STRATEGIC NOTE

Climate change adaptation for European infrastructure managers

CONTENT

EXECUTIVE SUMMARY

Climate change has both short- and long-term impacts, including extreme weather events and rising sea levels. This raises challenges for transport infrastructure and society as a whole. Railway infrastructure would be significantly affected by climate change, leading to deterioration, disruptions, and financial consequences. However, railways will play their part in resilience and mitigation efforts thanks to their lower carbon impact and their ability to provide emergency solutions during climate-related crises. To achieve this, railway infrastructure needs to evolve through changes in processes, tools and organisations. Assessing physical and functional vulnerabilities of the infrastructure, not only component by component but also network axis by network axis, considering regional climatic, geographical and geological variations, will help Infrastructure Managers (IMs) prioritize effective and sustainable action plans.

The present note summarizes the work carried out by the PRIME task force on adaptation to climate change. Launched in November 2022, the task force served as a platform for sharing knowledge concerning climate change risks for IMs, exploring adaptation solutions, quantifying the effects, and engaging in discussions regarding European Union (EU) adaptation policies. The findings were presented during the PRIME plenary, in June 2023, and include the following elements.

The increasing frequency and severity of intense precipitation and extreme temperatures are identified as major risks for rail infrastructure. In the past decade, incidents, delays, cancellations, and costs due to natural phenomena have steadily increased for most IMs. However, accurately quantifying the impact of climate change on performance and costs poses a significant challenge for IMs, both in hindsight and by anticipation, as climate projections focusing on infrastructure are still scarce. From this perspective, a clear definition of relevant and harmonized indicators seems essential to foster understanding, comparison, anticipation and adaptation regarding the concerned phenomena.

Many good practices and short-term solutions are already implemented to adapt, and most IMs are integrating climate change issues and solutions within their maintenance and construction policies. Notably, real-time weather monitoring holds significant potential for crisis management and future-oriented research. However, longer-term strategic visions seem essential to ensure a sustainable and efficient adaptation to the intensifying effects of climate change.

Adapting to climate change requires financial and human resources. Yet, currently, IMs do not generally allocate a specific budget to address this issue or have not received the required extra funding for it. In particular, the taskforce stressed out the need to channel both national and European funds towards climate adaptation actions. In line with this, the European Commission (EC) has initiated a study on the required investments for such adaptation on the TEN-T[1] network. Furthermore, guidance methodologies for climate-proofing in Connecting Europe Facility (CEF) projects holds the potential to enhance the level of adaptation across European networks. Lastly, the taxonomy system might constitute a relevant lever to secure funding for adaptation efforts.

[1] Trans-European Transport Network, the EU’s transport infrastructure development program.

1. INTRODUCTION

1.1- Climate change has short-, mid- and long-term impacts

Human-induced climate change is increasing the frequency, intensity and duration of extreme weather events. This trend – underlined by the fifth IPCC[2] report[3] - will continue over the course of the century.

Phenomena linked to climate change result in both:

- **Short and mid-term effects**, such as extremely high temperatures or intense precipitation (rainfall mainly but also snowfall)
- **Longer term impacts**, such as the rising of sea levels.

As a result, challenges will steadily increase for transport infrastructure, as well as society as a whole.

1.2- Railway infrastructure will be strongly affected by climate change but can also prove to be a factor of resilience

As all infrastructure, rail networks are and will be affected by climate related events both physically and functionally. Deterioration in robustness and punctuality, disruptions to traffic, premature ageing of infrastructure, damage and destruction are among possible effects. These will equally result in increased need for maintenance and renewal works, un-recovered investments, negative financial consequences as well as increasingly frequent crisis management.

But **railways are also a part of the global solution to the challenges arising from climate change.**

- **Because rail transport has a lower carbon impact, it can contribute to the mitigation effort,**
- **Because rail transport has proven resilient, it can bring solutions within climate related crisis.** To take one example, in October 2020, heavy rains and flooding have caused the destruction of road infrastructure and the collapse of several bridges, isolating many villages in the Roya Valley in South-Eastern of France. Though severely damaged, railways proved instrumental in rescuing people stranded in flood-affected areas where roads were inaccessible.

1.3- To contribute to mitigation and to adaptation, railway infrastructure has to evolve

Adapting the infrastructure and its management will require a wide range of changes in processes, tools and organisations. In order **to determine and prioritize the actions** to be taken, the current and future **vulnerabilities of the infrastructure must be assessed at two complementary levels**:

- the **intrinsic vulnerability** of infrastructure **components**
- and the **systemic approach** to the network's altogether vulnerability, which takes into account the variation in exposure to climate change from one region to another. This global view, complemented by territorial and business visions, should make it possible to define prioritized, effective and sustainable action plans.

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[2] The Intergovernmental Panel on Climate Change is the UN body for assessing the science related to climate change

[3] IPCC, AR5 Synthesis Report Climate Change 2014, October 2014 [https://www.ipcc.ch/report/ar5/syr/]

2. PRIME INFRASTRUCTURE MANAGERS LAUNCHED A TASK FORCE ON ADAPTATION

Considering the fact that climate change represents a strategic issue for European infrastructure managers in the short and long terms, a dedicated PRIME task force has been launched in November 2022[4] aiming at exchanging best practices and proposing some recommendations for the future EU policy on rail infrastructure climate resilience.

Eleven IMs[5], all PRIME members, met monthly to provide and share inputs on the following four topics:

i. identifying increasing climate change related risks and infrastructure vulnerabilities,

ii. identifying climate change adaptation solutions,

iii. quantifying the impact of climate change on rail infrastructure,

iv. discussing EU proactive policy on adaptation.

The task force produced two main outputs:

1. An input paper for a strategic discussion on infrastructure adaptation to climate change that was held at the PRIME Plenary meeting of June 2023.
2. A strategic note which identifies short-term solutions and good practices while it aims to catalyse a broader discussion amongst IMs on long-term challenges.

The present so-called "strategic note" highlights the outcome of the discussions the task force had and some of the key messages as discussed during the PRIME Plenary of June 2023. It includes:

- a presentation of the short-term and long-term risks of climate change that European IMs are most concerned with, along with their quantification;
- a set of best practices and the low-hanging fruits aiming at deploying frugal short-term adaptation measures;
- a call for a deeper commitment to climate resilience along with a highlight of the EU's proactive policy on the issue.

[4] PRIME plenary held in Naples in November 2022.

[5] ADIF, FTIA, INFRABEL, LTG INFRA, ÖBB INFRA, PLK-PLK, PRORAIL, RFI, SBB INFRA, SNCF RESEAU, TRAFIKVERKET

3. INCREASING CLIMATE RISKS FOR RAIL INFRASTRUCTURE: vulnerabilities, risk and cost assessment, perspective

3.1- Phenomena with higher frequencies and stronger potential impact on infrastructure: intense rainfall and extreme temperatures

Frequency and severity of intense rainfall[6] and extreme temperatures, such as heat (and even cold) waves, are expected to increase significantly in the coming years. The benchmark produced within the task force on the topic of climate change risks and vulnerabilities shows that, for all IMs, these two main climate phenomena are expected to have a major impact on rail infrastructure.

In particular, the increase of the frequency and severity of the combination of the two events is expected to have the strongest impact.

Flooding on dry grounds is pointed out as one of the major risks weighing on rail infrastructure by a vast majority of IMs. For PRORAIL, the pattern of recurrent droughts and heavy rainfall events could speed up soil inclination, in specific areas of the Dutch Polders. In Spain and France, ADIF and SNCF RESEAU believe that the combination of these two phenomena may result in making infrastructure physically more vulnerable to clay shrinkage and swelling: the occurrence of this geological phenomenon leads to critical deterioration or even destruction of the infrastructure.

IMs such as ÖBB INFRA, SBB INFRA and SNCF RESEAU indicate on the other hand that **reduced snowfall and melting of permafrost may lead to a potential increase of rock falls on their networks leading to strong functional disturbances**. Other IMs consider that this could also increase the risk of landslides. ÖBB INFRA and PRORAIL highlight the fact that such weather conditions would on the other hand lead to potential energy savings on the long term, in specific areas, as switches, for example, would require less seasonal warming.

Although the impact of strong winds on the infrastructure is functionally (lines' closures, temporary speed restrictions) and physically (damage to overhead lines) significant, the extent to which their frequency and severity will increase as a result of climate change remains uncertain and perceptions on this matter vary within the task force.

3.2- Both civil engineering and electrical components are vulnerable to these risks.

The benchmark produced within the task force reveals that:

- **the civil engineering part of rail infrastructure (such as tracks, bridges, earthworks and hydraulic structures) is particularly vulnerable to heavy rainfall,**
- **while electrical engineering (such as signalling, electric traction or electronics) is more vulnerable to extreme temperatures.** Nonetheless, this does not preclude electrical engineering from also being at risk from flooding or water-related hazards.

The following table summarizes the various impacts that weather events as perceived by participant IMs would increasingly have on infrastructure domains.

[6] While *heavy rainfall* may refer to short, severe and very localized phenomena, a long-lasting one over large areas is also to be expected as such according to INFRABEL.

Impacts of weather events on civil engineering

Tracks	Heavy rainfall	Flooding of tracks/ballast	ADIF, FTIA, INFRABEL, LTG INFRA, ÖBB INFRA, PRORAIL, RFI, SNCF R
		Washing out of lubricants in switches	INFRABEL, RFI
	Heat wave	Rail buckling	ADIF, FTIA, INFRABEL, LTG INFRA, ÖBB INFRA, PRORAIL, RFI, SBB INFRA, SNCF R
	Cold wave	Ice/snow on tracks / breaking of rails	ADIF, FTIA, INFRABEL, LTG INFRA, ÖBB INFRA, PKP-PLK, PRORAIL, RFI, SBB INFRA
	Storm	Trees on tracks	ADIF, INFRABEL, ÖBB INFRA, PKP-PLK, PRORAIL, SNCF R, RFI, SBB INFRA
Tracks surroundings	Heat wave	Wildfires	INFRABEL, ÖBB INFRA, PRORAIL, SBB INFRA, TRAFIKVERKET, SNCF R
Earthworks and hydraulics	Heavy rainfall	Mudflows, flooded platforms, landslides, erosion	ADIF, FTIA, INFRABEL, LTG INFRA, ÖBB INFRA, PRORAIL, RFI, SBB INFRA, SNCF R, TRAFIKVERKET
	Heat wave + heavy rainfall	Clay shrinkage/swelling	ADIF, PRORAIL, SNCF R
Engineering structures	Heavy rainfall, snowmelt	Destruction and critical instability	ADIF, FTIA, INFRABEL, PRORAIL, RFI, SBB INFRA, SNCF R

Impacts of weather events on electrical engineering

Electrical traction	Heat wave	Catenaries expansion	INFRABEL, ÖBB INFRA, PRORAIL, RFI, SNCF R
		Malfunctioning substations/catenaries	INFRABEL, PKP-PLK, PRORAIL, RFI, SBB INFRA, SNCF R
		Blackout on electrical network	INFRABEL, PRORAIL, SBB INFRA, SNCF R, TRAFIKVERKET
	Cold wave	Catenaries icing / malfunctioning	INFRABEL, PKP-PLK, PRORAIL
	Heavy rainfall	Flooding of low voltage equipment in substations	PRORAIL, SBB INFRA, SNCF R
	Storm, rainfall	Trees on catenaries	INFRABEL, ÖBB INFRA, PKP-PLK, PRORAIL, RFI, SBB INFRA, SNCF R
	Thunderstorm	Malfunctioning substations	PRORAIL, SBB INFRA, TRAFIKVERKET
Signalling equipment	Heavy rainfall	Compromised insulation	PRORAIL, SBB INFRA, SNCF R
	Thunderstorm	Malfunctioning	PRORAIL, SBB INFRA, TRAFIKVERKET
	Heat wave	Overheating	INFRABEL, ÖBB INFRA, PKP-PLK, PRORAIL, RFI, SBB INFRA, SNCF R
	Cold wave	Freezing	PKP-PLK, PRORAIL, SBB INFRA

3.3- Risk matrix as an instrument to establish priorities

Climate change risk matrices constitute strategic tools for prioritizing adaptation actions. However, currently only ADIF and PRORAIL are using and implementing such tools. Such *climate change* risks matrices differ from *climate* risks matrices that all IMs build on an annual basis, as they are set up according to climatic projections (in general the ones made or inspired by IPCC findings).

A risk matrix typically consists of a grid with a probability axis and a severity axis. Hazards are placed in their corresponding cells representing a level of risk. Different approaches can be used to establish risk matrices for the railway network. PRORAIL has favoured a top-down method since 2011, establishing matrices at the national network level and updating them on a regular basis.

In contrast, ADIF has adopted a bottom-up approach, developing risk matrices for each infrastructure project and gradually aggregating them to cover the entire network.

3.4- The increasing impact of natural hazards over the last 10 years

3.4.1- The need for collecting and monitoring common indicators

In the past decade, the frequency of extreme weather events seems to have increased, leading to a rise in train delays, cancellations, and higher investments and expenses in the infrastructure. Such trends that some IMs seem to witness testify to the fact that climate change has already had an impact on rail infrastructure in Europe.

As an example, over the last ten years, SNCF RESEAU reports an increase of 11% in cancellations, 1,4% in disturbances and 0,9% in delays, as results of weather events. Such increases have also been observed by SBB INFRA and RFI.

Nevertheless, it is interesting to note that regarding floods in particular, despite an increase in their frequency, RFI registered fewer functional disturbances linked to this phenomenon. This positive result can be attributed to investments made in recent years to mitigate the impact of flooding on its infrastructure. **Such an example could illustrate the effectiveness of allocating specific resources to climate change adaptation of rail infrastructure.**

3.4.2- Cost estimation

Participating IMs within the task force agree on the *magnitude of the costs incurred* due to climate change induced losses and maintenance. PRORAIL estimates that climate change related costs amount to 10 M€ per year currently and is expected to reach 90 M€ per year in 2036. RFI mentions about 20 M€ of losses per year and about 90 M€ of additional maintenance costs per year. Similarly, SNCF RESEAU totalizes 10M€ of such losses per year. Yet, these figures are average costs calculated on the basis of the entire year's events: they do not represent the individual costs that each event bears. For example, INFRABEL concluded that the cost of its 2021 extraordinary floods alone amounted to 65M€.

Such trends and figures have to be taken with caution. Today not all IMs are able to firmly link the performance indicators they measure to a potential origin/cause that would be "climate change". Though most IMs are able to connect the above figures to "weather events", they encounter difficulties as well in detecting a trend over the past ten years.

Common calculation methods and systematic harmonised indicators could help to monitor and compare climate change-related costs. The few values presented above remain scattered. As a matter of fact, assessing and comparing these costs is challenging due to the variety of methods used by IMs. Besides, some IMs are not yet able to provide such costs – but they do have ongoing processes to create dedicated databases and records on the issue.

3.5- Impacts of climate change on the next 30 to 50 years: climatic projections are still scarce but increasingly more IMs are launching them

30- and 50-year projections based on RCP 4.5 and 8.5 scenarios by the IPCC are already used by some of the participating IMs.

In January 2023, ÖBB INFRA conducted a climate risk and vulnerability analysis based on RCP 8.5 scenario for the periods 2021-2030 and 2021-2050 and assessed, over the entire network, changes in climate change risks such as heat waves or severe precipitation over these periods.

Since 2022, SNCF RESEAU has launched two types of climatic projections based on RCP 4.5 and RCP 8.5. scenarios on different time horizons (2050 and 2080).

- A projection taking into account the impact expected on the entire French network but focusing on five risks considered as major.
- Localized projections that provide detailed information on climate risks within a specific area. Such studies have been published concerning the Seine axis and the Languedoc arc (Southwest of France).

Similarly, INFRABEL cross-references geological and climatic data to perform comprehensive projections on defined areas.

To date, not all IMs have built projections in the long-term using IPCC scenarios. However, most have ongoing processes and some, such as ADIF, are already using national projections (based on the RCP scenarios), as previously mentioned. For example, though its project is not based on the scenarios provided by IPCC, SBB INFRA launched the development of a predictive model for a natural rail specific hazard map, encompassing hazards such as avalanches, landslides, water, and surface runoff for the 2060-2080 period.

Reliable cost estimates of the impacts of climate change for the periods 2050/2080 are lacking among most IMs. However, processes are being devised to understand the long-term effects of climate change on rail infrastructure. For instance, PRORAIL is currently developing adaptation plan for its rail network, PKP-PLK is updating its own one and broadening its scope while SNCF RESEAU is working on a global strategic approach in order to have a long-term view on such issues.

4 ADAPTATION SOLUTIONS TO CLIMATE CHANGE

4.1- Best practices and short-term solutions exist

4.1.1- Already implemented good practices

Concrete short-term practices, mainly dealing with the impact of more frequent and severe heat waves and precipitations, are already implemented by some IMs. Through the taskforce, IMs shared such practices and short-term solutions, efficient, cost effective and easily replicable, to prevent from or fight against negative consequences of climate change on the infrastructure.

Such practices may concern both

- Maintenance patterns
- Operational procedures

The following figures sum up shared adaptation solutions to the increasing risks related to heavy rainfall and extreme temperatures as identified as major climate change related risks by the task force.

Heavy rainfall adaptation solutions

- Redimensioning of culverts to adapt to larger water flows
- Cooperating with neighbouring field owners to adapt to water run-off
- Heightening of signalling boxes / electrical substations
- Stopping sealing parking spaces in stations and tracks surroundings
- Use of more resistant lubricants on switches

Extreme temperature adaptation solutions

- Extending summer maintenance tours
- Equipping substations / signalling boxes with cooling systems such as climatization rather than ventilation
- Using more resistant lubricants on switches
- Grinding trains accompanied with water reserves
- Painting signalling shelters or substations in white

To adapt to heavy rainfall, SBB INFRA shared one of its solutions that consist in **unsealing parking lots, stations and some tracks surroundings**. Rainwater is absorbed or stored locally instead of being discharged or channelled. It prevents from flooding during heavy rainfall and in case of heat waves, water evaporation cools down the surrounding environment. Though it requires years and investments, its implementation is ongoing on the Swiss rail infrastructure.

SNCF RESEAU cooperate with neighbouring landowners to mitigate the impact of water runoff on their infrastructure - in particular, embankments. Generally, SNCF RESEAU **supports neighbouring farmers and other landowners in planting trees, bushes, hedges, or other natural elements in their fields surrounding the tracks in order to impede water flows towards infrastructure**. This measure is efficient collectively, inexpensive for the IMs and can be eligible for ERDF funding. INFRABEL is considering implementing more actively similar arrangements with landowners neighbouring their infrastructure.

PKP-PLK is currently conducting research to **find lubricants that are more resistant to different weather conditions**. INFRABEL needs as well to use extra lubricants due to heavy precipitations that wash out the product (high temperatures causing evaporation of the product as well, and low temperatures results in freezing switches and so leading to switches malfunctioning).

Regarding heat waves, several infrastructure managers have tried to **apply white paint on infrastructure components such as signal boxes in order to reduce heat absorption and thus adapt to heat waves**. However, while this practice appears effective for signalling boxes or substations in France for example, painting the tracks white, as RFI does at local level, appears to be less relevant as it requires additional regular maintenance.

Conversely, **the increase in the rail neutralization temperature** i.e., the temperature at which the rail is heated before being laid on the track (32 - 33°C in Italy, 25°C in Switzerland and 24°C in France for example), **could be an efficient strategy to adapt to the rise of temperature**[7]. An increase by a few degrees higher minimizes temperature-related compressive forces between ballast, sleepers and rails: rails would then be more resistant to high temperatures. However, while this temperature raise is easily feasible in warmer regions, it could result in a challenge in colder climates.

Replacing ventilation systems with air conditioning for signalling boxes and substations during heat waves have also been implemented as a short-term solution by SNCF RESEAU. It is effective according to the French IM. INFRABEL improved the ventilation of their signalling boxes (yet, not necessarily thanks to air conditioning) and installed cooling systems in substations.

Regarding the risks of wildfires, IMs partly rely on public firefighting resources, but several of them have also created their own support resources dedicated to this risk pointed out as a major one in the years to come. For instance, ÖBB INFRA is currently **developing tunnel rescue trains equipped with firefighting capabilities**. As another example, PRORAIL has implemented the **creation of firebreak corridors to prevent the spread of fire**.

However, if these IMs allocate human resources to firefighting, it should be noted that these employees are not firefighters. If most IMs consider firefighting resources to be sufficient to prevent fire and fight against it by the end of the century, they acknowledge that such a consideration is hard to assess since they largely rely on public authorities.

Besides, IMs have also implemented **fire prevention measures, such as vegetation management around the tracks or equipping high-risk grinding trains with water reserves**.

It is important to note that **adaptation does not necessarily imply the full retrofit of the infrastructure** so as to offer the same level of service at all times: **operational strategies may prove more or less cost efficient** depending on the frequency and the intensity of the phenomena. For example, on the SNCF RESEAU network, train speeds are adapted in cases such as:

- high winds (northern high-speed lines)
- heatwaves
- snowstorms

4.1.2- The need to integrate climate resilience into maintenance and construction policies

[7] The method of calculating the neutralization temperature could differ from one country to another

The integration of climate change issues in new constructions and maintenance policies is currently carried out by most IMs. Still, integrating climate change into policy and maintenance work is a more complex task than constructing new resilient infrastructures.

New construction can be based on adaptation plans that incorporate infrastructure resilience to climate change. As an example, **new infrastructures built by TRAFIKVERKET are designed according to the projections from RCP 4.5 and RCP 8.5 scenarios.** In the same perspective, **PRORAIL has developed stress tests and scorecards** to be applied to all new construction projects.

PRORAIL have also drafted versions of these stress-tests and scorecards for maintenance projects. This demonstrates that strategic tools can be created by IMs to integrate climate change considerations into maintenance practices. **Updating maintenance guidelines to incorporate climate change is already envisioned by many IMs and some have already started this process to adapt to heat waves and floods**. Besides, the implementation of alarm systems and monitoring networks, combined with the adaptation of crisis management rules, ensure a more effective risk management by IMs.

4.2- Weather monitoring for crisis management and research

Though weather monitoring is a common practice among IMs, more efforts and funds would be required to properly adapt weather surveillance to more extreme and less predictable events. Due to the significant impact of weather on infrastructure use, traffic and safety, all IMs have implemented meteorological monitoring solutions, different from one another.

Currently, **only ÖBB INFRA has its own meteorological service called "*infra_wetter*".** This route related system provides macro weather information and supplies for 72 hours previews and other meteorological forecasts. If necessary, this system allows for direct notification of operational teams through warnings and alerts.

Some IMs such as INFRABEL and ADIF own weather stations. However, the Spanish IM has merely installed stations on high-speed lines where they are used for monitoring cross winds to better implement speed restrictions to train running in case of strong winds. INFRABEL's system of weather stations is also equipped to send out alerts to operational teams, especially with respect to heat related problems. These teams can also consult a weather dashboard to consult information in "real time". On the basis of data collected from their weather stations, **INFRABEL built a control algorithm for the automated management of the switch heating**. This is an energy savings measure – not specifically aiming at adaptation to climate change.

In the perspective of climate change, **monitoring the weather provides many benefits**. Weather data can be correlated with infrastructure data, provide alert systems to anticipate extreme events and enable appropriate action. Adapted maintenance can also be implemented according to weather conditions. All in all, it constitutes an essential tool to support decision on weather issues impacting the infrastructure. Therefore, given the expected increase of extreme climate-related hazards because of climate change, efforts to further develop weather monitoring should be or keep on being implemented by IMs.

4.3- Despite being rarely used, some European technological tools provide useful climate data for adaptation purposes

The European Earth observation system, Copernicus, collects data and provides monitoring and forecasting tools on environment and climate change. More specifically, the Copernicus Climate

Change Service (C3S) offers information on past, present, and future climate in Europe, enabling the development of appropriate policies. **SNCF RESEAU uses on a regular basis the European Monitoring Ground System (EGMS) platform of Copernicus to track ground movements by satellite**. This EU tool can be used use for expertise on unstable structures, valuable for IMs. This platform is also used in specific projects such as the ARGOSS project (a partnership between SNCF RESEAU and CNES, the French space centre) to predict future risks of land use.

Today **only TRAFIKVERKET and SNCF RESEAU seem to use Copernicus platforms.** RFI and ADIF, for instance, consider the data provided by this European tool as not really adapted to rail infrastructure needs. Thus, initiatives such as the EO4infrastructure project are welcome. This project consists in a collaboration between ESA and stakeholders such as SNCF RESEAU, RFI, and DB NETZ, aimed at redefining the railway sector's needs for European Ground motion Service. The concerned IMs have informed ESA of their interest in putting into orbit a satellite equipped with an L-band radar that can provide data on soil moisture content.

Other European tools providing data on climate change adaptation could potentially be used by IMs, **Climate-ADAPT and European Climate and Health Observatory for example**. These web portals deliver climate projections, geographical vulnerability, adaptation strategies, case studies, guidance, etc. They seem to be seldom used by IMs.

4.4- The need for long-term planning and studies

Long-term solutions have also been discussed by the task force as they are explored by IMs through research projects that require time and funding. Special attention is given to the monitoring and observation of soil stability, given its crucial role in upholding infrastructure and its vulnerability to the impacts of climate change. As an example, SNCF RESEAU has launched initiatives to monitor changes in land use adjacent to the railway tracks and to detect initial indications of soil instability in advance. Similarly, RFI considers hydrogeological instability during extreme rainfall or flooding as a top priority as well as INFRABEL which focus specifically the implementation of earth embankments in such conditions. The purpose of the study launched by the Belgian IM consists in identifying earth embankments of which the stability is at risk in case of heavy rain and/or flooding.

Other issues are also perceived as major ones. ADIF aims to minimize the **impact of extreme weather on local rail infrastructure in arid zones**. PRORAIL operates a monitoring system to **assess the effects of humidity and heat on their assets** in Amersfoort. PKP-PLK is working towards obtaining tools to identify trees and shrubs that pose a threat to the infrastructure due to increasingly severe and frequent winds, storms, and snowfalls.

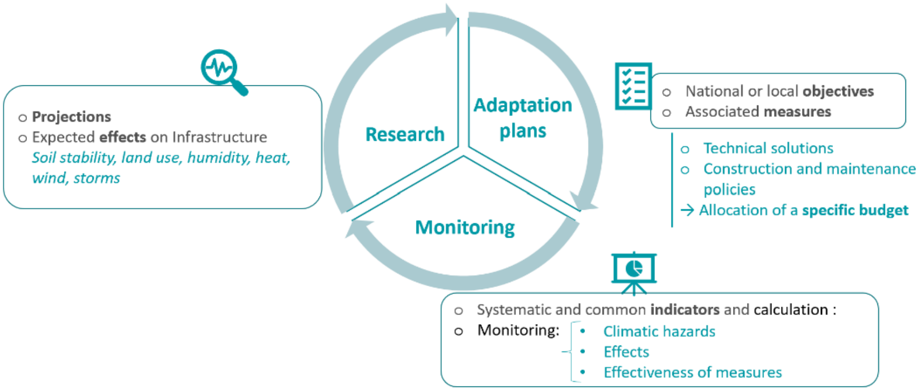
Each Member State provides national adaptation plans for climate change, with some outlining specific objectives for the railway sector and its infrastructure. The roadmaps usually concern the 2030 horizon, establishing objectives of varying specificity for different sectors, including transportation. For instance, Belgium focusses on the creation of vulnerability maps for the network and on the adaptation of technical guidelines for the dimensioning of drainage structures. The Polish national plan also takes climatic conditions into account in the process of design and construction of the transport infrastructure, alongside aforementioned measures. Distinctively, Spain, Italy, Finland, and France present a more general approach which does not include specific objectives for the railway sector.

These plans remain overly general and, to date, hardly any IM presents a long-term adaptation strategy. Likewise, systematic studies incorporating projections beyond the 20 or 30-year timeframe are quite rare.

Yet, **these two elements may constitute a "virtuous" cycle, helping to continuously improve the resilience of the networks**. Indeed, defining a strategy upstream helps to anchor the issue of climate resilience in the policies put in place by the IMs.

This entails dedicating a budget, defining indicators, setting objectives, and implementing clear measures, particularly regarding the adoption of technical solutions and associated policy frameworks.

The implementation of this plan is then reinforced by the **monitoring of indicators that facilitate real-time surveillance of climate-related hazards, their impacts, and the efficiency of implemented measures**. Furthermore, the collected data can be leveraged for extensive research,



encompassing future projections and the development of innovative technical solutions.

Ultimately, the outcomes of these studies can be used to draft a more comprehensive and effective long-term plan for the coming years.

In this context, research based on experience feedback and definition, acquisition and monitoring of appropriate indicators plays an essential role in understanding, anticipating and managing the risks involved.

5 FINANCIAL RESOURCES NEEDED FOR CLIMATE RESILIENCE

5.1- No budget is specifically allocated by the IMs to adapt their infrastructure per se

Typically, IMs do not allocate dedicated resources for climate change adaptation which is encompassed within the general budget. However, an increasing number of projects and employees are dedicated to climate change.

ADIF has expanded the number of R&D personnel focused on climate change. SNCF RESEAU is undertaking new projects related to climate change in the wake of the study of climate change effects by 2050 and 2080 on the Seine Axis which received a specific research tax credit. Similarly, PRORAIL tries to get distinct funds from the Dutch government to handle adaptation. In the end, many IMs seek resources for adaptation from external actors, either public or private.

Given the prominence of the issues related to climate change in European policies, materialized by the adoption of the EU Green Deal in 2020, numerous financial levers originating from the EU can potentially be triggered by IMs for climate change adaptation.

5.2- Facilitating the EU funding targeted at making infrastructure projects resilient would prove to be catalytic and provide the opportunity to adapt on a larger scale than today

For now, European Union funding opportunities, including CEF[8], ERDF[9], and Horizon Europe[10], are not directly used to support climate change adaptation projects. Most IMs regularly apply to CEF or ERDF calls. However, none of them has ever submitted a project properly asking for money to specifically adapt the infrastructure to climate change. Only ADIF has already used ERDF and CEF funds to finance project-related vulnerability studies. The 7 billion euros received by ADIF in the 2021 Resilience and Recovery Fund call will also help finance such studies. It is to be noted that SNCF RESEAU is currently considering the use of Horizon funds to finance studies related to climate change adaptation.

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[8] The Connecting Europe Facility is a key EU funding instrument to promote growth, jobs and competitiveness through targeted infrastructure investment at European level – especially transport infrastructure.

[9] The European Regional Development Fund provides funding to public and private bodies in all EU regions to reduce economic, social and territorial disparities.

[10] Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion

In the future, an increase of the dedicated existing CEF budget would have to be considered.

Some IMs also use funds that are not *directly* linked to the European Union. The European Investment Bank (EIB) financial instruments or funds from international cooperation such as ENI CBC[11] are used by ADIF or FTIA for instance.

Moreover, in the frame of CEF calls projects which aim at upgrading TEN-T infrastructure can apply for fund calls. As of today, "enhancing infrastructure climate resilience" is not considered as such as an "upgrade". The task force suggests then that the notion of "infrastructure upgrading" encompasses the enhancement of infrastructure climate resilience. This change would undoubtedly facilitate the channelling of CEF funds towards fostering the implementation of a more resilient TEN-T infrastructure to climate change.

5.3- The study launched on the TEN-T core network by the EC is a first step to make resilient infrastructure a capital issue at the heart of EU fund calls

The EC launched on 23 May the call for tender for a "Support study on the climate adaptation and cross-border investment needs to realize the TEN-T network". The study was initiated under DG MOVE's framework contract for impact assessments and evaluations. **The EC expects to get the first results available at the end of March 2024.**

The study will support the Commission in its analysis of the investment needs to implement the TEN-T network, in particular in view of making TEN-T climate resilient and removing its main cross-border bottlenecks. The aim of the study is thereby two-fold:

- to **identify climate risks** on the TEN-T network, corresponding **adaptation measures** to address them and the **costs/ investment needs associated** with these measures ;
- to **identify cross-border investment gaps** on the TEN-T core and extended core network (as defined by the 2021 proposal for a revision of the TEN-T Regulation).

An overall objective of the study is to inform the Commission's decision-making in determining the investments needed to increase the climate resilience and connectivity of the TEN-T network in the context of the next Multiannual Financial Framework (MFF) and the next Connecting Europe Facility (CEF III).

The scope of the study would comprise all 27 EU Member States, including important connections to third neighbouring countries with regard to the newly established European Transport Corridors. When it comes to the identification of investment needs, particular attention will be given to the geographical coverage of the TEN-T core and extended core network with their 2030 and 2040 completion targets, respectively, as defined by the proposal for a revision of the TEN-T Regulation. The climate risk assessment itself will aim to encompass the TEN-T network in its entirety.

The IMs having participated in the task force are ready to participate in the work of the Commission and the selected consultants. IMs hope that this initiative would lead to easier financing of adaptation by the EU.

[11] The European Neighbourhood Instruments Cross-Border Cooperation is a key element of the EU policy towards its neighbours. It supports sustainable development along the EU's external borders, helps reducing differences in living standards and addressing common challenges across these borders.

5.4- While answering to CEF calls, the application of common methodologies for climate-proofing would enhance the level of adaptation of the European networks

In order to be effectively implemented, the clarification and harmonization of Commission's recommendations on climate proofing for infrastructure projects in the frame of the TEN-T regulation[12] seem crucial for most IMs.

For now, IMs have not yet implemented this method to prove the climatic resilience of their projects - with the notable exception of ADIF. The technical guidance on the climate proofing of TEN-T infrastructures in the period 2021-2027 describes specific steps to be implemented on two pillars: mitigation and adaptation to climate change. Though it is not mandatory, the use of this method is going to be strongly favoured in CEF calls which are very competitive. Thus, IMs such as INFRABEL and RFI have already planned to implement these methods for the upcoming 2023 CEF calls. Other ones like ÖBB INFRA, FTIA or SNCF RESEAU intend to assess climate proofing in a similar way.

ADIF complies with the technical guidance of the Commission since 2020. The Spanish IM also follows those published by JASPERS[13] (a cooperation involving the Commission, the EIB and the EBRD[14]) and wants to expand the use of these two methods to the totality of their projects. However, due to the variety of projects, components and implied stakeholders, the Spanish IM encounters difficulty in trying to do so. This issue is shared by several IMs which struggle to understand and implement this guidance. Even though DB NETZ is not a member of the task force, the German IM did step in one of the task force sessions to highlight the issues raised by this guidance in its view. In particular, the German IM emphasized that the implementation of the adaptation pillar is not implemented yet and is still in its "learning phase".

The task force suggests that complying with the Commission technical guidance should be considered by IMs as a relevant way to streamline the climate resilience of the TEN-T infrastructure all over Europe.

5.5- Taxonomy could be used as a lever to enhance adaptation to climate change

At last, the European green taxonomy consists also in an important funding lever for IMs whose efforts should be pursued to align their activities with this classification system (especially considering the future adoption of the European Green Bonds standards). This is especially true in light of the substantial issuance of green bonds by some IMs such as SNCF RESEAU and ADIF. Since 2016-2017, these IMs, who are among the pioneers in this field, have been issuing several hundred million euros' worth of green bonds each year. The taxonomy lever stands for an excellent opportunity to showcase the low-carbon characteristics of rail projects and to unlock public or private funding for them. As adaptation to climate change is one of the six environmental objectives of the taxonomy regulation and to which IMs' activities shall contribute in order to be classified as green. **These funds could as well be used for climate change adaptation**.

[12] Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (2021/C 373/01)
[13] Joint Assistance in Supporting Projects in European Regions
[14] EIB: European Investment bank; EBRD: European Bank for Reconstruction and Development.

6 SUMMARY AND RECOMMENDATIONS

Rail provides a competitive climate-resilient solution by nature compared to other transport modes. However, ensuring the intrinsic adaptation of rail infrastructure to climate change is crucial in terms of service efficiency, public safety and infrastructure financing.

Frequency and severity of extreme climate events have risen in recent years. This trend is expected to escalate over time. Intense rainfall and extreme temperatures in particular entail significant risks, including physical impact and operational consequences that weigh on the rail infrastructure. **Adaptation to climate change the infrastructure is a strategic issue for infrastructure managers**.

Implementing efficient adaptation solutions to rail networks is crucial. IMs have already started to do it. **They need to go further with the support of their Member States and the EU**.

Recommendations that the participants to the task force deem essential to keep on enhancing the climatic resilience of rail infrastructure are highlighted in the following paragraphs.

6.1- Recommendations to Infrastructure Managers

1. The combination of a project-oriented perspective and a systemic approach to the network seem relevant to implement effective plans and strategies at various levels of detail.

2. To understand and anticipate climate change risks:

- **A clear definition of indicators** related to climate hazards, performance metrics (delays, disturbances, cancellations, etc.) and associated costs would improve the monitoring and understanding of these phenomena and their effects
- **Common calculation rules and harmonization of these indicators** among IMs would facilitate knowledge sharing and improve the necessary cooperation among them.
- **Projections based on the reference scenarios of IPCC** would enable better anticipation and comparison of future hazards and their consequences, facilitating appropriate adaptation.

3. Solutions should be selected based on a **common understanding of the climate phenomena, their anticipation, and the cooperation between IMs**:

- **Easily applicable best practices should be shared more widely among IMs and more systematically**. It remains crucial for IMs to persist **in sharing their experiences** on the subject to foster innovation and drive progress.
- **Development and implementation of weather monitoring systems** should be accelerated. The data derived from such services holds a substantial potential in crisis management, hazard anticipation, phenomena comprehension and conducting projections.
- **Incorporating climate change into maintenance and construction policies** is crucial to ensure ongoing anticipation and enhanced resilience. Key measures include the use of climate-related risk matrices, conducting tests to assess infrastructure resilience against climate phenomena.
- **The search for long-term solutions should be strengthened** with the development of comprehensive, long-term strategies with defined costs and budgets.
- **By considering and complying to national adaptation plans,** a logical and coherent approach can be fostered in relation to other sectors involved within the national territory.

4. The channelling of human and financial resources towards climate change adaptation is essential to effectively tackle this issue**:**

- **A specific allocation of internal and external personnel and funds** is necessary to properly address this issue.
- **The submission of projects directly related to climate change adaptation** to European funds such as CEF, ERDF or Horizon can be relevant. These funds can provide financial support, as already practiced for studies.
- **The implementation of the Commission's technical guidance on climate proofing** is recommended to encourage project applications in the frame of calls and enable better benchmarking among IMs.
- **Further efforts to align with the taxonomy** are appropriate given the low-carbon advantage of rail and the growing importance of the financing levers taxonomy would give IMs access to.

6.2- Recommendations to the European Commission

- **The clarification of the climate proofing guidance and harmonization of its implementation** for infrastructure projects in the frame of the TEN-T network is needed considering the challenges and uncertainties encountered by the IMs in implementing them.
- **Enhancing climate resilience of the infrastructure should be considered as an upgrade** in itself as it would allow IMs to apply to CEF calls in order to get fund specifically for adaptation to climate change.