



Preliminary Design for the Rehabilitation of the Railway Corridor VIII Rrogozhina – Pogradec

Specific Contract number: AA-010284-001

Climate Change Resilience and Vulnerability Assessment Report (CC Report)

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led by SUEZ Consulting (SAFEGE)

Name of Project

Preliminary Design for the Rehabilitation of the Corridor VIII Rrogozhina - Pogradec Section, Albania - AA-010284-001

Climate Change Resilience and Vulnerability Assessment Report

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This technical assistance operation is financed under the EIB's Economic Resilience Initiative (ERI). The ERI is EIB's response to the European Council's call to intensify its support for the EU's neighbourhood, in pursuit of economic growth and the achievement of the sustainable development goals (SDGs). The objective of this initiative is to rapidly mobilise additional financing in support of sustainable growth, vital infrastructure and social cohesion in Southern neighbourhood and Western Balkans countries. The Economic Resilience Initiative focuses on both the public and the private sectors, in support of EIB activities during different stages of the project cycle. The EIB is contributing to the ERI TA window with an envelope amounting to EUR 90 million from its own budget resources".

The authors take full responsibility for the contents of this report. The opinions expressed do not necessarily reflect the view of the European Investment Bank.

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LIST OF ABBREVIATIONS

DD	Detailed Design (also referred to as Main Design - MD)
EU	European Union
IFI	International Financial Institution
IPF	Infrastructure Project Facility
TA	Technical Assistance
WB	World Bank
ALB	Albania
WBIF	Western Balkans Investment Framework
RCP	Representative Concentration Pathway

1 Introduction

Current climate variability presents a major challenge to the operation and maintenance of transport infrastructure. In some countries, transportation systems are vulnerable to various extremes of weather, such as temperature changes, rainfall, thunder, strong winds, poor visibility, sea level rise, etc.

In the recent past, climate change and its impact on society have been the main focus of government policies and political programs around the world. Many industries and organizations have also begun extensive efforts to assess the impacts of climate change on transportation infrastructure in relation to their business goals. Developed Climate Change models showed that the Earth's average annual temperature will probably increase by 1° to 5.5°C. Additionally, annual precipitation is expected to increase in the Northern Hemisphere and decrease in the Southern Hemisphere. In addition, the daily intensity of precipitation and the possibility of extreme precipitation may increase in each region.

Climate change endangers and jeopardizes basic aspects of daily life for people around the world and further affects access to basic amenities such as food, health, water, land use and environment. An increase in extreme weather events such as temperature, humidity, winds, precipitation, sea level, and storm surge will have a significant impact not only on transportation infrastructure, but also on other related infrastructures.

1.1 Project Introduction, Context and Description

The overall objective of the project “Preliminary Design for the Rehabilitation of the railway Corridor VIII on the section Rrogozhina – Pogradec” is to contribute to the phased rehabilitation and improvement of the railway Corridor VIII in the territory of Albania to enable the provision of transport services and increased safety and speed to European Union (EU) standards. This will lead to improved transport connectivity, reduction of road traffic congestion, decrease of transit traffic in cities and reduction of local pollution and Greenhouse Gas Emissions (GHG) due to vehicle emissions.

The railway line Rrogozhina – Elbasan – Pogradec is part of the Trans-European Transport Network (TEN – T) Corridor VIII and serves the intercity transport needs of 5 districts accounting for almost 20% of the Albanian population. It was constructed between the 1950’s and the 1970’s, depending on the section. The Albanian railway line is built with a single track with a gauge width of 1435 mm and the substructure bed has a width of 5.5m, narrower than the standard railway substructure bed. The track infrastructure is currently in very poor condition, and in the section where there is traffic operation, this is with very low speeds, due to the lack of essential maintenance of the infrastructure. The permitted speed of train movement was 55 km/h for passenger trains and 45 km/h for freight trains.

The project will facilitate trade, regional integration, and sustainable growth and it will have a positive impact on the economy of Albania. The increased speed and uniform classification are to be accomplished through:

- Replacement and rehabilitation of outdated superstructure components (ballast, sleepers, fastening, switches and tracks);
- Rehabilitation and improvement of infrastructure components (track bed, culverts, bridges and tunnels);
- Consolidation of level crossings (proposals for reduction, rehabilitation and/or interlocking improvements);
- Improvement of interlocking and telecommunications equipment;

- Line fencing (where applicable) and exploring alternatives to physical line fencing.

The Project area extends from Rrogozhina town up to Guri i Kuq village. Most of the project's alignment has been built on a flat terrain, composed of soil deposits. While, the other is built on a hilly area, consist of molasses, limestones, melange formations-blocks in the matrix and ultra-basics rocks, which have been intensively affected by the tectonic movements and weathering crust processes.

The morphology of the studied area is closely related to the lithology¹. Generally, it represents one flat and less hilly morphological unit, which is built by alluvium and deluvium deposits, as well as molasses, pre-molasses, ultrabasic and blocks in matrix formations with above sea level varies from 15-50m (Rrogozhina-Peqin), 115m (Elbasan), 230m (Librazhd), 430-450m (Qukes), Perrenjas up to 720-730m (Memelisht village). The hilly morphological unit extend from northwest to southeast in chains form, which are divided by the streams and rivers valleys. Along of this region from southeast to northwest direction has established its valley the Shkumbini River with a valley like "U" shape.

Several mass movements have been distinguished at the project's alignment, along backslope (cut slope). Such movements have been classified as rock falls, debris slide, earth slide type and erosion. Landslide areas are located in soil deposits (diluvial), and weathered bedrocks. The majority of the landslides investigated in this area are rock falls which move very fast. They are a real threat for all the traffic users (train), due to their potential high risk to fall down on the Project trafficked alignment without any previous warning sign.

A general description of hydrological circumstances and interaction with adjacent infrastructure/urban development is given below for each segment of the rail line:

- Sub Segment: Rrogozhine - Peqin Station. The lines passes close to residents in many section due to the construction after 90 and crosses several water bodies.
- Sub Segment: Peqin-Elbasan. The line passes through several urban areas. Due to the construction after 90, the residents are close to the railway. Water sources are present.
- Sub segment: Elbasan - Librazhd Station. Natural monument and protected area are distanced from the railway footprint. From Miraka Station – Librazhd, Asbesto is noticed at almost on all abandoned ex buildings facilities, already damaged, out of use.
- Sub Segment: Librazhd - Perrenjas Station. Segment Librazhd - Qukes passes almost along the Shkumbini River. This river is the most sensitive natural resource to be impacted during this project as there is no other significant sensitive natural sources to be potentially impacted along this segment.
- Sub Segment: Perrenjas - Lin station. Administrative Unite Rrajce is the most impacted resident area as the railway passes through it as per all alternatives considered.
- Segment: Lin - Pogradec Station. All this segment is part of Traditional use and sustainable development area of Lake of Pogradec, Protected Landscape, Category V (IUCN), DCM no. 80, dated 18.02.1999. Part of the EMERALD network.

¹ Muceku Y. Lamaj M., Avxhiu A. (2021): Geotechnical Map of Albania, Scale 1: 200 000. Institute of Geosciences, Polytechnic University of Tirana and Albanian Geological Service.

The specific objective of the service is to carry out a Climate Change and Vulnerability Assessment in compliance with national and EU and International Financing Institution (IFI) environmental, social and climate change standards and policies.

1.2 Legal Bases/Albania & EU

1.2.1 European Policy, Legislation and Strategy on Climate Change

The EU is committed to taking action to limit global warming to well below 2°C above pre-industrial levels, in line with the 2015 Paris Agreement on climate change. Article 191 of the Treaty on the Functioning of the European Union (TFEU) meanwhile establishes climate action as one of the objectives of EU environment policy.

In November 2019, the European Commission issued the European Green Deal, setting out plans to “transform” the European economy and set it on “a more sustainable path”. In order to implement this political commitment, European legislators first approved the EU Climate Law in 2021. The European Climate Law² writes into law the goal set out in the European Green Deal for Europe’s economy and society to become climate-neutral by 2050. The law also sets the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

Given the systemic nature of the EU Strategy on Adaptation to Climate Change (adopted on 24 February 2021) , adaptation action in transport will be implemented in an integrated manner with other European Green Deal initiatives such as Sustainable and Smart Mobility Strategy. This Mobility Strategy, together with an Action Plan, lays down the foundation on how the EU transport system can achieve its green and digital transformation and become more resilient to climate change. The Fit for 55 package includes a legislative proposals and policy initiative on a revision of the EU Emissions Trading System (EU ETS), including its extension to shipping, revision of the rules for aviation emissions and establishing a separate emission trading system for road transport and buildings.

The European Commission has published a new “Technical guidance on the climate proofing of infrastructure in the period 2021-2027”. This document aims at providing climate considerations in future investment and development of infrastructure projects from buildings, network infrastructure to a range of built systems and assets. Climate proofing is a process that integrates climate change mitigation and adaptation measures into the development of infrastructure projects. Developers seeking funding from the EU are required to ensure projects like railways in the Member States can cope with extreme weather events.

Climate-proofing EU-funded Trans-European Transport Network (TEN-T) is ensured by the EU-legislation on Union guidelines for the development of the TEN-T network. The 2019 European Commission TEN-T evaluation process has led to the revision of the Regulation and respective guidelines. The purpose of this evaluation process is to develop a transport network, which is efficient, safe, smart and sustainable, which takes digitalization on board, and which addresses climate change. Based on results of the evaluation process the revised TEN-T Regulation will be prepared and put forward by the Commission in November 2021.

² Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (‘European Climate Law’). <http://data.europa.eu/eli/reg/2021/1119/oj>

On October 23, 2014, the European Council approved the “Legal Framework for Climate and Energy 2030” for the period 2020-2030, which aims to make the economy and the energy system in the EU more competitive, more sustainable and more secure, on the way to the economy with low carbon, in line with the long-term perspective set out in the plan for the transition to a competitive low-carbon economy in 2050 - the Energy Plan 2050 and the Transport White Paper.

Also, the EU has adopted the “Low Carbon Economy Plan” in 2011, setting out a cost-effective way to make the European economy more climate-friendly and with less energy consumption. The plan suggests that by 2050, the EU should reduce its emissions to 80% below 1990 levels. Milestones for achieving this are 40% reductions in emissions by 2030, and 60% by 2040.

1.2.2 Albanian Policy, Legislation and Strategy on Climate Change

With the signing of the Paris Agreement by the Government (New York, April 22, 2016), Albania has entered the new era of the international climate policy process, where all parties collectively aim to keep the global temperature increase to 2°C above the pre-industrial level.

Albania joined the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, and the Kyoto Protocol in 2005. As a non-Annex I country of the UNFCCC, Albania has no defined obligations to reduce greenhouse gas emissions; however, Albania has the obligation to communicate, relevant information for the implementation of the Convention, regarding discharges and absorption. In this context, Albania has made great strides towards the implementation of the UNFCCC, with the preparation of the four national communications on climate change (2002, 2009, 2016, 2022). In December 2017 the Albanian Parliament unanimously approved a resolution confirming the country’s commitment to Agenda 2030 and achievement of the Sustainable Development Goals (SDGs).

The General National Strategy of Climate Change and Action Plans (GNSCC&AP, Tirana, 2019) is designed to support the implementation of EU legislation on the environment and climate, aiming to strengthen inter sectoral coordination in Albania for measures on climate, protection of environment and sustainable development, in order to respond to the need to approach EU requirements, given that currently, Albania holds the official status of a candidate country for EU membership (since June 2014).

The GNSCC&AP document is carried out in accordance with the decision 1/CP16 of the UNFCCC and the decision 525/2013/EU for the mitigation part. Meanwhile, the accession process in Albania is guided by the “Technical Guidelines for NAP processes”, prepared by the UNFCCC’s Least Developed Countries Expert Group (LEG)1 and published in December 2012 (the so-called “Technical instruction”). The (National Adaptation Plans) NAP process has been performed in accordance with the EU Strategy for Adaptation to Climate Change, approved by the European Commission in April 2013.

The GNSCC&AP document (mitigation part) focuses on the following four reporting sectors of the greenhouse gas inventory in Albania: Energy (with special focus on Transport), Agriculture and the sectors of Land Use Change and Forestry (LUCF), thus covering 80% of Albania's discharges.

The vision of the national climate change strategy focuses strongly on three main components of climate change in Albania: mitigation measures, adaptation and sustainable development, resulting in the overall vision as follows:

- “Recognizing that climate change represents an urgent and potentially irreversible threat to human societies, especially for the Mediterranean area, development towards a low-carbon economy is key to achieving global mitigation targets and allowing for an adapted generation of future with

reasonable environmental, economic and social costs”.

Albania has started the process of changing its status, from a developing country to a developed country, in the context of the UNFCCC. This process is an integral part of the integration process in the European Union, and includes the development of national-level capacities for annual GHG monitoring and reporting, formulation and implementation of policies for GHG reduction and adaptation to climate change, alignment and implementation of European Union legislation on climate change.

In accordance with the objectives of the EU, "Climate and Energy Package 2020", Albania has defined quantitative objectives related to energy efficiency (increase by 9%) and renewable energy sources (increase up to 38%), in the framework of Energy Community Treaty. These targets are currently being revised in the framework of revisions 2 and 3 of the National Energy Efficiency Action Plans.

In November 2015, the Republic of Albania presented its first Nationally Determined Contributions (NDC), with the commitment “to reduce CO₂ emissions by 11.5% compared to the baseline scenario, during the period 2016 and 2030, or to achieved a reduction of 708 kT CO₂ by 2030”.

An important law is that no. 155/2020 “On climate change” which approximates Regulation (EU) no. 525/2013 of the European Parliament and of the Council, dated May 21, 2013 “On the mechanism for monitoring and reporting emissions of greenhouse gases and for reporting other information related to climate change at the national and European Union level”.

Law No. 2/2023 “On fluorinated greenhouse gases” partially aligned with Regulation (EU) no. 517/2014 of the European Parliament and the Council, dated April 16, 2014 “On fluorinated greenhouse gases”, in order to reduce emissions of fluorinated greenhouse gases, in order to achieve environmental protection.

Also, Decision of the Council of Ministers no. 10, dated 9.1.2019 “On the adoption of rules for the production, import, export, placing on the market and use of ozone-depleting substances, as well as for the import, export, placing on the market and use of products and equipment containing these substances”.

1.2.3 Financial Institution Policy

The European Investment Bank (EIB), in November 2019, in line with the political ambition behind the European Green Deal, decided to increase the level of climate and environment commitment³. In this context, the EIB has mainstreamed a climate risk management tool into its project appraisal. The Climate Risk Assessment (CRA) system was introduced to provide a systematic assessment of the physical climate risk in direct lending. The CRA system is a business process that helps the EIB and its clients understand how climate change may affect their projects and identify adaptation measures.

The CRA system includes two levels of screening and a more detailed assessment for projects ranked at risk. An initial screening is performed automatically when an operation is created, based on the subsector and country of operation. In the case of high or medium risk, a second more detailed screening takes place before appraisal to identify project vulnerabilities.

The CRA is the cornerstone of the EIB’s alignment framework in relation to climate-resilient development. It concerns the project alone and it is important to situate the project within the wider strategic context of climate resilience of the system it is a part of, as set out in regional or national climate resilience plans. For instance, within the EU, such plans are now required at the national level and are reflected within the National Energy and Climate Plans and the national adaptation strategies. In developing countries,

³ EIB Group Climate Bank Roadmap 2021-2025
(https://www.eib.org/attachments/thematic/eib_group_climate_bank_roadmap_en.pdf)

Nationally Determined Contributions (NDCs) and national adaptation plans identify investment priorities in support of long-term climate resilience.

According to the EU Joint Research Centre, the economic damage to critical transport infrastructure in Europe alone could multiply six fold by mid-century due to climate change⁴. Ensuring the resilience of a transport system starts with the proper planning and design of new infrastructure, but equally important is the proper maintenance, rehabilitation and renewal of existing transport assets. The resilience challenge is therefore to modernise and upgrade infrastructure networks so that they are safer, future-proof and adaptive to global warming and its related changing environmental conditions.

In 2021, EBRD committed to aligning all of the Bank’s activities with the goals of the Paris Agreement⁵. Paris alignment is an integral part of the Bank’s work to support the climate action of the economies in which it operates. It builds on the Bank’s commitment to promoting “environmentally sound and sustainable development” in the full range of its investment and technical cooperation activities. The Bank’s approach to Paris alignment for climate change mitigation and adaptation entails demonstrating that each project meets the following four conditions:

- a. consistency with long-term low-carbon development, to give assurance that it is part of a transition to a future consistent with the Paris Agreement mitigation goals;
- b. a low likelihood of carbon lock-in, to give assurance that the project does not enable an emissions-intensive asset to continue operating when economically preferable, lower carbon options could replace it.
- c. physical climate risks have been identified and addressed; and
- d. its activities do not undermine climate resilience in the context in which the project operates.

Also, EBRD proposes the new Green Economy Transition (GET) approach for the period 2021 to 2025 is ambitious, comprehensive and pragmatically anchored in the climate change and environmental challenges of its countries of operations. The EBRD will support the acceleration of the transition to a green, low-carbon and resilient economy by:

- aligning its activities with the principles of international climate agreements, including principally the Paris Agreement;
- enhancing policy engagement for the development of long-term low carbon strategies and greening of financial systems; and
- scaling up investment by innovating across a set of specific environmental and climate mitigation and adaptation thematic areas such as green digital solutions, just transition, circular economy, natural capital and green value chain financing.

⁴ Transport Lending Policy 2022: The Way Forward – Investing in a cleaner and smarter transport system. European Investment Bank, 2022. (https://www.eib.org/attachments/publications/transport_lending_policy_2022_en.pdf)

⁵ Methodology to determine the Paris Agreement alignment of EBRD investments. December, 2022 ()

2 Assessment Methodology

The proposed assessment process consists of identification and analysis of physical and environmental factors, which determine the sensitivity/susceptibility of the township to the impact of climate change (e.g. increasing temperatures; change in seasonal patterns) and/or hazard (e.g. flood, drought), using a qualitative method. More specifically, the proposed methodology involves a desk review of literature and use of environmental data, mainly from the data of the national institutions and National Communications of the Republic of Albania on Climate Change to the United Nations Framework Convention on Climate Change (UNFCCC).

An assessment methodology based on cause-and-effect analysis has been used for the assessment of climate change impacts on railway infrastructure. Weather data include temperature or precipitation, which are then used for building climate scenarios.

The assessment methodology consists of the following stages:

1. Identifying weather-related failures of railway infrastructure.
2. Analyzing the failure of railway infrastructure due to weather events.
3. Determining the vulnerability of railway infrastructure to climate change.
4. Developing adaptation strategies

Based on the Commission Notice - Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (europa.eu), climate proofing for climate resilience includes identifying (1) which climate risks the project is vulnerable to, (2) assessing the level of risk and (3) integration of adaptive measures to reduce that risk at an acceptable level. The process begins at the beginning of the feasibility and options evaluation phase and it must be integrated into all subsequent stages of project development. The results are used to inform making decisions as the project develops the progression through the four main steps of work as follow:

Step 1: Preparation - A clear description of the project:

Step 2: Screening for Climate Change Vulnerability:

- a. Sensitivity - Which climate hazards influence, considering typical components of this type of project?
- b. Exposure - To what degree is the project location currently exposed to climatic hazards, and by how much will this change in the future due to climate change?
- c. Vulnerability - Is the project potentially vulnerable to climate change, and require a detailed risk assessment?

Step 3: Climate Change Risk Assessment:

- a. Consequence or Impact - How significant is the impact of the occurrence of the hazard on different aspects or components of the project?
- b. Risk - Is the project as a whole, or are individual project components, resilient to climate change impacts or are there risks that need to be addressed through adaptation measures?

Step 4: Mitigation (adaptation measures):

- a. Adaptation Options - What options are available to make the project resilient to climate change?
- b. Options Appraisal - Which adaptation options are most appropriate for the project based on the project's specificities?

- c. Adaptation Planning - Embed climate adaptation measures within the project description, EIA process, Feasibility Study and Economic Appraisal. Include details of monitoring and responsibility for future adaptation.

Sensitivity

The sensitivity analysis is to identify whether the typical instance of project components is sensitive to climate hazards. The starting point is the full list of climate related hazards to be subject to the sensitivity analysis. Significance can be considered as the level of change in design or operation that would be necessary to perform, or the ability of the project component to perform as designed if it was to be affected by a climate hazard. Any climate hazard with no impact has no sensitivity and should be assigned a score of zero (0). The numerical scores are based upon the JASPERS CCVRA guidance for the 2014-2020 programming period. The overall project sensitivity is the worst sensitivity score for a climate hazard from all project components.

Exposure

The exposure analysis involves determining the extent to which the project location is likely to be affected by climate related hazards, now and in the future. This is determined firstly through understanding current climate conditions and then secondly through consideration of the likelihood of future change and how this will affect hazards.

Vulnerability

The vulnerability analysis is a simple combination of sensitivity of project aspects and exposure of the project location to climate hazards (or drivers). A simple matrix should be produced with the climate hazards (or drivers) mapped across. This shows how vulnerable the project is to specific climate-related hazards in its current location and enables prioritization of the climate hazards the project is most vulnerable to. The score for each climate hazard is the sensitivity score multiplied by the highest of the current and future exposure score for that climate hazard. If the climate hazard has high vulnerability, then these must progress to the detailed risk assessment. Any medium vulnerability hazards should be considered to move forwards to the detailed risk assessment as there is a possibility that further analysis could help improve the resilience of the project to climate change.

3 Expected Climate Change and Main Effect in Albania

Many climate change studies have been carried out through UNDP programs in Tirana. They are specific with regard to impacts in specific sectors and analyze in detail specific regions of importance for biodiversity, water resources, floods, agriculture, forests, but in no case for the impacts of expected temperatures and rainfall on infrastructure. More detailed are the Communications of Albania on climate change (3rd and 4th communication on climate change).

For climate changes in the Shkumbin river basin, we have referred to three studies. First, we are based on the conclusions of a study of the trend of temperatures and rainfall in the coming decades for the region, which is based on long-term data: “Study on climate change in the Western Balkans region”⁶

Representative Concentration Pathway⁷ *RCP) is considering in this assessment as more adequate option of climate change for the future - *One high pathway which leads to >8.5 W m⁻² in 2100 (the corresponding ECP, Extended Concentration Pathways, has constant emissions after 2100 until 2150 and constant concentrations after 2250).*

Summarized, from the two-scenario analysis (RCP 4.5, RCP 8.5), the temperature and precipitation trends are as follows:

According to the minimum impact model (RCP 4.5) (until 2050):

- a) Temperature change is significant across the region, with an average increase of 0.8°C, and significant seasonal variation in maximum and minimum temperatures is expected;
- b) The change in rainfall is not expected to be significant; the variability in annual and seasonal values is within the range of -5% and +5%, with decreasing trends in most of the region.

Under the maximum scenario (RCP 8.5):

- a) Temperature changes are significant for the entire region with a regional average increase of 1.0 °C, reaching the highest increase during the period 2050-2060. In some places in the southern regions of Albania, the average annual temperatures can reach about 3.0 °C higher than currently.
- b) The change in precipitation still shows no statistically significant change in the annual mean or in the seasonal values, but the decrease in the annual values tends to spread.

⁶ Ana Vuković, and Mirjam Vujadinović Mandić, 2018, Study on climate change in the Western Balkans region, 76 pages.

⁷ Representative Concentration Pathways (RCPs): Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes the fact that not only the long-term concentration levels but also the trajectory taken over time to reach that outcome are of interest (Moss et al., 2010). RCPs were used to develop climate projections in CMIP5. The RCPs are listed below for reference should the SSP impacts not yet be available for countries or regions: o RCP2.6: One pathway where radiative forcing peaks at approximately 3 W m⁻² and then declines to be limited at 2.6 W m⁻² in 2100 (the corresponding Extended Concentration Pathway, or ECP, has constant emissions after 2100). o RCP4.5 and RCP6.0: Two intermediate stabilization pathways in which radiative forcing is limited at approximately 4.5 W m⁻² and 6.0 W m⁻² in 2100 (the corresponding ECPs have constant concentrations after 2150). o RCP8.5: One high pathway which leads to >8.5 W m⁻² in 2100 (the corresponding ECP has constant emissions after 2100 until 2150 and constant concentrations after 2250).

the dates of the events with the highest amounts, we estimate that the risk of flooding, erosion and landslides will be in the months of November and March.

5.1. Hydro meteorological Factors of the Basin

The railway along the Shkumbin valley passes through Peqin, Elbasan, Librazhd, Perrenjas, and the Qafe-Thanes tunnel from an altitude of 150 m asl (Rogozhine) to 690 m asl (in Perrenjas). The local hydro meteorological factors which are important elements of the impacts consist of temperatures (average and extreme) as well as rainfall (average and extreme). Their trend in the horizon of the years 2050 or 2100 is the same as that described above, which include southern Albania and consist of increasing periods of high intensity rainfall for 24 hours; the increase in extreme positive temperatures and the extension of periods of heat waves.

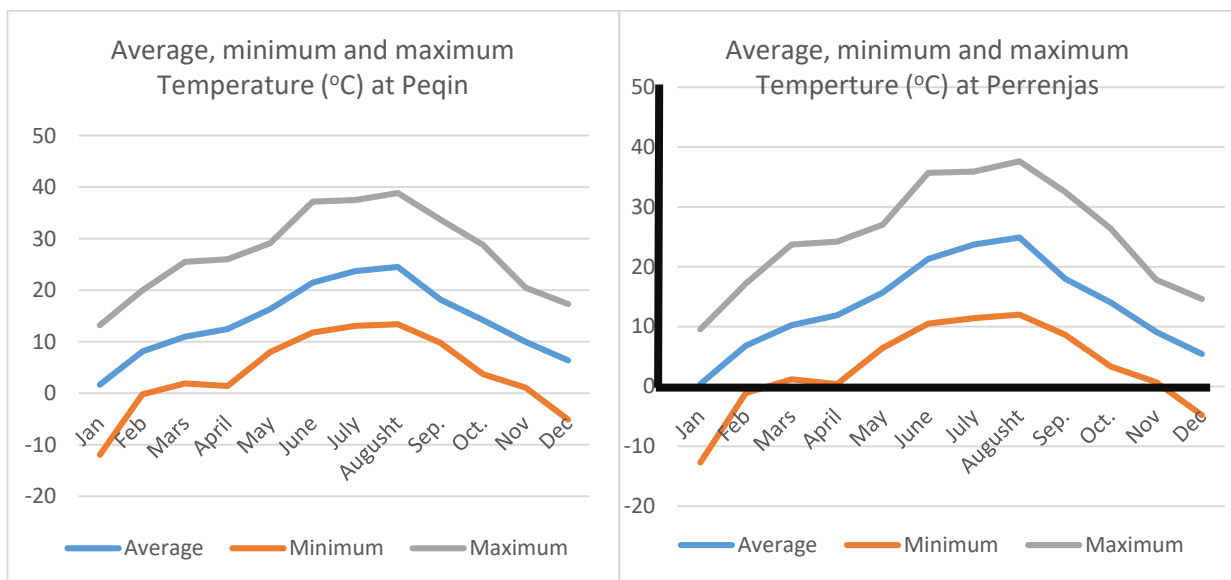


Figure 2: The extreme temperatures observed for the last 30 years in the two outermost urban centers (Peqin and Perrenjas)

The extreme temperatures observed for the last 30 years in the two outermost urban centers (Peqin and Perrenjas) are given in figure 2. It is noted that the temperatures were more than 30 °C for a period between June and the end of September for both cities, Peqin and Perrenja, while temperatures higher than 35 °C were around 40 days in Peqin and almost 20 days in Perrenja. Expectations for higher temperature increases and high temperatures in longer periods undoubtedly have greater impacts in Peqin and less in Perrenjas.

The days with extreme negative temperatures presented in the figures below show that temperatures <0.0 °C are differentiated along the railway axis; they vary from only 22 days a year for Peqin to 63 such days for Perrenjas. Such temperatures differ in the months of January, February and December between the two cities.

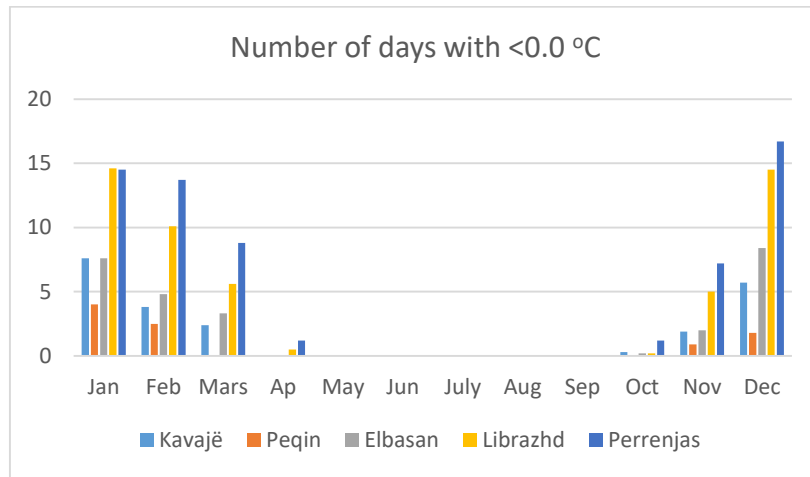


Figure 3: Number of days with <0.0 °C

The same situation occurs for temperatures < -5.0 °C. In Peqin they last only 0.7 days, while in Perrenja they last, on average, 12.7 days (figure 3). In terms of temperatures, we can say that the railway stretch is divided into two segments of the action of average temperatures, minimum and maximum, the first segment from Rogozhina to Elbasan and the second segment from Librazhdi to Pogradec. Their biggest changes in the coming years are expected in the first segment.

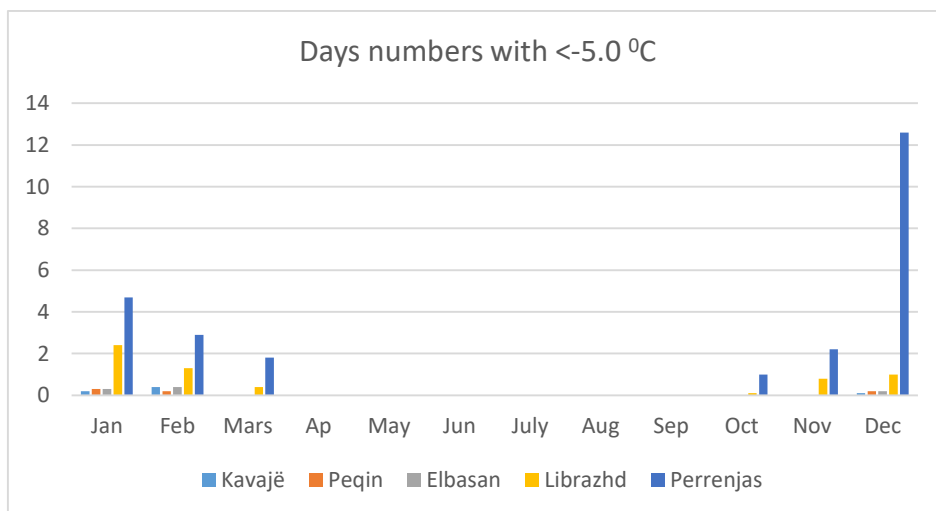


Figure 4: Number of days with <-5.0 °C

Rainfall

The figure below shows the expected rainfall in 24 hours with over 40 mm of rain, considered as a source of important impacts such as flooding, landslides, rock falls, flooding of tunnels and overpasses. Hourly rainfall in Rrogozhine increases about twice as much in 1% probabilities (or once in 100 years) than currently, while for a 24-hour period the difference between a 1% event and a 50% event increases more than twice.

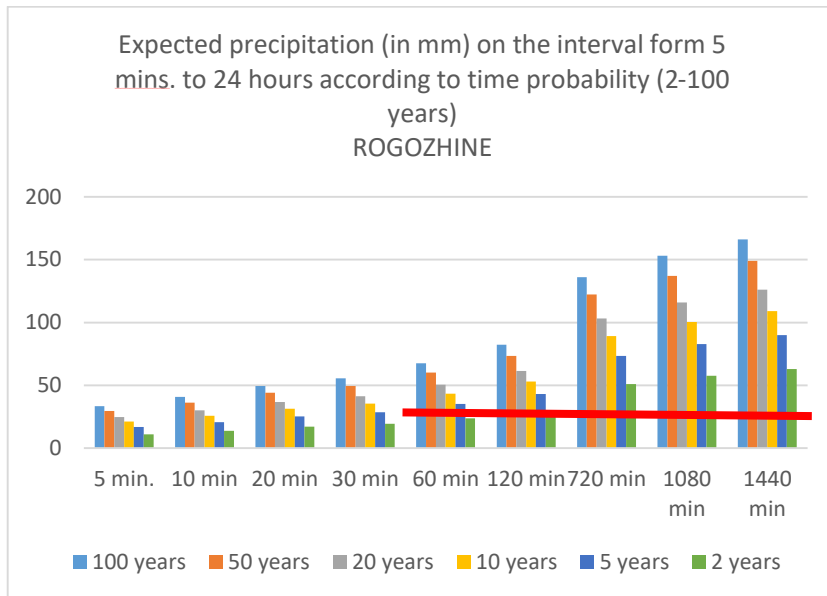


Figure 5: Expected precipitation (in mm) on the interval from 5 min to 24 hours according to time probability (2-100 years), Rrogozhine

In Pogradec, the expected rainfall intensity in the horizon of 2050 and 2100 in 24 hours is also high while the intensities for 1 hour do not have the same ratio as in the case of Rrogozhine. Despite the expected intensity, the rains are worrying for flooding.

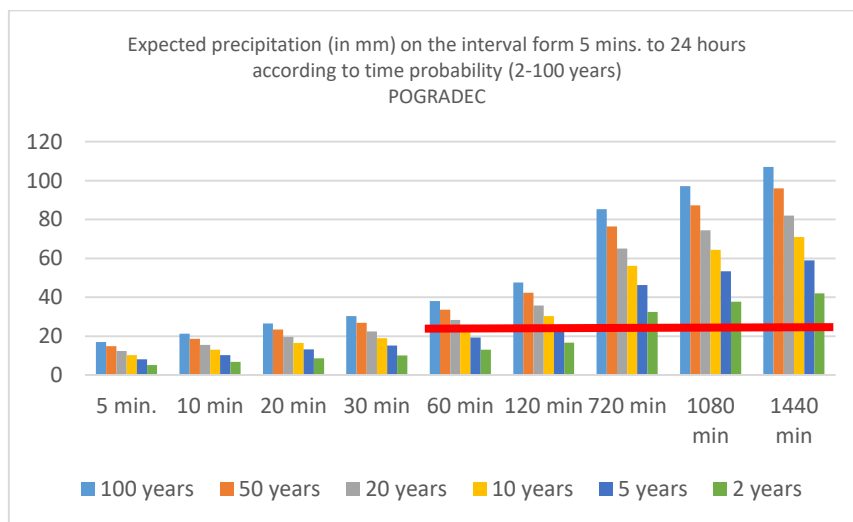


Figure 6: Expected precipitation (in mm) on the interval from 5 mins. to 24 hours according to time probability (2-100 years), Pogradec

A map prepared by GEO-ASIG (figure 6) shows that the section from Rrogozhina to Elbasan is the most vulnerable to flooding. The current railway track from Rrogozhina to Elbasan passes through the hilly system on the side of Shkumbin, but far from being threatened by the expected floods.

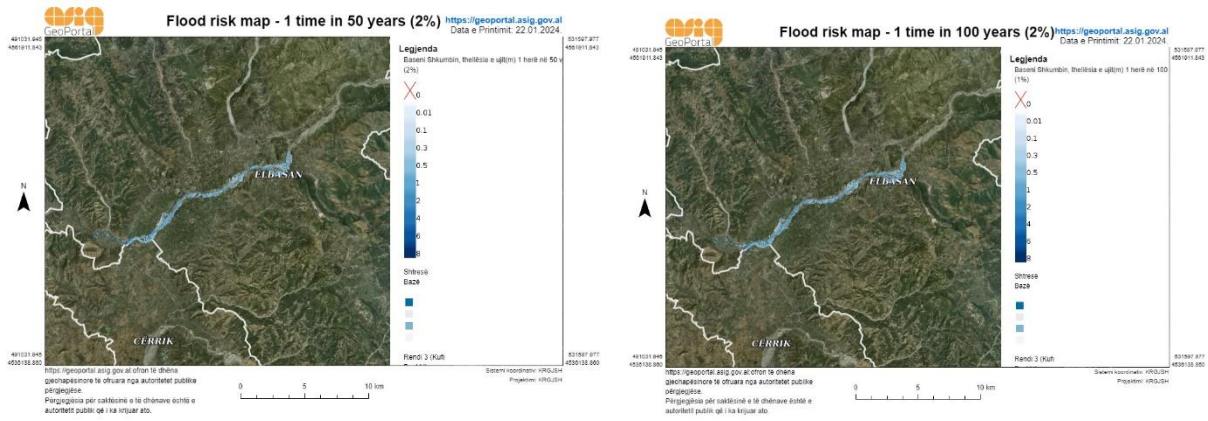


Figure 7: Flood risk map once in 50 and 100 years (2%) - water depth (m)

Meanwhile, the railway segment in Elbasan and Librazhd, where the railway track is located at a height of +3 m to +5 m above the water level of the River, feels threatened by the expected floods, especially in the probability of 1% (once in 100 years).

4 Extreme Weather-Related Events Affecting Railway Infrastructure and Risk Assessment

4.1 Identification of Extreme Weather-Related Events

Impact exposure versus vulnerability

The impact of climatic factors activated by expected climate changes on the railway infrastructure itself (eg, damage requiring repair or replacement) may lead to a negative effect on the capacity for safe and efficient operation of the railway service.

The impacts of weather on railway infrastructure should be considered in the decision-making process for maintenance and renewal programmes, as part of asset management strategies, to help minimize the risk or severity of impacts. All components of the railway infrastructure such as tracks, catenary (connections of the electric network with the electric locomotive), bridges, embankments, rails, etc., are affected by extreme weather events. In some cases, such as tracks, higher temperatures/lower temperatures, rain and snow storms can lead to traffic disruptions and in worst cases lead to track damage. However, in some cases, it is difficult to measure the impact of these events on the railway infrastructure. Therefore, an adequate understanding of weather events during the planning, design, operation and maintenance of railway infrastructure should be evaluated to increase the serviceability and lifetime of the assets. The impacts of climate change are difficult to understand because they vary with geographic location, long-term effects, the frequency of extreme weather events, and the lack of data on consequences. Therefore, to design and develop an effective strategy to deal with climate change, a comprehensive analysis is essential taking into account local climate conditions, potential impacts of climate change, stakeholder involvement and infrastructure variations during the operation and maintenance phase.

However, given the concrete conditions of the Project area and previous design and maintenance decisions - for existing infrastructure - detailed information on assets, including condition, sensitivity, exposure and vulnerability is required. Moreover, within a network rail system, such assessments should be made consistently throughout the network, to avoid conflicting reliability standards

Table 1: Climate factors, potential impacts and consequences on the railway infrastructure and its good functioning

Climate factor	Possible Impacts	Consequences to railway infrastructure	Consequences to railway operations
Heavy rainfall	<ul style="list-style-type: none"> • Flooding 	<ul style="list-style-type: none"> • Destruction to railway embankments and culverts ; • Less support to bridge scour • Increase in water content on track ; • Destruction to railway track; • Damages to other equipment and surrounding infrastructures; 	<ul style="list-style-type: none"> • Stoppage or cancellation of train services ; • Reduction in braking distance ; • Lower driving conditions; • Increase in accidents ; • Damages to rolling stock materials ; • Accumulation of snow surrounding railway track thus reduction in speeds. • Freezing of switches results in delays ; • Reduce in transport quality;
Windstorms	<ul style="list-style-type: none"> • Rise in sea level • Destruction to power cables • Falling of trees adjacent to railway track • Damage to electricity • Increase in freezing • Blockage of tracks 	<ul style="list-style-type: none"> • Destruction to railway embankments and culverts ; • Less support to bridge scour ; • Increase in water content on track ; • Destruction to railway track ; • Damages to other equipment and surrounding infrastructures ; • Power cable falls 	<ul style="list-style-type: none"> • Stoppage or cancellation of train services ; • Reduction in braking distance ; • Lower driving conditions ; • Increase in accidents ; • Damages to rolling stock materials. • Accumulation of snow surrounding railway track thus reduction in speeds. • Freezing of switches results in delays ; • Reduce in transport quality;
Snowfall	<ul style="list-style-type: none"> • Heavy floods ; • Increase in freezing ; • Destruction to power cables ; • Damage to electricity ; • Blowing of snow ; • Blockage of tracks; 	<ul style="list-style-type: none"> • Destruction to railway embankments and culverts; • Less support to bridge scour ; • Increase in water content on track Increase in vegetation; • Destruction to railway track ; • Damages to other equipment and surrounding infrastructures; 	<ul style="list-style-type: none"> • Stoppage or cancellation of train services ; • Reduction in braking distance ; • Lower driving conditions ; • Increase in accidents ; • Damages to rolling stock materials ; • Accumulation of snow surrounding railway track thus reduction in speeds. • Freezing of switches results in delays ; • Reduce in transport quality;
Low temperature	<ul style="list-style-type: none"> • Destruction to power cables ; • Damage to electricity; • Increase in freezing. ; • Frost; 	<ul style="list-style-type: none"> • Burning of safety devices ; • Damages to other equipment and surrounding infrastructures; • Cracking of Frost Increased freezing of other equipment and structures ; • Damage to power cables; 	<ul style="list-style-type: none"> • Stoppage or cancellation of train services; • Reduction in braking distance ; • Lower driving conditions; • Increase in accidents. • Damages to rolling stock materials.

Climate factor	Possible Impacts	Consequences to railway infrastructure	Consequences to railway operations
		<ul style="list-style-type: none"> • Destruction to rail track; 	<ul style="list-style-type: none"> • Accumulation of snow surrounding railway track thus reduction in speeds. • Freezing of switches results in delays ; • Reduce in transport quality;
Blizzard	<ul style="list-style-type: none"> • Combination of lower temperature, increase in snowfall, and windstorms 	<ul style="list-style-type: none"> • All the above consequences excluding high temperature 	<ul style="list-style-type: none"> • All the above consequences excluding high temperature

4.2 Impacts on the components of infrastructure and the services

In detail, the implication of hydro meteorological factors in vulnerable direct assets (assets of railway structures) and indirect (effects derived from infrastructural problems) are given below.

Slopes

Track railway slope refers to the slope of the railway track.

Many slopes along the railway were built more than 60 years ago, before modern design standards existed. The average angle of these slopes is usually much higher than would normally be allowed for modern transport infrastructure. The problem of slopes is a problem especially in the segment Librazhd - Perrenjas. Common problems affecting slopes are shallow landslides caused by high rainfall. Deep rotational failures caused by weak subsoils which are caused by increased loading and/or changes in water location, slope geometry or inclination; and rockslides caused by freeze-thaw effects.

Shallow failures

Shallow landslides usually occur after periods of high rainfall on high-angle slopes where there is poor soil cohesion or distinct shallow horizons have formed. Examples of shallow landslides on the lines are encountered in the Elbasan - Librazhd and Librazhd - Lin segments and occur near the entrance of the tunnels where the slope angles are usually the highest.

Because of the relatively small volume of soil involved, the consequences of shallow distortional landslides occurring on embankments (when the track is over the fault) are usually low. In cuts where the track is below the slope, the impact is closely related to the space between the edge of the slope and the track. In cases where the failed material covers the tracks, it derails unless adequate detection monitoring is in place. Repeated failures along the shear lines are also a feature of this failure type.

Deep rotational failures

Deep rolling slope problems usually involve large volumes of material and in this case the track is involved along with the slope in which soil displacements require long term work.

Retaining walls

Most modern retaining walls are flexible embedded structures that mobilize soil strength to provide stability. However, given the railway's 60-plus year age, a large proportion of the load-bearing structures are gravity structures, which rely on a combination of the structure's own weight and the retained soil for stability. These walls are not homogeneous (eg, they are built from discrete blocks) and it is not easy to assess structural integrity, the condition of the drainage system or to determine the condition at the wall-soil interface, which is critical. Given their low safety margins, these structures are particularly sensitive to any changes in loading.

Tunnels

Weather impacts on tunnels include flooding and drainage problems, which lead to increased stress and seepage/ice formation. Icing leads to ice hitting passing trains (either falling or crossing the gauge line)—especially a safety hazard for drivers and/or a potential derailment hazard if it falls on the tracks. Heavy rainfall can cause flooding and temporary closures. A more serious problem is coastal flooding of tunnels, which can result in the need to reroute sections of track. The tunnels that can be most affected by this phenomenon are those of Librazhd - Lin, Pogradec.

Track

Extreme heat causes the steel rail to expand, leading to the risk of buckling. This increases the risk of train derailment, jeopardizing the safety of passengers.

Track flooding is also a serious problem that can lead to derailments. When the track is located near a watercourse prone to flooding, embankment erosion can occur, where the supporting soil can be eroded. The most likely for this to happen is in the field of Elbasan and in the gorge of Librazhdi, especially the segment of the railway station.

Strong winds can also cause objects, such as fallen trees, to block the line.

Segment sidings on switching tracks (movable sections of track that allow trains to move from one line to another) can easily fail during floods, high temperatures (excessive expansion of the shift mechanism) or low temperatures (from ice or snow), thereby causing service interruption.

The presence of leaves on the tracks during the fall can also cause derailment problems - that is, wet leaf matter on the tracks is pressed by passing trains into a smooth coating that reduces wheel grip. In these conditions, trains must travel more slowly to reduce the risk of “overrunning stations”, where the train cannot brake efficiently enough to come to a complete stop near the platform.

Bridges

During flood events, material can be washed away from surrounding foundations into the water - a process known as scour/erosion.

The loss of material causes - at a minimum - a loss of stiffness and can lead to collapse. Foundation scour has been identified as the leading cause of bridge failure worldwide and has led to the failure of many important railway bridges. Bridges founded on shallow foundations are more vulnerable. Considering the technology developed in the 70s of the last century, it is assumed that a rigorous engineering inspection of their sustainability regarding floods is necessary. The intervention, if it is evident, can be done in today's conditions of the development of knowledge and climate information.

Electrical systems

Electrical Substation and telecommunication as railway infrastructure are included in this section.

Overhead power line integrity can be affected by heat (excessive damping) or cold. Strong winds can also knock down power lines or their supporting structures.

Freezing rain can lead to rapid ice accumulation on wires and support structures. This significant additional load can form, during high winds, into aerodynamic shapes that then cause excessive cable movement leading to failure of cables or junctions.

Sensitive electronic signaling equipment can overheat in hot weather, especially if placed in poorly ventilated enclosures; and - where alongside the tracks - can be prone to flooding. Signaling systems that use electrical currents in the tracks to detect trains can also be disrupted by leafy material on the rails, as such material interferes with wheel-rail contact.

4.3 Vulnerability and Risk Assessment

Vulnerability

Albania is vulnerable to the impacts of climate change, with increased vulnerability due to its infrastructure needs, and poverty in rural areas¹⁰. The country is prone to numerous natural hazards, including, hydro-meteorological hazards: floods, droughts, forest fires, and landslides. The country is also at high-risk to geophysical hazards such as earthquakes. Changes to Albania’s climate, specifically the frequency of extreme weather events and temperature variations, are expected to have the most significant impacts to the country’s key sectors, its economy and population¹¹.

Natural hazards in Albania such as intense storms, floods, heatwaves and wildfires are becoming more frequent, unpredictable and severe due to projected climate change trends. Climate change is expected to increase the risk and intensity of flood and rainfall events leading to the heightened risks of loss of life and damage to property and infrastructure from direct floods and/or landslides and soil erosion. Intense rainfall and flooding may also result in soil erosion and water logging of crops, decreasing yields and increasing food insecurity. Higher temperatures and increased aridity may also lead to livestock stress and reduced crop yields.

This may result in significant economic losses, damage to agricultural lands and infrastructure as well as human casualties. Furthermore, land degradation and soil erosion, exacerbated by recurrent flood and drought adversely impacts agricultural production, coastal zones, water resources and is likely to further adversely affect livelihoods of the rural poor.

Table 2: Natural disasters in Albania, 1900–2020¹²

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	1	0	3,200,000	0
Earthquake	Ground Movement	6	47	8,429	0

¹⁰ Republic of Albania (2016). Third National Communication of the Republic of Albania under the United Nations Framework Convention on Climate Change. URL:

https://unfccc.int/sites/default/files/resource/Albania%20NC3_13%20October%202016.pdf

¹¹ FAO (2018). Comprehensive analysis of disaster risk reduction and management system for agriculture in Albania. URL: <http://www.fao.org/3/i8866en/i8866EN.pdf>

¹² EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir, Brussels, Belgium. (Data accessed April 20 2019) URL: http://emdat.be/emdat_db/

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Epidemic	Viral Disease	1	7	66	0
Extreme Temperature	Heat Wave	2	3	150	0
	Severe Winter Condition	3	79	237,085	0
Flood	Coastal Flood	1	0	8,000	0
	Flash Flood	2	12	56,002	15,900
	Riverine Flood	8	4	134,484	17,673
Landslide	Avalanche	1	57	26	0
Storm	Convective Storm	2	8	525,000	0
Wildfire	Forest Fire	1	0	75	0

Albania’s significant vulnerability to floods contributes to a profile of the country as particularly disaster-prone. The country’s increasing urbanization has increased flood risk locations due to the absence of functioning water drainage systems and settlement in flood-prone areas. Combination of increased temperatures, longer periods of aridity and the country’s high forest coverage make Albania exceedingly vulnerable to forest fires.

Floods present the most dangerous natural disaster for Albania as the country is highly exposed as its river and stream systems are a major threat to the floods that are generally originate from smaller rain events.

Floods in the lower flow can cause great damage as they are more frequent and catch larger surfaces. These are formed by heavy rainfall and high intensity rainfall, which fill the soils with water and cause leakage out of the riverbed. Albania’s hydrographic profile makes riverine flooding highly dangerous and damaging. Historical records show that flooding has occurred in all major catchment basins of the country¹³. The projected increase of more intense precipitation and higher rainfall events, is expected to increase the likelihood of floods¹⁴. The total exposure from private assets is greater than from public assets, although the exact ratio of private to public asset exposure is unknown.

As explained above, determining the value of vulnerability is preliminary work to make a risk assessment of the climate change parameters on infrastructure of railway. The vulnerability of a project to climate change is a function of how sensitive a typical project of the type proposed is to climate hazards (sensitivity) and the presence of these hazards at the project location under current and future climatic conditions (exposure).

Sensitivity

The scoring of sensitivity, exposure and vulnerability should be based on qualitative high/medium/low criteria. The EC Climate Proofing Technical Guidance recommends three sensitivity score categories, as presented below with an additional no sensitivity category. Significance can be considered as the level of

¹³ Uruci, R. (2018). Flooding Intervals in Albania. Natural Sciences Knowledge in Practice. 28(40). DOI: <https://doi.org/10.35120/kij28041421R>

¹⁴ Republic of Albania (2016). Third National Communication of the Republic of Albania under the United Nations Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/Albania%20NC3_13%20October%202016.pdf

change in design or operation that would be necessary to perform, or the ability of the project component to perform as designed if it was to be affected by a climate hazard.

High sensitivity (score 3)
The climate hazard may have a significant impact on railway assets
Medium sensitivity (score 2)
The climate hazard may have a slight impact on assets
Low sensitivity (score 1)
The climate hazard has no (or insignificant) impact
No sensitivity (score 0)
No possible impact of the climate hazard on any of the project components. No impact on the ability to manage the infrastructure-

Source: Suggested sensitivity criteria and scores (from the 2014-21 programming period JASPERS CCVRA guidance) with example thresholds for a flood management project.

Exposure

The exposure analysis involves determining the extent to which the project location is likely to be affected by climate related hazards, now and in the future. This is determined firstly through understanding current climate conditions and then secondly through consideration of the likelihood of future change and how this will affect hazards. The exposure assessment is often best undertaken in parallel or following the sensitivity assessment.

The Climate Proofing Documentation must present the scoring table and method used for assigning an exposure score to each climate hazard. The scoring method should explicitly mention a data source and thresholds which link a climate index or indicator to a climate hazard. For example for the temperature the score proposed is following.

High Exposure (score 3)
Any hazard: hazard has occurred (current exposure) or expected to occur (future exposure) a number of times in five years. Extreme temperature: Region with very high average temperatures in summer (above 23 °C) and a large number hot days (Tmax≥35 °C). Very high average temperatures in summer (over 23 °C). Heat waves have a frequency ≥ 1 event per year
Medium exposure (score 2)
Any hazard: hazard has occurred (current exposure) or expected to occur (future exposure) twice in 10 years. Extreme temperature: The average summer temperature exceeds 20 °C. Heat waves have a frequency of 1 event every 1-5 years
Low exposure (score 1)
Any hazard: hazard has occurred (current exposure) or expected to occur (future exposure) once in 25 years. Extreme temperature: The average summer temperature has acceptable values (≤20 °C). Heat waves have a frequency ≤ of 1 event every 5 years.

No exposure (score 0)
Any hazard: there is no possibility that the hazard can occur in the project location, Extreme temperature: Heat waves are not expected

Vulnerability score

The vulnerability analysis is a simple combination of sensitivity of project aspects and exposure of the project location to climate hazards (or drivers). A simple matrix should be produced with the climate hazards (or drivers) mapped across. This shows how vulnerable the project is to specific climate-related hazards in its current location and enables prioritisation of the climate hazards the project is most vulnerable to. The score for each climate hazard is the sensitivity score multiplied by the highest of the current and future exposure score for that climate hazard. If the climate hazard has high vulnerability, then these must progress to the detailed risk assessment. The Vulnerability scoring approach is presented below:

Severity, consequence, or magnitude

The severity, consequence or magnitude of an impact is also scored. The scores should account for how well the project can cope with the impact and what level of risk is tolerable. The method, scale, data and approach used must be explained in the climate proofing documentation. The EC Climate Proofing Technical Guidance requires scoring of the severity of an impact from each climate hazard by risk area. The process is replicated with an overall climate hazard overall severity taken from across the risk areas. The previous 2024-2020 programming period JASPERS CCVRA guidance only covered the engineering, asset and operational impact. The non-paper Guidelines do include the following aspects recommended in the EC Climate Proofing Technical Guidance, and so this is not a new requirement.

The example of score to assess the severity and consequences of climate hazard is presented as follow:

Almost certain (score 5)
Incident if very likely to occur, possible several times. 95% chance of occurring (over lifetime of project). Project component is shown as exposed in high probability hazard

Likely (score 4)
Project may be vulnerable to this climate hazard. Consider taking forwards to detailed assessment (phase 2)

Possible (score 3)
Incident is likely to occur. 80% chance of occurring (over lifetime of project). Project component is shown as exposed in medium probability hazard

Unlikely (score 2)
Given current practices and procedures, this incident is unlikely to occur. 20% chance of occurring (over lifetime of project). Project component is shown as exposed in low probability hazard

Rare (score 1)

Not likely to occur.
 5% change of occurring (over lifetime of project).
 Project component is not shown as exposed in any climate hazard

4.4 Risk Assessment

If the vulnerability result as medium score weather hazards the climatic factor/parameter should be considered to move forwards to the detailed risk assessment as there is a possibility that further analysis could help improve the resilience of the project to climate change. The climate change risk assessment can be based on either qualitative or quantitative assessment. The approach should reflect the level of vulnerability of the project and uncertainty in the climate impact data. If impacts are highly uncertain and cannot be effectively modelled without crude assumptions a quantitative assessment may imply greater precision than is possible. Project components and climate hazards can be grouped together for the risk assessment where the impacts, in-built resilience of the component or approach to mitigation would be similar. This helps in developing a useful, concise and meaningful climate proofing document.

Risk analysis, which is the detailed examination of identified risks, includes examining the causes and sources of the risk while accounting for the presence and effectiveness of any existing controls.

An initial consideration of risk assessment is based on “classical” terms, as a function of the likelihood of a future climate event under a scenario of climate change and its impacts. In particular, many extreme events require special attention in terms of community warning and preparedness as it may not be possible to systematically protect against them. Where possible, a climate change risk assessment should consider the full range of potential impacts and responses; he must also consider the potential for opportunities as well as the risks.

Two concepts must be analyzed as variables: **P – the Probability of climatic events** and **C – the Consequences** of the event in time and intensity (magnitude and significance) which, placed in an algebraic expression, the risk (level) is equal to $P \times C$. This “classical” definition of risk can be applied in a stationary climate, but is difficult to apply in practice in a context-changing climate (climate change). To address this, risk has been linked to the concepts of “vulnerability”.

The risk assessment of the hazards of climatic change components on railway infrastructure assets is presented bellow:

Extreme Risk (score ≥ 20)
Mitigation measures to major risks must be considered for the project.
High Risk (score ≥ 12)
Mitigation measures to major risks should be considered for the project)
Medium Risk (score ≥ 8)
Mitigation measures to major risks should be considered for the project.
Low Risk (score ≥ 4)
Monitoring of these risks should be part of the project adaptation plan

Negligible Risk (score ≤ 3)
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No adaptation plan for these risks is likely to be necessary
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4.4.1 Vulnerability and Risk Assessment

To assess the level of risk assessment of hazard apart Assessment of vulnerability, Climate-related critical thresholds and impacts, Interactions with user and community are considered the Probability, Severity and Magnitude of Consequence rating.

Table 3: The assessment of Variability (sensitivity x Exposure) and Risks (Probability/Likelihood x Severity score) according the climate variable

Hazard Categories and Climate Hazard	Rail infrastructure impact	Climate Variables	Sensitivity	Exposure	Vulnerability	Severity/ magnitude	Risk Assessment
High temperatures	-Expansion of moveable assets such as swing bridges hindering operation; -General increase in failure rate of assets in high temperatures; -Sagging of the overhead line equipment;	Annual / seasonal / monthly average (air) temperature	1 Slight impact on bridge structures, overhead line, signaling and related electrical cables	1 National data (hydrological Institute) on high temperatures	1	3 Possible impact during the lifetime	3 Negligible risk
		Extreme temperature occurrences (including heat waves)	1 Possible effect on heating electrical transformer substation and other related equipment	2 Number of days with high temperature according the temperature trend predictions in 2050	2	3 Possible impact during the lifetime	6 Low Risk
		Wild Fire	2 All electric cables, electric substation and all equipment	3 According data of National Civil Emergencies	6	3 Possible impact based on data of Emergency National Agency	18 High Risk – Extreme Risk
Low Temperatures	-Rail breaks, cracks and/or associated misalignment problems; -Ice-jam flooding damaging infrastructure, particularly bridges;	Cold spells	0 No Impact	0 No Impact	0	1	0 Negligible risk
		Freeze-thaw damage	0 No Impact	0 No Impact	0	1	0 Negligible risk

Hazard Categories and Climate Hazard	Rail infrastructure impact	Climate Variables	Sensitivity	Exposure	Vulnerability	Severity/ magnitude	Risk Assessment
	-Tree and branch falling onto tracks due to snow loading; -Icefalls in tunnels, under bridges and other structures causing damage or derailment of trains.	Ice	1 Possible impact on bridges element and electrical overhead wires	1 Days of snow and ice expected is lower than current however possible impact	1	1	1 Negligible risk
High precipitation	-Increased risk of earthworks failure and landslides in wet weather; -Increased risk of bridge scour arising from flood events; -Failure of other structure supports due to increased risk of scour; -Standing water fouling track ballast; -Lahars causing structural damage to infrastructure;	Annual / seasonal / monthly average (air) rainfall	2 Standing water fouling track ballast and erosion	2 Possible impact by increase rain Intensity	4	2	8 Medium Risk
		Extreme rainfall (frequency and magnitude)	2 Bridge structure risk by Flooding and track erosion	2 Possible impact by increase rain Intensity expected	4	3 Possible impact based on data of Emergency National Agency	12 High Risk
		Land slide	2 Land slide due to terrain slope in limited section of railway	3 Possible impact by increase rain Intensity expected	6	3 Possible impact based on data of Emergency National Agency	12 High Risk
		Rocks fall	2 Rock fall due to terrain slope in very limited limited section of railway	3 Possible impact by increase rain Intensity expected	6	3 Possible impact based on data of Emergency National Agency	18 High Risk – Extreme Risk

Hazard Categories and Climate Hazard	Rail infrastructure impact	Climate Variables	Sensitivity	Exposure	Vulnerability	Severity/ magnitude	Risk Assessment
		Danger of the supporting legs of bridges from floods	2 Possible impact on bridge legs	2 Possible accident on small bridges based on old project design	4	2	8 Medium Risk
High Winds	<ul style="list-style-type: none"> -Increased risk of leaf fall leading to low track adhesion; -Damaged trees and debris falling onto track; -Excessive wind loading on structures such as masts and towers; -Increased risk of damage to bridges in high winds 	The wires of the railway overhead lines (electrical and communication) endangered by high-speed wind	1 Possible damages of wires	1 Possible accident on electrical and communication wires	1	1	1 Negligible risk
		Bridges risk from high speed wind	1 Possible damage of bridges supported elements	1 Possible damage on expected climat change	1	1	1 Negligible risk Negligible risk

4.4.2 Discussion and Conclusions

In the table above, the impacts on the detailed railway infrastructure are discussed and evaluated according to climate variables (Rainfall and Temperatures (as average, extreme values due to periods of drought and those with snow or ice, expected from climate change) and the wind variable.

In the assessment, it is considered important to highlight in particular some expected consequences of climate change in the future, consequences which have high significance and probability in the past events in the local climate of Albania, such as: landslides, rock falls and wild fire which were present in the forest segments and on the steep terrain of the railway.

As outlined in (*Commission Notice (C(2021) 5430). Technical guidance on the climate proofing of infrastructure in the period 2021-2027*) for quantitative evaluations (scoring) of the impacts of all variables in the railway assets is difficult. The quantitative assessment is made more difficult by the fact that the expected climate change data for Albania are global, although there are at least three climate zones. On the other hand, the utilization of the archive of accidents in infrastructure or environment (for example Wild Fires) are fragmented and not for a long period of time. However, we were able to perform a quantitative assessment of each climatic variable over the railway.

From the above table it appears that the sensitivity scoring is different for different environmental variables; it is higher (higher negative impact) for Seasonal and extreme rainfall where the biggest impact is for landslides, rock fall and bridges (their legs).

Exposure is moderately influenced by expected extreme temperatures and high impact by Wild Fire for all electric cables, electric substation and all other equipment. Exposure is higher in two consequences due to slates: in landslides and rock fall in a steep segment Librazhd - Perrenjas.

Particularly influenced by the exposure scoring and less influenced by sensitivity Vulnerability is high in areas of high temperatures (mainly due to wild fire), extreme rain fall (Land Slides and Rock Fall)

According to the risk assessment ranking, six variables are categorized as Negligible Risk (score ≤ 3):

- Annual / seasonal / monthly average (air) temperature;
- Cold Spells;
- Freeze – thaw damage;
- Ice;
- High Wind (for the wires of the railway overhead lines (electrical and communication) endangered by high-speed wind and bridges risk from high-speed wind).

Variable with **Low Risk (score ≤ 8)** results only in the case of extreme temperatures (including heat wave). In this case, the relatively low level of vulnerability has an impact. However, wave heat has impacts on wild fire (frequency and intensity, railway infrastructure).

Medium Risk (≤ 12) is assessed risk assessment in the variable of high rainfall (Annual / seasonal / monthly average (air) rainfall) as well as in the danger of the supporting legs of the bridge. Risk assessment at level High risk (=12) included the impact of two variables related with high precipitation (extreme rainfall (frequency and magnitude) and landslide).

Risk assessment at the level of **High - Risk to Extreme Risk (12-18)** includes extreme rainfall (rock fall) and extreme temperature - heat wave (wild fire) variables.

Mitigation measures must be taken at the levels of adoption, management and engineering measures to avoid and/or reduce the impacts of the expected variables, according to the risk hierarchy described and prioritized as above.

5 Mitigation Measures

Adaptation approaches are usually driven by the goal of risk mitigation by considering the following:

- a) Increased resilience — i.e., adaptation reduces risk by increasing protection against the risks involved, thereby reducing the vulnerability of assets to risks and thereby allowing continued operation under a wider range of conditions. For example, raising electrical systems above anticipated flood water levels either temporarily or permanently;
- b) Asset redundancy within the system—that is, additional or alternative capacity exists to enable continued service even if the infrastructure asset is unable to function;
- c) Quick activation and/or recovery — i.e., infrastructure plan management has the capacity available to provide timely and effective feedback to restore infrastructure and thus services. This may include temporary interventions such as portable flood barriers to control and limit damage to infrastructure and speed up recovery.

Adaptation interventions in infrastructural assets should not only be direct such as engineering or technological ones (“gray” or “hard”). Regulatory and/or policy-based (“soft”) adaptation that improves management, communication and response to extreme events within and between organisms/institutions is extremely valuable and is a step towards "transformative" adaptation. This concept "refers to actions aimed at adapting to climate change that result in significant changes in structure or function that go beyond the regulation of existing practices".

On the other hand, the Albanian railway system should consider a comprehensive long-term and proactive strategy for climate adaptation of the railway infrastructure for the future according to European guidelines that include "soft" adaptive measures and focus on:

- Risk and vulnerability assessment should not be carried out only on the basis of past events. An exploratory approach should be followed considering various well-developed technologies and tools to be applied in conjunction with existing methods. Using artificial intelligence (AI) methods to detect, predict and recommend the necessary measures, adapting both, satellite and field monitoring equipment, to be able to be proactive against uncertain future conditions for rail transport threats and vulnerable areas.
- When designing or building new infrastructure, measures should be taken to incorporate climate adaptation so that the effects of extreme weather events can be minimal.
- There is a need to increase public knowledge and awareness of the potential threats of climate events to rail infrastructure to reduce unnecessary costs, loads and inconveniences that occurred due to unjustified traffic interruptions and other effects.
- Necessary emergency plans should be developed for forecasting the climate as well as measuring the impacts on the railway infrastructure that can reduce the consequences due to unexpected climatic events.
- From a governmental perspective, the necessary policy development and revision of standards should be initiated and encouraged to accommodate future climate change needs throughout the life cycle phases of railway infrastructure.

5.1 Green Mitigation Measures

Nature-based solution (NbS) present long-term, cost-effective and sustainable mitigation and adaptation options to climate change. However, as an effective alternative or complementary to gray (engineered) solutions, they are still at the beginning of application, especially in the railway sector. Recognizing the importance of the need of the railway industry to adapt its infrastructure to accommodate the current extremes of weather and a changing climate, the NbS adaptive measures implemented/planned in other sensitive sectors in our country can be adapted to the railway network. Adaptation to climate change can include a number of possible actions in this option. Along with “soft” and “grey” interventions, there is widespread recognition that nature-based (or “green”) solutions can complement these approaches.

Below are summarized the current (applied and described in the European guides) and potential Nature-based Solution adaptation measures related to hydro meteorological factors and their impacts on the railway network.

Table 4: Key hydro-meteorological hazards to railway infrastructure and adaptation

Hydro meteorological hazard	Rail infrastructure impact	Current adaptation measures	Potential NbS alternative and/or complements*
High temperatures	<ul style="list-style-type: none"> -Rail buckling and/or associated misalignment problems; -Expansion of moveable assets such as swing bridges hindering operation; -General increase in failure rate of assets in high temperatures; -Sagging of the overhead line equipment; -Increased fire risk; -Permafrost degradation causing heaving, sinkholes, potholes and settlement. 	<ul style="list-style-type: none"> -Change rail installation procedure to increase temperature threshold for thermal expansion; -Replacement of jointed track with continuously welded rail; - Upgrade timber switches and crossings to concrete; - Painting rails white in areas of known high risk to thermal expansion in direct sunlight. -Sprinkler systems; -Replacement of bridges with heat resistant materials with lower thermal expansion coefficients; -Use of coolers, fans and air conditioning to improve tolerance of signaling equipment; -Double-skinned equipment casing to assist cooling; -Removal of fixed termination overhead line equipment; -Improved balance weight and head span technologies; -Vegetation management along tracks; -Establishment of tree-free zones in rail corridor -Clearing snow to preserve permafrost stability; -Installation of thermosyphons, air ducts, awnings and ‘cooled roadbeds’ using crushed rocks; 	<ul style="list-style-type: none"> -Green corridors -Vegetation shading Vegetation Management - specific species selection
Low Temperatures	<ul style="list-style-type: none"> -Rail breaks, cracks and/or associated misalignment problems; -Snow blocking tracks; obscuring signals and preventing train contact with conductor rails on ‘third rail’ networks; 	<ul style="list-style-type: none"> -Use of signal hoods to prevent build-up of snow; -Potential heating of conductor rails; -Points heater installation; 	<ul style="list-style-type: none"> -Green corridors -Vegetation shading -Bioengineering and biotechnical stabilization -Green walls and embankment; -Natural drainage solutions;

Hydro meteorological hazard	Rail infrastructure impac	Current adaptation measures	Potential NbS alternative and/or complements*
	<ul style="list-style-type: none"> -Ice-jam flooding damaging infrastructure, particularly bridges; -Ice-jam flooding damaging infrastructure, particularly bridges; -Tree and branch falling onto tracks due to snow loading; -Icefalls in tunnels, under bridges and other structures causing damage or derailment of trains; -Frost heave of track bed and earthworks; -Freeze-thaw damage to rock cuttings and associated landslides; 	<ul style="list-style-type: none"> -Installation of dams, ice booms, ice-retention structures, dykes, or various channel modifications; -Establishment of tree-free zones in rail corridor; -Review of drainage provisions for bridges and tunnels; -Capping of tunnel shafts; -Installation of geothermal piles; -Rock slope stabilization and protection; 	<ul style="list-style-type: none"> -Selection of suitable vegetation for near the rail corridor; - Use of plants with relatively high moisture content and low levels of volatile oils; - Practice the controlled removal of vegetation to prevent wildfires
High precipitation	<ul style="list-style-type: none"> -Increased risk of earthworks failure and landslides in wet weather; -Increased risk of bridge scour arising from flood events; -Failure of other structure supports due to increased risk of scour; -Standing water fouling track ballast; -Lahars causing structural damage to infrastructure; 	<ul style="list-style-type: none"> -Planting of ‘protection forests’; -Slope stabilization programmers including installation of gabion walls, soil nails and sheet piles; -Counterfort drains in slopes and crest drain refurbishment; -Bridge scour protection programs; -Expanding drainage capacity for infrastructure including culvert size, design for new flood event thresholds; -Increasing maintenance including clearing debris from culverts to reduce flooding; -Installation of emergency culvert and aboiteaux; -Installation of pumped drainage solutions; -Installation of containment channels and dikes; -Revetments using riprap, gabion mattresses and concrete facings; 	<ul style="list-style-type: none"> -Bioengineering and biotechnical stabilization -Green walls and embankments -Natural drainage solutions --Protection forest -Soil bioengineering, cultivation or restoration of slopes, live fascines, vegetating crib walls, optimize management of forests, rivers and streams; -Vegetation strategies to ensure the stability of earthworks and soil structure; -Vegetation strategies to reduce risks from flooding; -urges and release slowly Plant trees, hedges and/or perennial grass strips to intercept surface run-off.

Hydro meteorological hazard	Rail infrastructure impac	Current adaptation measures	Potential NbS alternative and/or complements*
		-Soil bioengineering, cultivation or restoration of slopes, live fascines, vegetating crib walls, optimize management of forests, rivers and streams	
High Winds	<ul style="list-style-type: none"> -Increased risk of leaf fall leading to low track adhesion; -Damaged trees and debris falling onto track; -Excessive wind loading on structures such as masts and towers; -Significant wave formation causing damage to the track; -Increased risk of damage to bridges in high winds 	<ul style="list-style-type: none"> -De-vegetation programs; -Establishment of tree-free zones in rail corridor; -Strengthening of existing equipment, build in resilience to design of new equipment; -Improved overhead wire tensioning systems; -Elevate infrastructure; -Improved flood defenses; -Use of guide vanes; -Install damping devices 	<ul style="list-style-type: none"> -Bioengineering and biotechnical stabilization; -Green walls and embankments; -Vegetation management – specific species selection Shelterbelts

5.2 Grey Mitigation Measures

Table 5: Adaption measures on vulnerable infrastructure assets

Impact	Adaptation	Characterization of vulnerability
Slope failure	Re-engineering of slopes to change grade, improve drainage or provide stabilization; local monitoring	Reducing vulnerability through robustness
Slope failures—shallow failures	Detailed slope risk evaluation model for Albanian railway	Enabling prediction of when and where debris flow is most likely to occur, thus enabling better vulnerability assessment to be factored into warnings
Slope failures—shallow failures	Vegetation management to enhance slope stability	Reducing vulnerability
Slope failures—deep rotational failures	Vulnerability mapping by geo-hazard organizations	Enabling improvements in risk assessment
Failure of retaining wall	Upgrading drainage, rock bolting/anchoring, regrouping	Reducing vulnerability by managing pressure on retaining wall structure
Flooding and icing in tunnel	Pressure relief duct and ventilation shaft shields inside the tunnel; applying hydrophobic coatings in tunnel structures	Diverting water and ice build-up outside gauge of tunnel thus reducing impact
Track buckling	Maintenance of track to ensure pre-stressing of rail and ballast strength is maintained; Use of slab track as an alternative to ballasted track— slab track is less able to buckle; Painting rails white at particular buckle-prone locations, to reduce solar gain	Pre-stressing enables expansion to occur safely and ballast prevents lateral motions, reducing both vulnerability and impacts; Reducing vulnerability; Reducing vulnerability
Flooding of track, points and crossing	Maintenance and upgrade of drainage, including outfalls, for higher capacities predicted by higher precipitation intensities; Elevation of the track and/or other assets.	Enhancing redundancy through increased capacity, reducing vulnerability; Reduced vulnerability
Bridge scour	Risk-informed inspection of assets, both routinely and after flood events.	Enabling improvements in risk assessment both in short-term forecasting and long-term
Bridge scour	Foundation countermeasures or replacement	Reducing vulnerability of asset
Low-temperature issues at points and crossings	Enhanced heating units, predictive failure maintenance and changing materials used for low-temperature tolerance	Reducing vulnerability and/or impacts

Impact	Adaptation	Characterization of vulnerability
Windblown debris	Vegetation management; engagement with adjoining landowners to control vegetation and land use; fencing	Reducing secondary hazard and impacts
Permafrost related track deformation	Insulation of embankments; sun sheds; high-albedo surfacing materials; air ducts in embankments; heat drains; thermosyphons	Reducing vulnerability and impacts