can result in system failures, where trains must be manually controlled, or entire sections of track become unusable due to safety concerns. Damaged signalling systems lead to delays, reduced frequency of services, or complete shutdowns of affected lines. The repair of electrical and signalling infrastructure is expensive and complex, requiring specialists to replace damaged components. In 2012, London's rail network experienced severe flooding that knocked out several signalling systems, leading to the suspension of services on multiple lines. The cost of restoring the damaged systems was estimated at over £10 million, with long-term service disruptions affecting millions of passengers.

Station Closures and Flooded Platforms

Flooding can also make stations and platforms unsafe for passengers. Damage to station infrastructure, such as electrical components, ticketing systems, and platforms, can require extensive repairs. Station closures directly disrupt passenger travel, often leading to overcrowded alternative transport modes like buses. The economic impact extends beyond rail operators, affecting local businesses that rely on the foot traffic generated by the station. In 2015, York railway station was flooded during Storm Desmond, leading to the closure of the station for several days. Thousands of commuters were affected, while local businesses around the station lost significant revenue due to the reduced footfall. The costs to repair the station and restore services was estimated at over £5 million.

Government agencies and Network Rail face substantial repair costs and the need to compensate affected passengers and businesses. Moreover, government funding is often redirected to emergency infrastructure repairs, diverting resources from other important projects. When storm Ciara caused severe flooding across the North of England, resulting in the temporary closure of the Leeds-Manchester rail line, Network Rail spent over £15 million on emergency repairs and compensation for passengers. The government allocated an additional £50 million for flood resilience improvements in the region's rail network to prevent future disruptions.

11 https://www.networkrail.co.uk/stories/storm-dennis-how-were-responding/
12 https://www.bbc.co.uk/news/uk-wales-64263107

Impacts

Damages to rail services have seen extended closures, delays, and increased costs for maintenance and repair. These impacts are interconnected and affect not only the rail industry but also passengers, communities, businesses, and the government. Below is an expanded overview of how damages can have direct and indirect economic, environmental and social costs.

Economic Impacts

The economic fallout from flood-related damage to rail infrastructure includes direct financial costs to repair damaged infrastructure, losses in productivity, disruption to supply chains, and long-term effects on business and tourism.

Flooding causes direct damage to rail infrastructure such as tracks, signals, embankments, and stations. Repairs are expensive, requiring immediate financial investment from Network Rail, rail operators, and the government. Prolonged repair times also mean lost revenue for rail operators. The UK rail network plays a vital role in the movement of goods across the country. Flooding disrupts freight services, delaying the delivery of critical materials such as coal, steel, and goods for industries like manufacturing, retail, and agriculture. Businesses are forced to turn to more expensive road transport, increasing logistical costs and reducing competitiveness. The closure of the Dawlish rail line during the 2014 floods disrupted freight movement to and from the southwest, forcing businesses to reroute shipments via road at an increased cost. This led to a decline in local manufacturing and agricultural production, costing the regional economy an estimated £1 billion[13]. Flooded rail lines can also cut off access to popular tourist destinations, deterring visitors and reducing revenues for local businesses such as hotels, restaurants, and shops. This is particularly detrimental in rural and coastal areas where tourism is a major source of income. Commuters and businesses alike suffer from lost productivity when rail services are suspended or delayed. Employees are late to work, meetings are missed, and supply chains are disrupted, affecting a wide range of industries. This leads to lost working hours, delayed projects, and reduced business output.

Environmental Impacts

Flooding damage to rail infrastructure is both a symptom and a contributor to environmental challenges. Railways that are damaged or closed due to flooding also have environmental consequences related to carbon emissions, waste, and long-term planning for climate change resilience. Events have highlighted the vulnerability of rail infrastructure to climate change. The need for more resilient designs and sustainable land use planning is becoming increasingly critical as extreme weather events become more frequent. Poorly designed drainage systems, low-lying tracks, and embankments are more prone to flood damage, requiring long-term environmental planning to ensure resilience.

When lines are flooded and services are suspended, passengers and freight services often switch to road transport. This leads to an increase in traffic, fuel consumption, and carbon emissions, negating some of the environmental benefits of rail travel, which is typically a lower-emission form of transport. This has a direct negative impact on the environment and the UK's ability to meet its carbon reduction targets. Shifting from rail to road transport increases air pollution and greenhouse gas emissions, particularly in densely populated urban areas.

Floodwaters can carry debris, pollutants, and chemicals onto rail lines, contaminating both the tracks and surrounding land. This not only damages the rail infrastructure but also contributes to soil and water pollution, especially in areas where railways pass near rivers and natural reserves. This effects local ecosystems, wildlife, and water sources. Contaminated floodwaters can damage habitats, disrupt wildlife, and affect agriculture if the polluted water is not properly managed.

Social Impacts

Disruptions to service impact the daily routine for millions of people, with effects that extend beyond mere inconvenience. The social implications of disrupted rail services include reduced mobility, unequal access to transport, and challenges to public safety.

Rail closures due to flooding significantly reduce mobility for daily commuters, especially in regions heavily dependent on rail as the primary mode of transportation. With limited alternative transport options, people may find it difficult to travel to work, school, or access essential services. This impacts individuals and families, but in particular can have a disproportionate consequence on those without cars or access to reliable public transport alternatives. Rural communities are also particularly vulnerable since they often rely heavily on rail services.

When flooding creates dangerous conditions around rail lines, stations, and pedestrian crossings, there is an increased risk of accidents, delays in emergency services reaching affected areas, and hazardous environments that can contribute to increasing public safety concerns. Additionally, prolonged service disruptions can contribute to mental health issues such as stress and anxiety, particularly for regular commuters. In 2014, after severe flooding affected rail services in Somerset, commuters reported increased anxiety and stress due to lengthy detours, extended travel times, and uncertainty about when services would resume[14]. Those who rely on affordable public transport options – particularly lower-income individuals – are disproportionately affected. Rail has typically been one of the most affordable means of long-distance travel for many, and disruptions can exacerbate social inequalities, especially in terms of access to employment and education, for groups such as low-income households, students, and elderly individuals who are dependent on rail travel for mobility.

13 https://www.bbc.co.uk/news/uk-england-devon-31140192

14 https://www.somersetriversauthority.org.uk/wp-content/uploads/2018/06/22-July-2015-ITEM-8-Economic-Impact-Assessment-full-report.pdf

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