Future proof railways

RISKS AND SOLUTIONS FOR RAILWAYS FACING CLIMATE CHANGE

INTERNATIONAL UNION
OF RAILWAYS

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Foreword

“Rail has an in-built resilience due to its centralised management and network structure. In the face of uncertainty surrounding climate change, it is crucial to maintain and improve reliability and operational safety, as having rapid and resilient capacity will be a vital asset. By investing in climate-resilient rail infrastructure and proven adaptation measures, we can ensure that railways continue to be a reliable backbone of sustainable mobility. I congratulate our members for their efforts in improving their adaptive capacity and call upon policymakers and political decision-makers to include concrete plans for resilient railways in their commitments to combatting climate change.”

François Davenne
UIC Director General

UIC ACTION ON CLIMATE CHANGE RESILIENCE AND ADAPTATION

This paper explores the importance of **climate change adaptation** (CCA) within the railway context. It provides insights from past incidents and identifies a variety of climate change related risks. Going from problem to solution, this paper explores evidence-based measures for railway systems to increase their **adaptive capacity**. Far from seeing CCA as a burden for the railway industry, this report features nature-positive solutions that can help restore the environment and make the overall system more resistant to different effects. It also addresses the substantial investment that the sector needs to play its role in sustainable mobility, as well as the policies for future-proofing rail.

RERA
Resilient Railways facing Climate Change

The International Union of Railways (UIC) is committed to enhancing the sector's resilience to climate change and, for this purpose, has launched a Resilient Railways Facing Climate Change (RERA)[1] series of projects with members from around the world. The working groups have explored consequences and solutions for the impact of heavy rains, high temperatures and desertic conditions, and strong winds on both operations and infrastructure. Related guidelines are in the pipeline that will help railways to assess and prioritise work to build resilience and adapt climate change. This report also contains summaries from the different projects.

KEY DEFINITIONS

Climate change: Changes in climate patterns, particularly in temperature and extreme weather events, due to human activity such as fossil fuel combustion and deforestation.

Criticality: The importance or essentialness of an asset or process, especially concerning how its failure could impact an overall system or operation.

Resilience: The ability of a system to absorb, adapt to, and recover from adverse events while maintaining essential functions or quickly restoring them.

Risk: The probability or likelihood that a harmful event or hazard will occur and have negative consequences, often evaluated concerning the severity of the potential damage and the vulnerability present at the time.

Vulnerability: The degree to which a system is susceptible to harm or damage when exposed to hazards. It reflects weaknesses or exposure to threats.

[1] RERA-Rain | UIC - International union of railways

Climate change is here

The impact of climate change is already being felt, whether through incremental changes or extreme events, such as heat waves, droughts, floods and storms. Although it is one of the modes of transport most able to recover and keep running in extreme weather, the railways are already feeling the impacts of climate change, as infrastructure is damaged and services disrupted, with consequences for people and the economy. Moreover, climate-induced damage and interruptions bring the risk of depriving communities of safe and sustainable transport, limiting their inclusion in the local economy and putting global value chains at risk.

Who benefits from resilient railways?

With 2,470 billion passenger-kilometres globally in 2022, railways play a critical role in the lives of its many passengers,[2] as well as supply chains relying on a well-functioning and stable railway system. As the most energy-efficient mode of mass transport, carrying 7% of global passenger and 8% of international freight volumes with only 1.2% of total transport emissions, functioning railway systems must be the backbone of sustainable transport. Any interruption of railway services, such as speed restrictions or line closures, directly impacts people and the economy. As identified by the 6th IPCC Assessment Report, the frequency and geographical spread of extreme weather events have increased drastically because of the world's changing climate. Therefore, as a key part of decarbonising transport is to shift more passenger and freight traffic onto the railways from modes of transport with higher emissions, keeping and improving reliability and safety standards are paramount to engendering this modal shift.

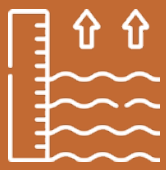
Railways are experiencing increasing climate risks in every region of the world, although with different causes and consequences. In the northern countries of the northern hemisphere, winters are becoming warmer and wetter, requiring a greater capacity for storm water storage, as well as landslides and washouts becoming more frequent. Those further south are experiencing more regular and more extreme high temperatures and increased desertification, bringing about new challenges such as the accumulation of sand on tracks. Railway lines on coastlines are also increasingly affected by storm surges and coastal erosion, meaning that they must move inland or invest in solutions to better protect the lines. Among UIC's approximately 200 members globally, not a single one has been spared the effects of climate change and catastrophes, with conditions being more extreme and unpredictable.

[2] Railisa UIC Statistics, "International Railway Statistics 2022 PART C: Timeseries and Maps."

The top climate change related impacts on rail

Railways are exposed to a multitude of risks, which in turn effect each part of the system differently. The most vulnerable assets are usually the track, the train or the two most critical systems: signalling and electrical power.

The most common consequence of this is a reduction in customer service standards including customer comfort, delays and cancellations, and, although less common, there are also serious safety implications such as the risk of derailment.




Rising sea levels	Heavy rain and storms	Droughts	Heat
▪ Immediate or long-term damage, earthwork and track erosion	▪ Flooding on tracks and in stations ▪ Landslides carrying the risk of derailment ▪ Fallen trees and wind-blown debris on tracks ▪ Damaged bridges over rivers ▪ Winds damaging overhead electricity lines ▪ Energy supply disruption	▪ Lineside wildfires ▪ Destabilised embankments and vegetation loss ▪ Desertification and sand accumulation effecting track and train engines	▪ Buckled tracks ▪ Malfunctioning air conditioning and other electronic and telecommunication systems ▪ Sagging overhead lines ▪ Reduced workforce health and safety ▪ Reduced customer comfort on trains and at stations

HEAVY RAIN AND FLOODS

Rainfall and floods tend to have the greatest impact on railways, as heavy rainfall can be the source of operational and infrastructural limitations for railway companies, with significant financial consequences. The past decade has seen a drastic surge in flooding, many of which have had a heavy toll on railway infrastructure.[3]

Intense or prolonged rainfall can harm railways, especially if there has been a lack of infrastructure investment and upgrades in drainage system efficiency and capacity. The **triggering** of rain-related hazards depends on the intensity of rainfall and local geography. While railway resilience levels vary from case to case, studies show that the most severe consequences occurred after precipitation of 150mm or more within 24h.[4] The **impact** of this heavy rain usually includes overflowing drainage systems, flooding and damage to tracks, landslides and even the collapse of bridges. While wet tracks often make it necessary to introduce speed limits or line closures, landslides can put passengers in danger through derailment or collisions with debris. Furthermore, intense rain can damage signalling, communications, and power supply systems, as well as stations, which poses a risk to passenger safety and equipment such as elevators.

[3] Robinson et al., "Increasing Heat and Rainfall Extremes Now Far Outside the Historical Climate."
International Union Of Railways (UIC), "RERA Resilient Railways Facing Heavy Rains."

[4] Flood Damage on Key Austrian Rail Link to Take Months to Repair (accessed 14/11/2024)

The European floods of 2024

European infrastructure managers and railway companies saw large-scale damage to infrastructure in the floods of September (in Eastern Europe) and October (in Spain). The IMs reported considerable damage to their complex technical railway networks, with debris, weakened tracks, and flooded stations, requiring electrical infrastructure, emergency systems, and ventilation systems on some of the tracks to be replaced. Insurance companies are also making the first claims related to the floods in Austria, with an estimated total damage of 700 million Euros.

Floods impacting railway operations in Austria; © ÖBB

Canadian meltwater causing a derailment

© VIA Rail

A train derailed due to a railways bed slump of the Canadian National Railway in Saskatchewan. The embankment collapse occurred due to the ground having high levels of water saturation from a rapid snowmelt, coupled with inadequate water drainage due to the formation of an ice plug in the culvert.

Coastal erosion in the UK

Severe weather washed away 80 meters of track in Dawlish

© NetworkRail

In the reconstruction, new walking and cycling infrastructure was also introduced to benefit the local community.

OUR COASTAL RAILWAYS

Rising sea levels and more regular storms accelerate coastal erosion, which significantly impairs the operability and overall safety of railway infrastructure,[5] as the natural material composition on which railway tracks are built is weakened. Consequently, severe weather events paired with rising sea levels can cause railway lines to destabilise and even wash away once the sea walls breach. Landslides risk carrying away relevant material, forcing railway companies to stop operations. Additionally, infrastructure damage comes with significant economic costs to the infrastructure manager due to the required reconstruction work.

Railway companies are not the only ones affected, passengers cannot travel on a given route and must rely on other means of transport, while freight needs to be redirected or moved onto lorries, which causes delays and significantly worsens the carbon footprint of the given trip.

In light of immense reconstruction costs, it is imperative to shed light on preventive solutions. For coastal areas, robust and shock-resistant sea walls can help protect rail lines and stations from incoming waves, even during stormy conditions and extreme weather.

Nature-positive responses can be employed to create a natural barrier between the water and track while providing fertile ground and a habitat for flora and fauna.

Nature Based Solution - Living shoreline

Lamberts Point in Norfolk, Virginia, is a critical marine terminal for railway operations. When the terminal faced flooding due to the considerable and increasing erosion rates at the nearby Elizabeth River shoreline, Norfolk Southern partnered with the Elizabeth River Project to develop a nature based solution in preference to a tradition hard engineering design. The project used a living shoreline to stabilise the area.
These efforts included using 2,300 cubic yards of sand, 24,000 marsh plantings, 2,000 cubic yards of stone and 90 cubic yards of oysters, creating a shoreline with sustainable protection against issues related to climate change.
By providing crucial protection against flooding for the railway's land and infrastructure, Norfolk Southern converted a challenging erosion issue into a collaborative win benefiting biodiversity.

Credits: Norfolk Southern

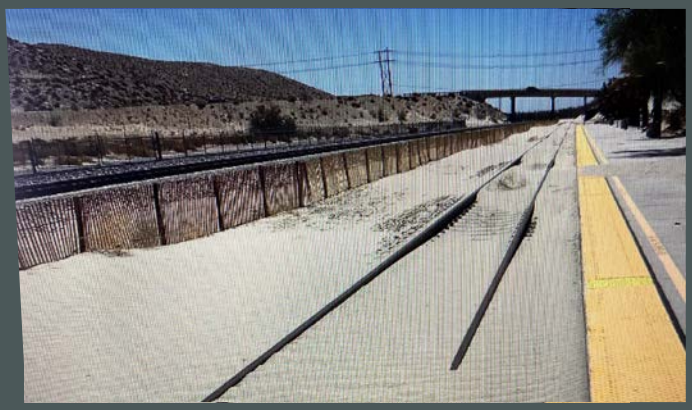
[5] Erridge, "Five Years since We Reopened Dawlish."

HEAT, DROUGHTS AND DESERTIFICATION

Global climate change is resulting in more frequent and severe heatwaves, which alongside rising temperatures and extreme events create desertic conditions in many regions where people, services and goods rely on railways.

For example, ground desiccation can lead to a destabilisation of the embankments on which tracks are built, forcing operators to introduce speed reductions. The reaction of metals is another problem, as the tracks can buckle under temperatures beyond the range for which they were designed. Heat also causes overhead electrical wires to stretch, requiring the wires to be tensioned to avoid sagging. If signalling and telecom systems overheat, operations are put at risk, slowing down or suspending traffic. While extreme temperatures pose health problems to railway employees on the tracks, passengers are also exposed to heat if the usual cooling systems fail. Moreover, during heatwaves and droughts, wildfires are increasingly common with railway assets being directly destroyed or smoke affecting safe operations.

Rail buckling causing derailing in Argentina © Junta de Seguridad en el Transporte



Sand ingress at Palm Springs Station, California ©AMTRAK

Lusail tramway project in Qatar © ALSTOM

Climate change adaptation also plays a significant role for rolling stock manufacturers, as they need to identify technical solutions for enhanced heating, ventilation, air conditioning functions, as well as making power supply substations resilient to high temperatures and equipment designed to resist significant volumes of snow, rain and corrosion from saline atmospheres. The Lusail Tramway Project in Qatar requires coaches to maintain an interior temperature of 23-25 degrees Celsius with external temperatures of 50 degrees Celsius, which requires powerful and reliable on-board HVAC systems.

Solutions

Research and learning

- Cross-sectoral learning with the maritime, road, and energy sectors, for example
- Regular risk assemenents and audits of new vulnerabilities as conditions change
- Research and development into new technology and more resilient materials
- Training programms to prepare drivers
- Simulation excercises to prepare staff and test emergency plans
- Public awareness campaigns to educate passengers about safety procedures during adverse weather conditions, e.g. hydration during heat waves

Adaptive design

- Elevate assets including electrical and tracks above flood levels to prevent water damage
- Install water resistant braking systems
- Upgrade the capacity of drainage systems
- Redesign water catchments/waterways for better flow and capacity regulation

Consider nature based solutions for water managment, embankent stabilisation or cooling

- Proof tunnels and signalling systems against water

Resilient construction

- Use reinforced bridge supports
- Stabilise embankments through, for example, geotextiles
- Use expansion devices to absorb the expansion of tracks under heat - preventing track buckling

Maintenance

- Use reinforced bridge supports
- Stabilise embankments through, for example, geotextiles
- Use expansion devices to absorb the expansion of tracks under heat - preventing track buckling

Emergency management

- Implement protocols for handling extreme events including passenger/customer information and communications with other transport providers and energy suppliers
- Install temporary flood barriers, pumps and sandbags
- Have back up power systems
- Desgin recovery plans to coordinate action

Monitoring

- Use advanced weather forecasting systems
- Install automated track monitoring systems and drone technology
- Have frequent temperature monitoring systems in vulnerable areas

Climate finance projects for railway resilience

Belgrano Sur (Buenos Aires) Passenger Railway Line modernisation project

Climate resilient infrastructure

- **Structural and hydrological upgrades** on railway bridges and viaducts on the Belgrano Sur Line, including drainage system renovation
- **Hydraulic system and pumping** construction, equipped with generators to handle power outages, alongside new rainwater conduits and efficient lighting systems

$675 million World Bank Group financing

https://projects.worldbank.org/en/projects-operations/project-detail/P178067

Serbia Railway sector modernisation programme

- Renewal of tracks and stations in line with **resilience standards**
- **Technical and expert advice** for railway network resilience analysis and plans

$400 million World Bank Group and Agence Française de Développement (AFD) financing

https://projects.worldbank.org/en/projects-operations/project-detail/P170868

Policy action to boost climate adaptation in rail

While tangible solutions exist for climate adaptation in rail, there are bottlenecks to their implementation. UIC is working to provide a platform to boost awareness and share knowledge on how to boost railway resilience on a global scale.

The cost of reconstruction and climate-resilient designs and maintenance is keeping many railways exposed to climate change related risks, which can also affect the deployment of adequate management practices and monitoring systems. To ensure the vitality of rail as the backbone of sustainable transport, there must be investment in railway resilience to protect its infrastructure and, ultimately, its passengers and transported goods from the devastating consequences.

SET CLEAR TARGETS AND POLICY

When analysing current Nationally Determined Contributions (NDCs), only 25% of the documents included railways, and only 10% had specific targets in this respect. Additionally, only 13 NDCs currently include railways in their adaptation plans.

By increasing the ambition of having rail comprehensively covered in the adaption plans for version 3.0 in 2025, parties can demonstrate their drive and set clear a direction for more resilient and sustainable transport.

Good practice: Vietnam's NDC focuses on adaptation to the railway sector. The plan defines the economic cost of the disruption of railway lines at a cost 2.3-2.6 million USD per day.

INVEST IN A SAFE AND RELIABLE RAILWAY

Railways need investment to:

- Recover and rebuild infrastructure after disasters
- Install data systems to understand the exposure and vulnerability of assets
- Share knowledge and build capacity
- Understand interdependencies and coordinate efforts with other modes and infrastructure
- Integrate adaptation into infrastructure, operations and rolling stock design standards
- Have emergency planning and weather forecasting
- Innovate with nature-based solutions and new technologies or materials
- Integrate social benefits and community dialogue

LOSS AND DAMAGE FUNDS FOR RAILWAYS

To support the continuity of railway operations as having a proven mitigative impact, negotiations on climate finance, especially the operationalisation of the UNFCCC Loss and Damage fund,[6] must guarantee that appropriate financing is channelled into railway support. Enhanced dialogue, coordination and synergies among relevant stakeholders from climate finance and the railway industry can support a unified approach to protecting rail systems. Being one of the most critical initiatives within climate finance, the fund can ensure that railways are able to recover from the impacts of climate change and continue providing reliable low-emission transport services for goods and passengers.

[6] UN Environment (UNEP), "About Loss and Damage | UNEP - UN Environment Programme."

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Authors

Anton Beck and Lucie Anderton, International Union of Railways

INTERNATIONAL UNION OF RAILWAYS
16, rue Jean Rey - 75015 Paris - France
Tel. +33 (0)1 44 49 20 20
Fax +33 (0)1 44 49 20 29
E-mail: info@uic.org

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