Transport Community Treaty Permanent Secretariat

Improving climate resilience and adaptation measures in the indicative extension of TEN-T road and rail networks in Western Balkans

Final Report

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Project context

1. The Project

1.1 Introduction

Considering the ongoing impacts of climate change on our environment, the imperative to fortify our infrastructure against these effects has never been greater. This assignment's key objective is to strategically prioritize vulnerable road and railway sections, criticality assessment and adaptation measures for future investments, specifically focusing on enhancing climate resilience.

Guided by the Terms of Reference (ToR), the entire project aligns with the sustainable development goals (SDG 13) of Climate Action outlined in the Global Agenda 2030 and the EU Green Deal. It concentrates on the existing indicative extension of TEN-T roads and railways networks in the Western Balkans region, encompassing both current and planned sections under development or part of mature projects in the Five-Year Rolling Work Plan for the Development of the Indicative TEN-T extension. This network mirrors the core network established during the Prime Ministers meeting in Brussels in 2015, as illustrated in Figure 1.

All project actions comply with the TCT APs[1], involving in particular Road Action Plan (2020) and Sustainable and Smart Mobility Strategy for the Western Balkans (2021) published by the TCT Secretariat.

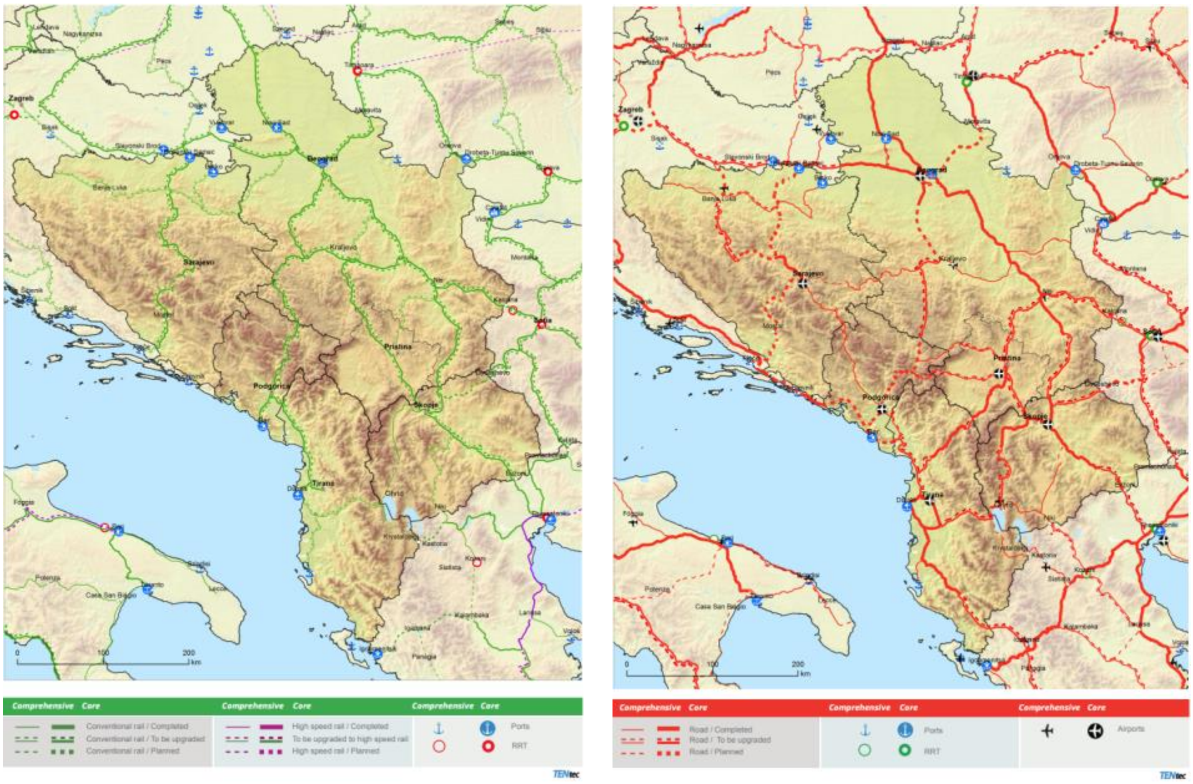


Figure 1 Indicative trans-European transport (TEN-T) extension of Comprehensive and Core Road (left) and Railway (right) Network to the Western Balkans

The project applies to several WB Regional Parties (RP) and therefore involved stakeholders including:

- Albania
- Bosnia and Herzegovina
- Kosovo*[2]
- Montenegro

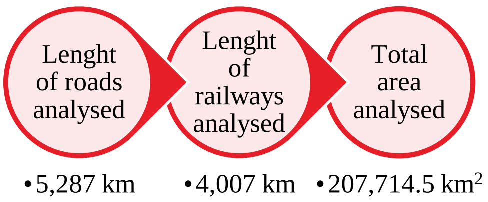
[1] Transport community, Energy community and Innovation community are closely related into the six joint and coordinated action plans (APs) for the WB, aiming to the safer, green, smart and sustainable transport services: road, and road safety, railways, transport facilitation, the waterborne and multimodal transport, plan for training capacities from activities relevant of the transport of dangerous goods.

[2] *This designation is without prejudice to positions on status and is in line with UNSCR 1244 (1999) and the ICJ Opinion on the Kosovo declaration of independence.

- North Macedonia
- Serbia.

1.2 The Scope

The project is centred around assessing the vulnerability to climate change-related factors and conducting a criticality assessment of the indicative extension of the TEN-T Comprehensive and Core Road and Railway networks in the Western Balkans. This includes assessment of 5,287 km of TEN-T roads, out of which 3,540 km on the Core Network; 4,007 km of TEN-T railways, of which 2,623 km on the Core Network and 207,714.5 km^2 for the total surface area of interest (AoI).



The project aims to protect roads and railways from climate-related problems like floods and landslides. We're figuring out ways to adapt and safeguard critical parts of the networks. This involves things like building flood defences and improving drainage. We have also estimated the costs of these measures based on past projects and data. This helps us make smart decisions about where to invest in protecting the roads and rails from climate issues.

The main goal is to make sure the roads and railways in the WB can handle changing climates. We're identifying important sections in each region and planning investments to make the infrastructure more resilient. This way, we can tailor our plans to meet the specific needs of each area, ensuring that transportation remains reliable for communities and businesses. This report shows what we've achieved in the project, including vulnerable sections, costs, and suggested actions.

1.3 Project activities

Within the project framework, four primary task sets have been outlined to achieve the predefined objectives and outcomes depicted in the following Figure 2:

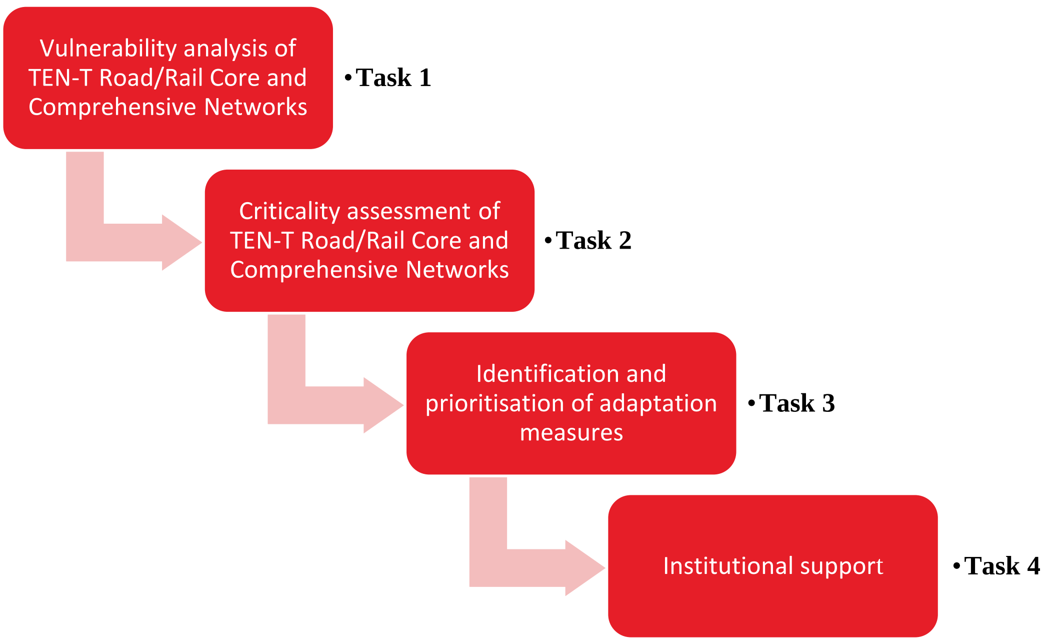


Figure 2 Project tasks

Task 1 - Undertake vulnerability analysis of TEN-T Road/Rail Core and Comprehensive Networks

Task 1 aims to evaluate the vulnerability of TEN-T road and rail networks to climate hazards. This assessment is crucial for guiding strategic investments by infrastructure managers and governments. By understanding the sensitivity of critical infrastructure and the likelihood of climate-related events, we can prioritize where funding is needed most.

The project considered the impact of climate hazards on the networks for the years 2030 and 2050. Sub-tasks under Task 1 include:

- Sub-task 1.1 Sensitivity analysis
  - Identify which climate-related hazards are relevant to road and rail infrastructure based on available historic data for damages caused.
- Sub-task 1.2 Exposure assessment
  - The evaluation of exposure to climate-related risks involves the overlaying of the road and rail networks (considered as assets or elements at risk) with hazard maps within a Geographic Information System (GIS) environment.
- Sub-task 1.3 Vulnerability analysis
  - This step involves assessing the risk for particular hazards or multi-hazard scenarios. To augment the TEN-T network data, additional specifics regarding internal network characteristics or vulnerabilities per network link were included. This information encompasses vector geometry from exposure maps along with supplementary data on traffic frequency, load, road/rail type, category, monitored state (such as road roughness), speed limits, etc.

Task 2 - Carry out a criticality assessment of TEN-T Road/Rail Core and Comprehensive Networks

Task 2 aims to evaluate the most crucial links in the TEN-T road and rail networks, identified in Task 1. This assessment involves a socio-economic evaluation to prioritize these links for additional investments. By understanding the criticality of these links, we can systematically plan interventions that are economically feasible and aligned with strategic priorities. This ensures a focused and efficient approach to addressing vulnerabilities and improving the overall resilience of the networks.

Main activities under Task 2 include:

- Road/Rail failure assessment:
  - Assess the impact of the certain hazard on road/rail failure, considering functional vulnerability, which is the loss of a functionality of certain road/rail link/sub-link. It's quantified by disruption duration and space impact (low, medium, high failure levels). Operational capacity reduction is evaluated based on failure levels, considering speed, capacity reduction, and section closures.
- Transport demand assessment:
  - The specific objectives of the transport demand assessment are to analyse current passenger and freight flows in the study area, compare and validate these flows with baseline data from the Sustainable and Smart Mobility Strategy for the Western Balkans (SSMS), integrate electric vehicle scenarios, model hazard impacts on the network's capacity, assess changes post-2022 energy crises, and provide model outputs for cost-benefit and multi-criteria analysis.
- Socio-economic assessment:
  - The social significance of the road/rail network implies its importance in meeting social needs of people that live in certain region, including impact on jobs/businesses and use transport links or sub-links. The coverage of the analysis is the whole population that live in the gravity area around certain sub-link.
- Prioritisations od sub-links:

– The prioritization employs a multi-criteria analysis, referencing risk areas outlined in the Technical Guidance on climate-proofing infrastructure (2021-2027), serving as a basis for discussions with RPs. Stakeholder engagement ensures inclusion of crucial decision-making aspects. This involves calculating indices to compare criticality across road/rail sections, considering socio-economic data, connectivity loss impact, and overall societal and economic dislocation effects.

Task 3 - Identification and prioritisation of adaptation measures

The goal of Task 3 is to devise a catalogue of recommended engineering interventions to mitigate road and rail vulnerability to climate-related hazards in critical links/sub-links. This involves estimating costs based on standardized rates from construction contracts, maintenance cost lists, or typical area-specific rates.

Task 4 - Institutional support

Task 4 is focused to institutional capacity building support to relevant authorities of Regional Parties such as Ministries of Transport, Road Managers, Rail Infrastructure Managers and others.

This support is carried out by conducting two specific workshops aiming at raising the awareness of the relevant authorities on climate change projections, risk assessment and identification of adaptation measures for transport infrastructure (road and rail).

1.4 Project time frame

The Project commenced on January 26, 2023, with the Kick off Meeting (KoM). The KoM was held in person in the Client’s premisses in Belgrade. During the meeting technical and administrative topics were discussed and mutual agreement on both have been reached. Project ends with the end of year 2023.

1.5 Project Deliverables

Project deliverables were classified into 6 different deliverables, ranging from Inception Report to Final Report, following project activities and defined time frames, represented in the next figure.

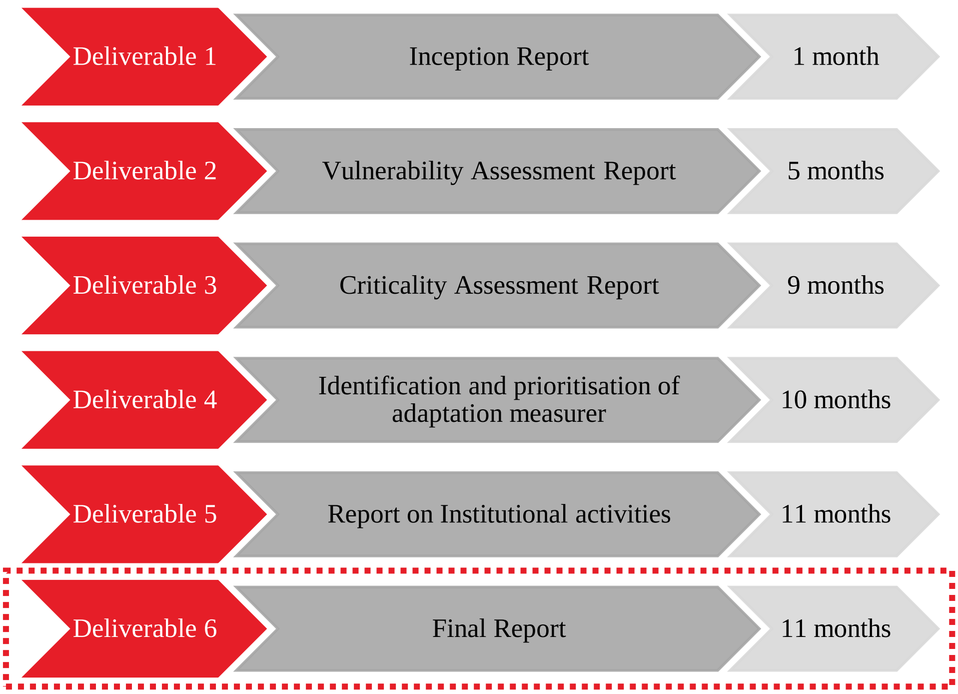


Figure 3 Project Deliverables

Results

2. Vulnerability – processes and outputs

2.1 Vulnerability assessment process

The project heavily relies on the methodological approach suggested by higher instances (EC or particular RPs). In this case, since none of the RPs have their own regulations and modelling procedures on vulnerability assessment and are otherwise directed to use the higher instance (EC) regulations, the vulnerability assessment is based on the EC Guidance on climate proofing[3], with some improvements or additional details, aligned to serve the Project needs.

Therefore, for assessing vulnerability at regional and larger scales, like the Western Balkan Region, the utilized method involves downscale existing Vulnerability (or Hazard) models of broader areas to fit the specific context of the area.

The methodology of the vulnerability assessment can be roughly split into:

- Data and materials preparation:
  - We gathered data from EC JRC repositories, focusing on open-access sources related to our goals. We also communicated with TCT and RPs for specific data needs.
  - We used existing modelling methods, adjusting broader spatial models to fit our specific context.
  - To plan for future climate-resilient infrastructure, we have chosen a realistic climate scenario. The IPCC[4] C6 (RCP4.5) scenario, predicting a 2-3°C temperature rise and a 0.7m sea level increase by 2100, seemed suitable. Climate Change Centre Austria, under the ClimaProof project framework[5], provides 3,000+ observations and models tailored for the WB region, aiding in scenario selection through a tool enabling model customization based on precipitation and temperature estimates for desired future conditions.
- Hazard modelling:
  - Even though several hazard models were overtaken from the original source, they all endured some interventions at least technical, while other models were built from scratch.
- Vulnerability calculation:
  - The key focus involves preparing raster hazard models and then proceeding to calculate the exposure of the target network to these hazards on a relative 0–1 scale. This procedure encompasses sensitivity calculation, leading up to exposure calculation, as per the Guidance methodology.

The methodology flow chart is given in Figure 4.

[3] Technical guidance on the climate proofing of infrastructure in the period 2021-2027, Brussels, 29.7.2021 C(2021) 5430 final

[4] Intergovernmental Panel on Climate Change

[5] https://climaproof.net/

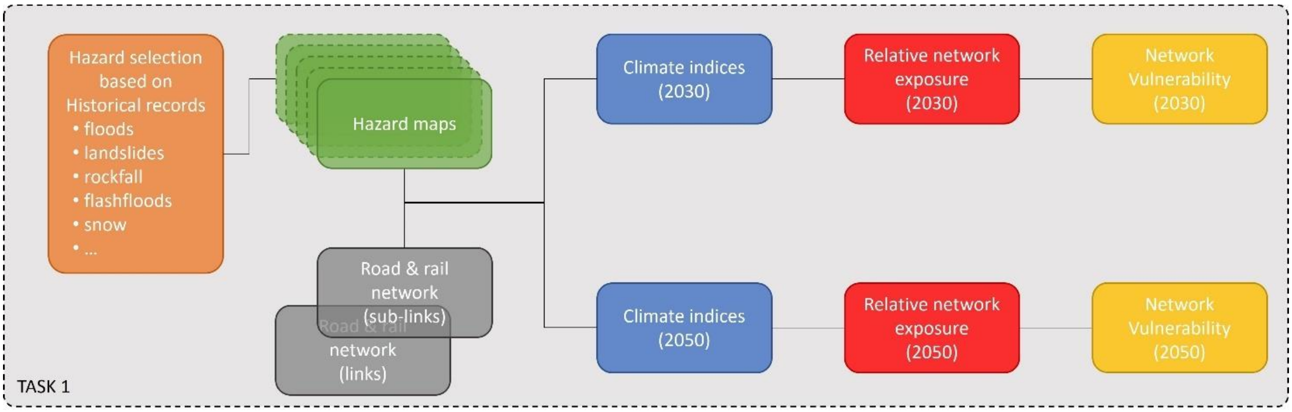


Figure 4 Vulnerability assessment process

Key insights:

- **Optimized Approach:** Combining Guidance-based methods and spatial hazard modelling for an optimized methodology.
- **Vulnerability Overestimation:** Sole reliance on Guidance may overestimate vulnerabilities, potentially missing critical links.
- **Exposure Mix Limitations:** Current and future exposure mix in Guidance limits meaningful comparisons between different timeframes.
- **Lack of Scoring Hindrance:** Lack of scoring in Guidance hampers comparisons between equally classified highly exposed links within the same timeframe.
- **Limited Sub-link Impact:** Sub-link analysis helps identify vulnerable segments but doesn't significantly aid Guidance parameter distribution.
- **Localized Hazard Effectiveness:** Multi-hazard assessments serve general purposes, but individual hazard scores address specific local issues more effectively.
- **Comprehensive Network Analysis:** Combining TEN-T network analysis with other interacting networks, especially local roads, provides a holistic impact view.
- **Timeline Consistency:** Adapting network vectors to correspond with the actual timeline improves analysis quality but lacks consistency across rail and road networks.
- **Biased Climate Change Implementation:** Climate change implementation indicates decreased hazards overall, but biases exist regarding disruptions without considerable damage.
- **Overlooked Human Interventions:** The assessment overlooks human interventions like hydropower systems and snow barriers, impacting accuracy.
- **Limited Reach Hazards:** Certain hazards with limited reach may not be accurately represented at the large scale of assessment, affecting outcomes significantly.
- **Projection Limitations:** Limitations exist in projecting future states due to a reliance on global trends and averaged parameters influenced by selected climate change scenarios.
- **Bias Mitigation Strategies:** Multi-hazard approaches treat all hazards equally; weighted scoring or observing hazards independently could mitigate biases but require further research.
- **Applicability for Prioritization:** Outputs in map and tabular form are easily applicable for subsequent criticality assessments and prioritization.
- **Planning Facilitation:** The outputs facilitate planning, broad assessment, and identifying areas for more detailed analysis.

2.2 Vulnerability Map Outputs

This section provides an overview of the vulnerability assessment results for both the road and railway networks, considering individual hazards and integrating two distinct timespans: 2030 and 2050.

2.2.1 Vulnerability of the TEN-T road network

2.2.1.1 Multi hazard

Overall vulnerability to multi-hazards for both timespans are presented in Figure 5.

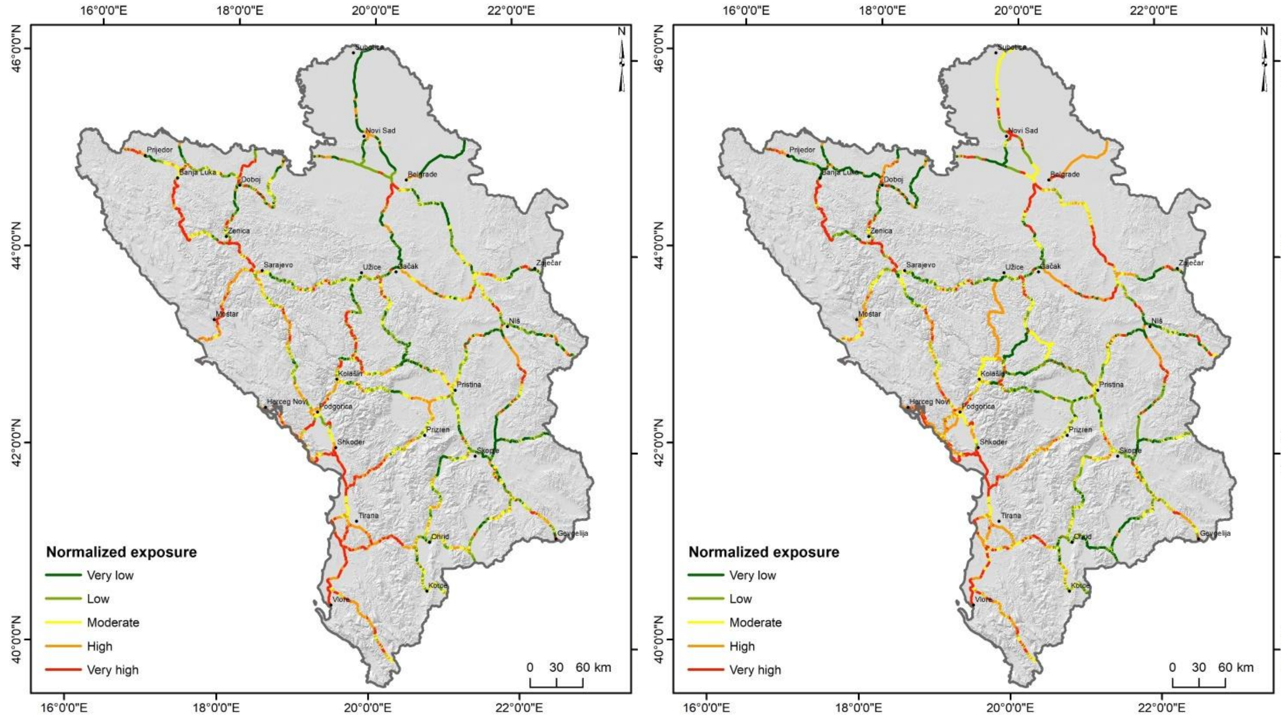


Figure 5 Spatial extent of the road sub-link multi-hazard exposure for 2030 and 2050 time split

2.2.1.2 Floods

Vulnerability to flood hazards for both timespans are presented in Figure 6.

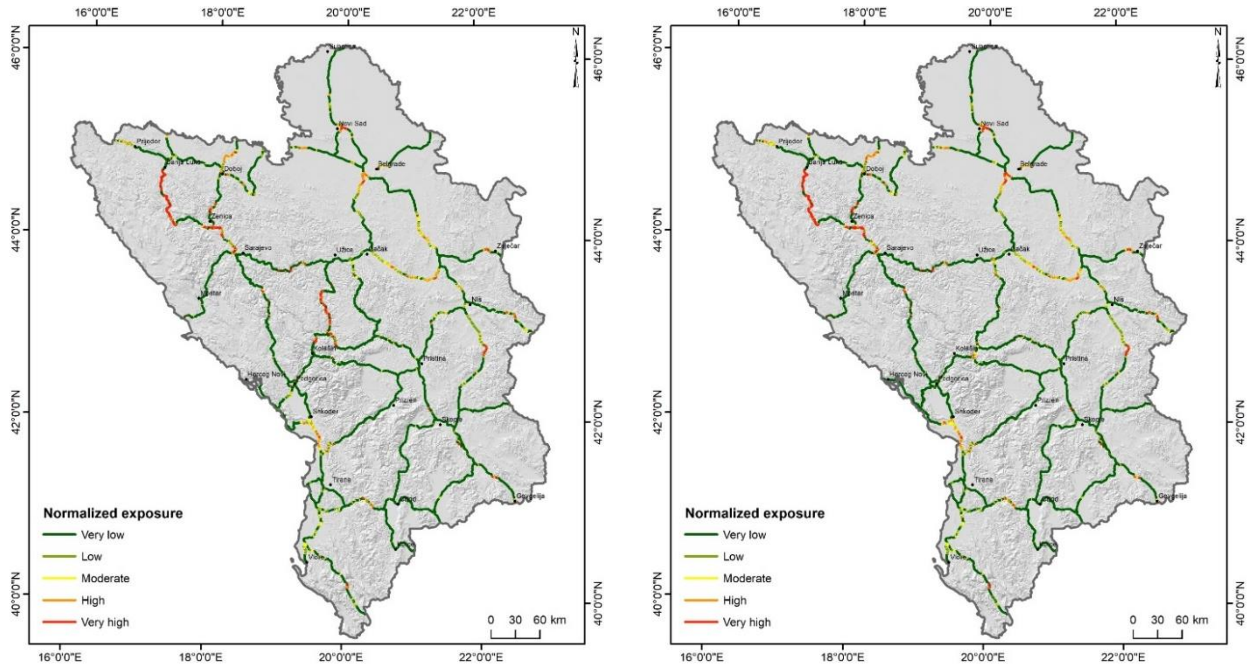


Figure 6 Spatial extent of the road sub-link exposure to flood hazard for 2030 and 2050 time split

2.2.1.3 Landslides

The hazard seems to slightly increase in 2050 time split.

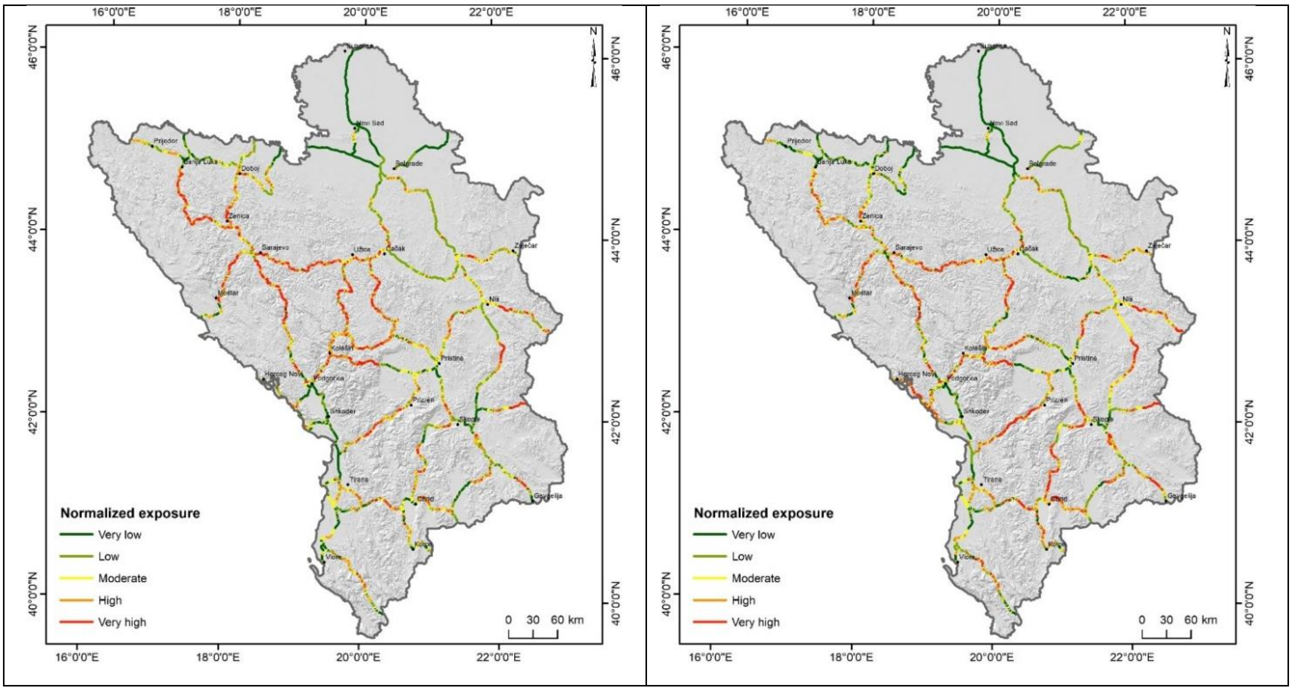


Figure 7 Spatial extent of the road sub-link exposure to landslide hazard for 2030 and 2050 time split

2.2.1.4 Sea surge

The sea surge hazard is only presented as binary class, due to calculation method, i.e., averaging along a sub-link. Changes in 2050 are very subtle, and mainly decreasing, and are best reflected in new links, which are less exposed.

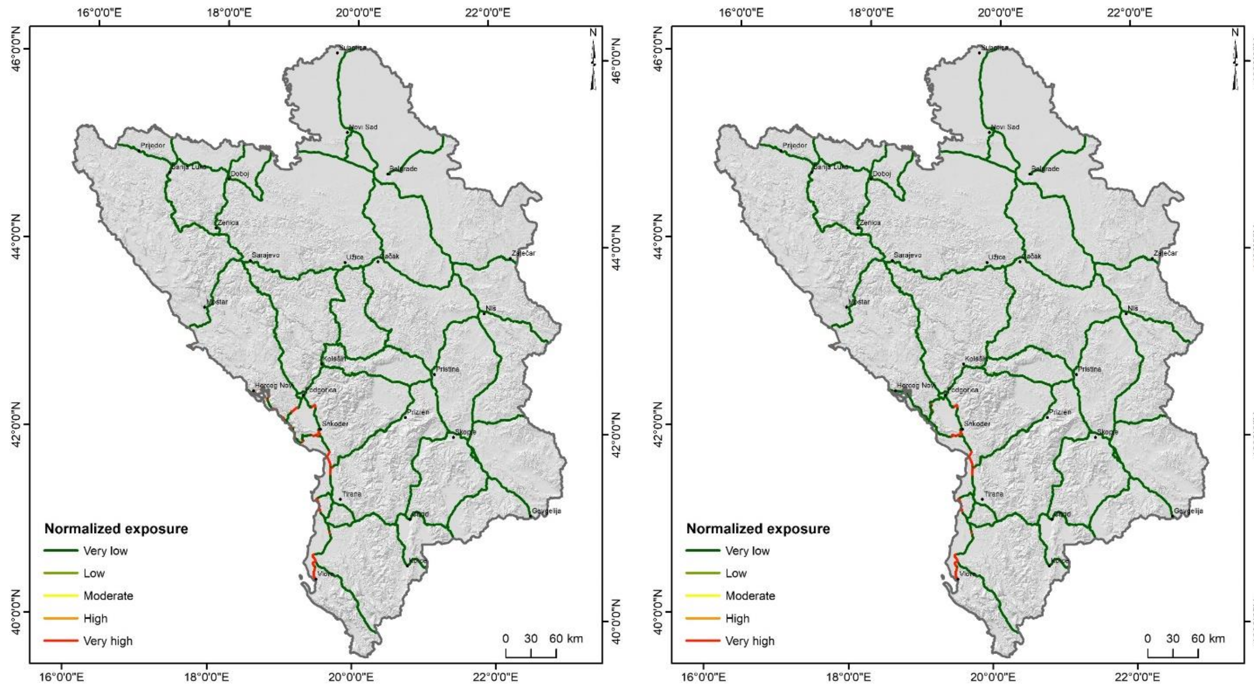


Figure 8 Spatial extent of the road sub-link exposure to sea surge hazard for 2030 and 2050 time split

2.2.1.5 Snowdrift

The snow drift hazard is also benefiting from the sub-link view, although the major routes remain classified as highly exposed. Still, the increase is evident in the north for the 2050 time split, while intriguingly the exposure dramatically drops in the south and west of the area.

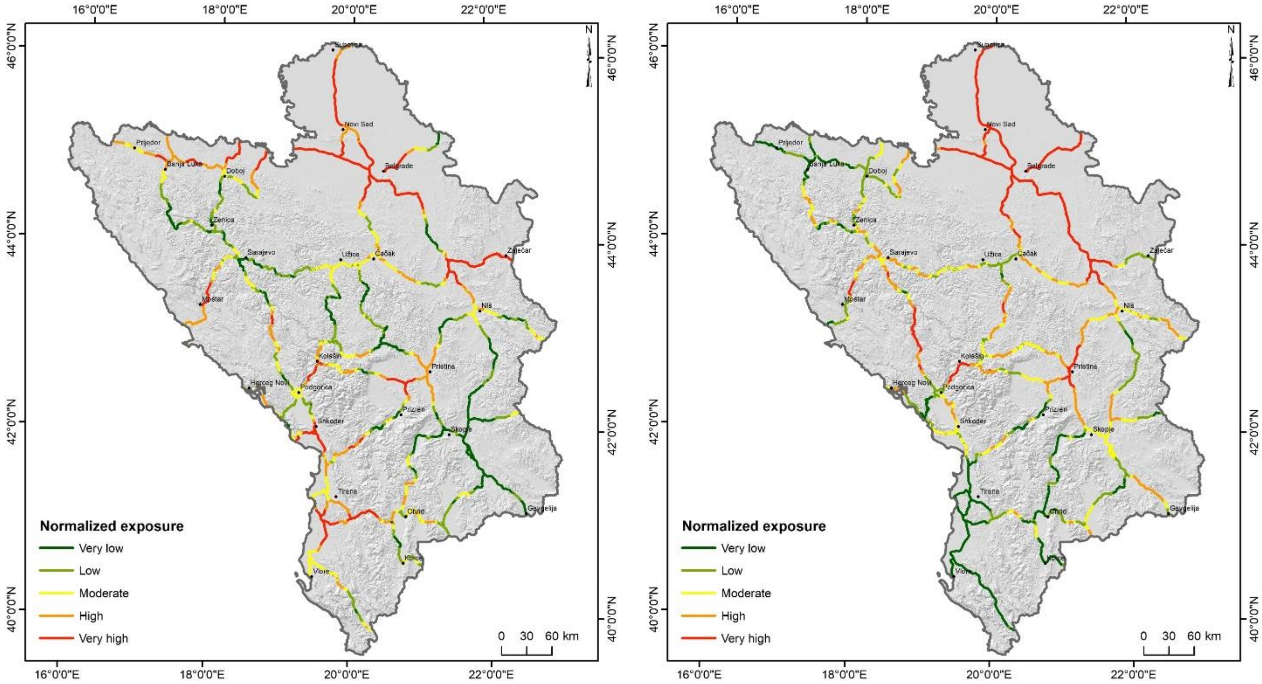


Figure 9 Spatial extent of the road sub-link exposure to snowdrift hazard for 2030 and 2050 time split

2.2.1.6 High temperature

High temperatures are also better visualized by using sub-links represented in the next figures. Similar trends and changes (increase and cooling) in respect to the 2050 can be observed as in the per link case.

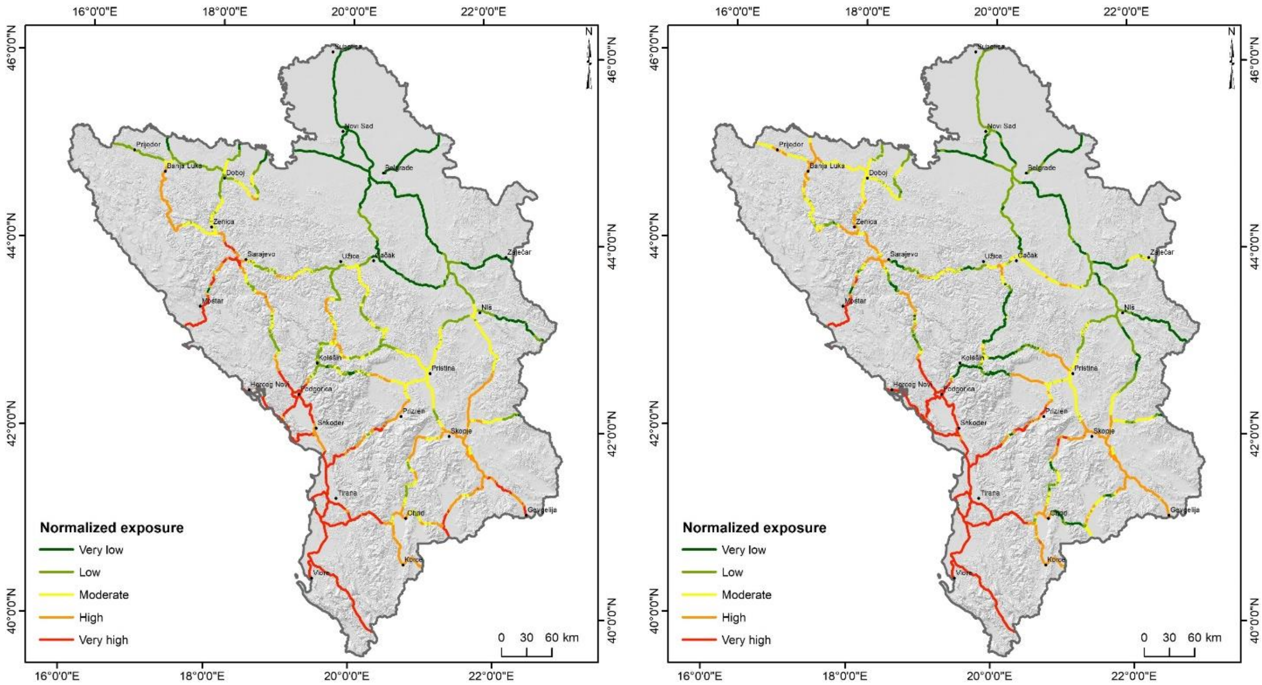


Figure 10 Spatial extent of the road sub-link exposure to high temperature hazard for 2030 and 2050 time split

2.2.2 Vulnerability of the TEN-T railway network

2.2.2.1 Multi hazard

Overall vulnerability to multi-hazards for both timespans are presented in Figure 11.

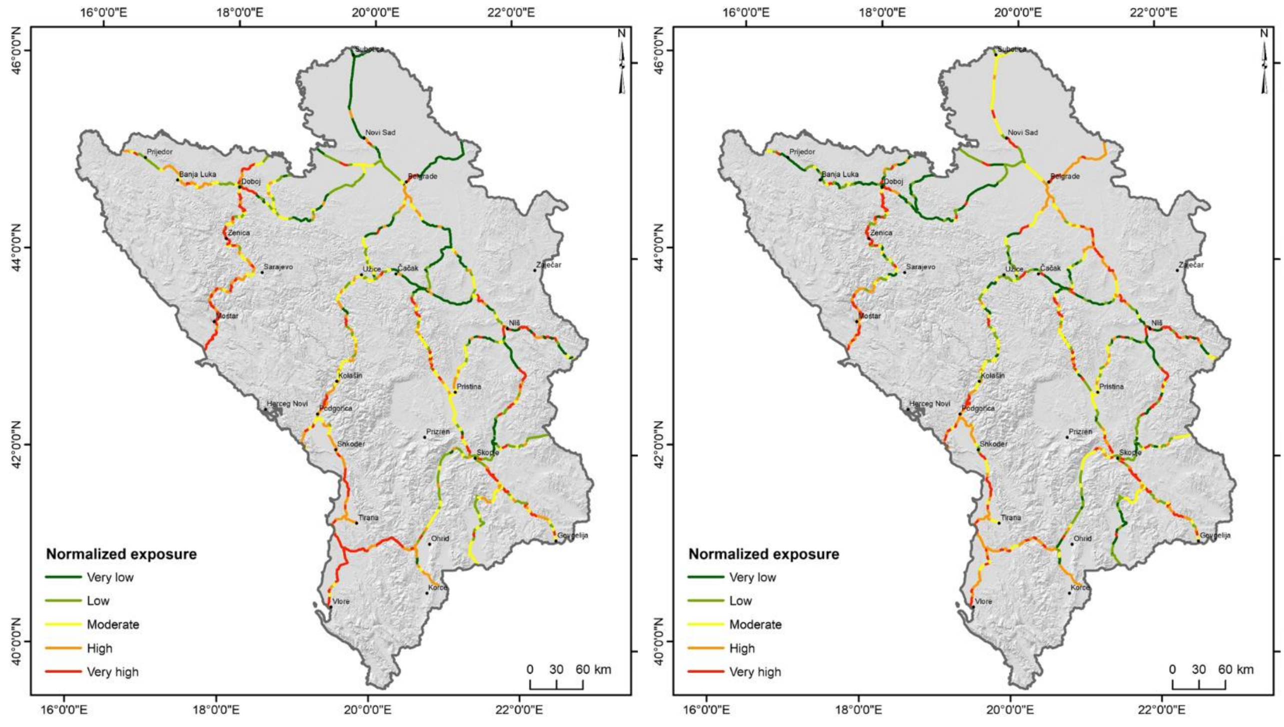


Figure 11 Spatial extent of the railway sub-link multi-hazard exposure for 2030 and 2050 time split

2.2.2.2 Floods

In the case of flood hazard per sub-link on the railway network, the changes and local influences are well discerned in the next figures. The changes introduced in 2050 are very subtle, almost indiscernible, but slight increase of the exposure is noted, which is the opposite to the per link case.

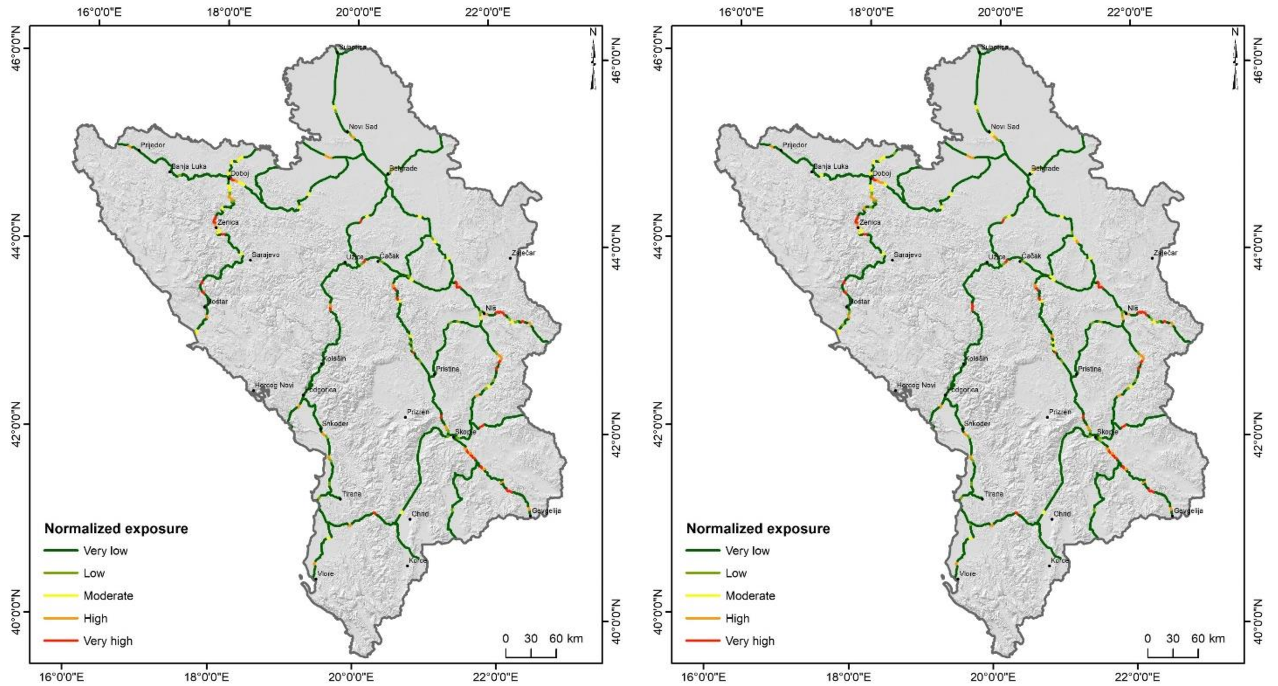


Figure 12 Spatial extent of the railway sub-link exposure to flood hazard for 2030 and 2050 time split

2.2.2.3 Landslides

The landslide hazard exposure in the railway sub-link case is also revealing fine details along the railway network, which generally comply to the per link analysis. Slight differences are present in the 2050 time split, and they are both, increasing and decreasing, but only locally.

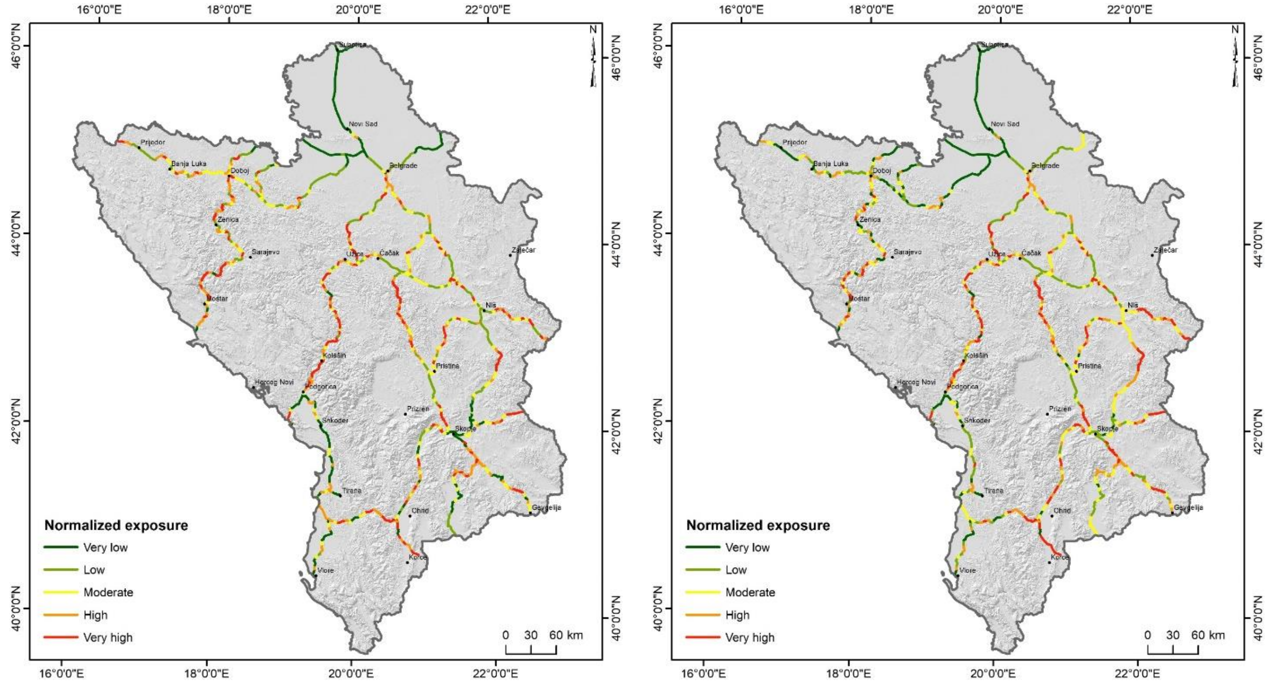


Figure 13 Spatial extent of the railway sub-link exposure to landslide hazard for 2030 and 2050 time split

2.2.2.4 Sea surge

The sea surge hazard is not particularly benefiting from sub-link view as it has very limited extent. There is no observable change in 2050 in relation to 2030 time split.

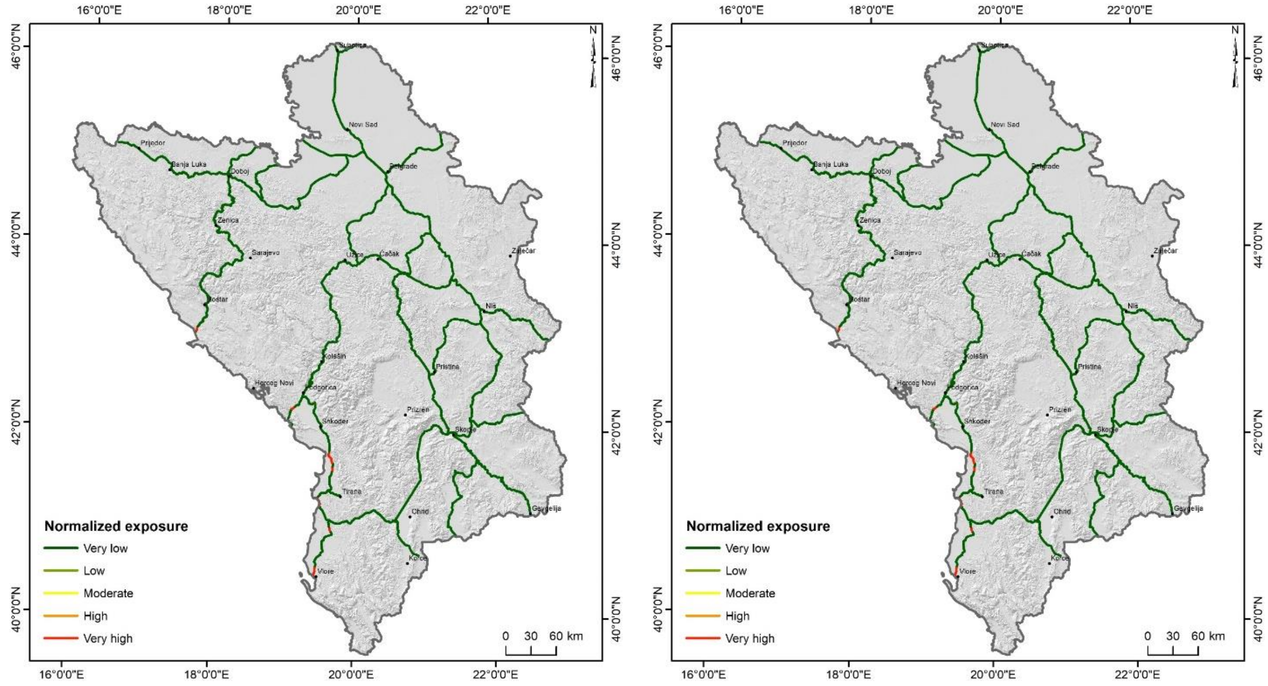


Figure 14 Spatial extent of the railway sub-link exposure to sea surge hazard for 2030 and 2050 time split

2.2.2.5 Snowdrift

The trend of high increase in the north (NE) and dramatic decrease in the south is also evident in the 2050 time split, as in the case of the road network.

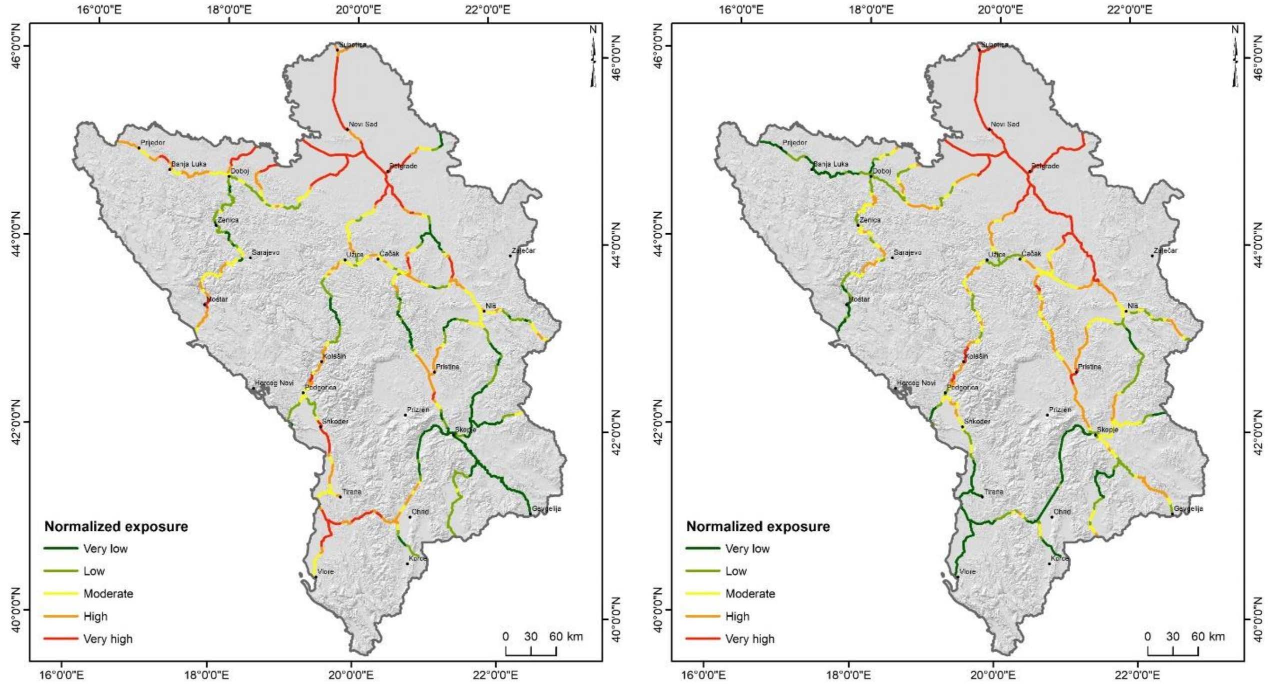


Figure 15 Spatial extent of the railway sub-link exposure to snowdrift hazard for 2030 and 2050 time split

2.2.2.6 High temperature

High temperature hazard is also great visualized by using sub-links. Due to its greater importance in railway management (in perspective) it is much better to identify local increase, rather than actin on the entire railway links. However, the scoring showed that highly exposed links are indeed exposed in their entirety, in the southern parts of the area. The change introduced in the 2050 split confirms the warming trend and particularly impacts the North Macedonia, whereas Albania remains at the same level of the highest exposure (next figure on the right).

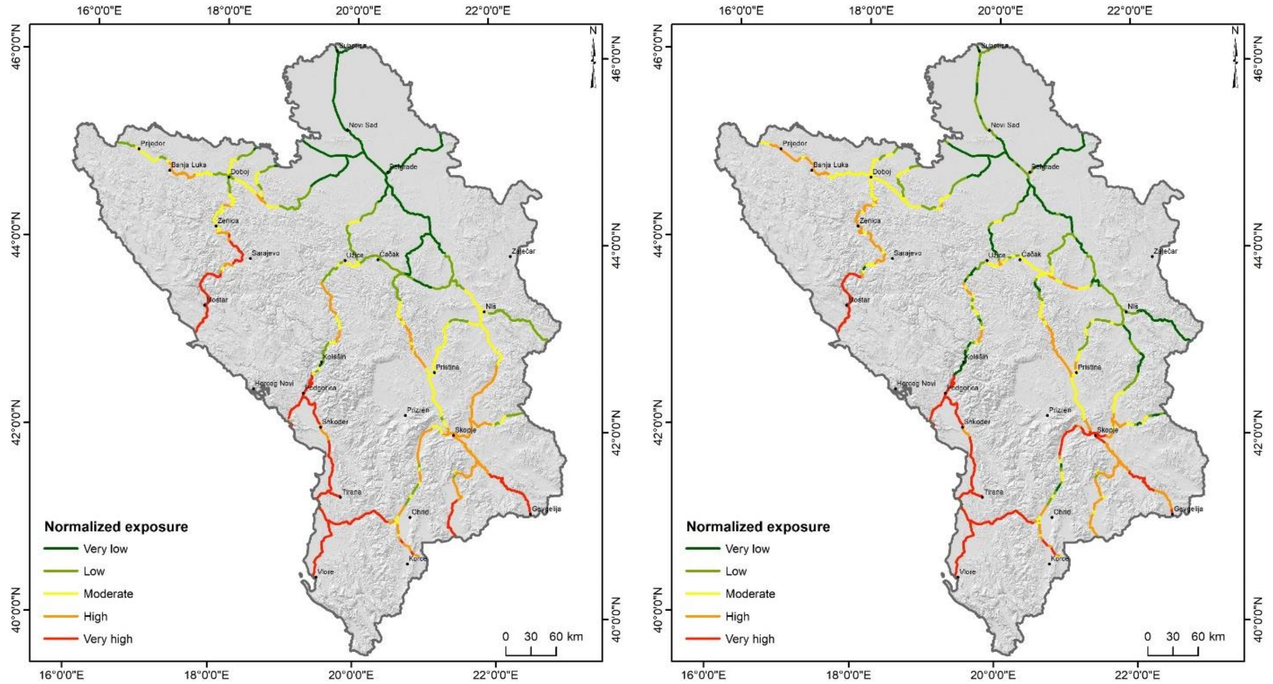


Figure 16 Spatial extent of the railway sub-link exposure to high temperature hazard for 2030 and 2050 time split

3. Criticality assessment – process and outputs

3.1 Criticality assessment – process

In conducting this assessment, it is crucial to align with established guidelines, particularly those recommended by the European Commission (EC) and relevant Regional Parties (RPs). RPs are advised to follow EC regulations while allowing room for enhancements, detailed in subsequent sections.

Approach: The criticality assessment utilizes data from the Vulnerability Assessment Report, regional traffic demand projections, EC guidance, international best practices, and project ToR.

Methodology: The process aims to identify and evaluate sections of the TEN-T network in the Western Balkans most susceptible to climate change impacts.

Assessment Focus: The Road/Rail failure assessment evaluates hazards' impact on functionality, operational capacity, and potential disruptions.

Quantification of Failure: Criticality is assessed by quantifying road/rail failure in terms of duration and spatial disruption, categorized as low, medium, or high levels.

Operational Capacity Impact: The evaluation considers speed reduction, capacity reduction, and link closures to gauge the impact on operational capacity.

Natural Hazards Analysis: The assessment analyses physical breakage of road/rail sections due to natural hazards, considering timelines related to traffic flow interruptions.

Transport Demand Integration: Integrating transport demand is crucial for understanding broader disruptions' impact on traffic flow and accessibility.

Environmental and Societal Effects: For instance, road failures due to hazards impact the environment and society, necessitating vehicle rerouting. Cost-benefit analyses, considering potential savings from adaptation measures, are essential.

Structured Planning: A systematic, prioritized approach aids in identifying negative impacts, conducting cost-benefit analyses, and creating structured plans for economically feasible adaptation measures.

The primary tasks encompassed within the criticality assessment process are presented in the following Figure 17.

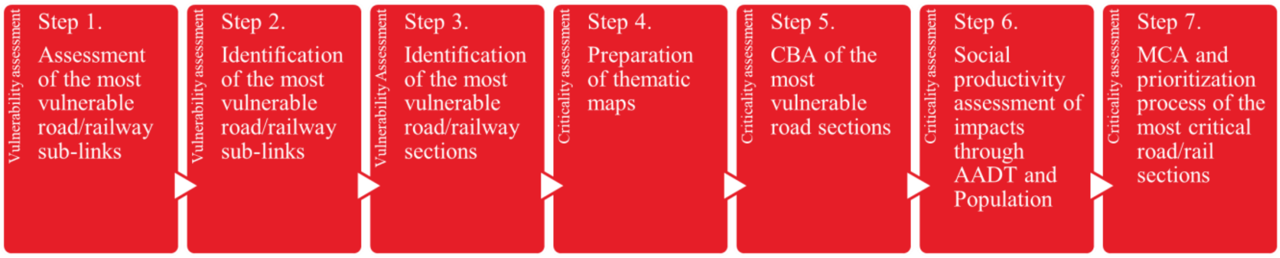


Figure 17 Criticality assessment process

A detailed explanation of the criticality assessment process, covering all steps (1 to 7), has been presented in Deliverable No. 3: Criticality Assessment Report.

3.2 Identification of hazards and proposal of adaptation measures

The main aim is to use the earlier vulnerability assessment to identify the key hazards affecting the road and rail segments in the Western Balkans' TEN-T extension network. This involves assessing the intensity of these hazards and proposing measures to mitigate their impact from climate change.

The analysis also sets up an investment framework to guide strategic budget planning. Specific focus is on **the 10 most vulnerable sections**, identified through comprehensive vulnerability and criticality assessments.

To pinpoint hazards affecting each link, a detailed spatial analysis is conducted, considering terrain conditions and the link's positioning relative to potential dangers. This includes evaluating hazard scores for each sub-link and incorporating expert assessments for a comprehensive overview.

Specifically, the following steps were undertaken in this analysis for each individual link[6]:

1 Review of vulnerability analysis results

- Analysing the length of each individual link
- Identifying the number and length of sub-links
- Summarizing the list of hazards present on each link, and
- Assessing their scores regarding infrastructure sensitivity to their occurrence.

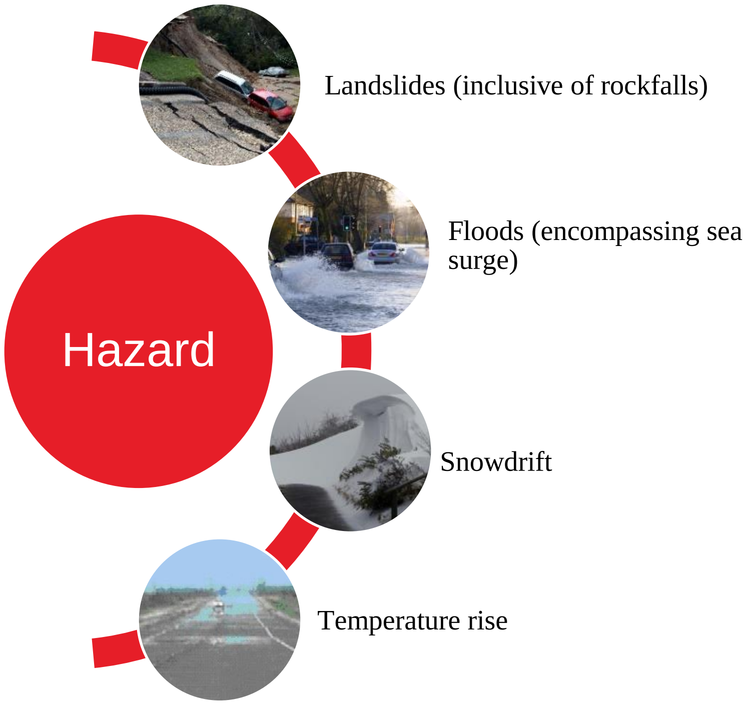
2 Determining spatial conditions

- Reviewing terrain conditions – topography
- Determining the road/rail classification
- Analysing the relationship between the road/railway and nearby water bodies (considering parallel alignment, intersections, and distance)
- Examining the interaction between the road/railway and nearby hills/mountains (including foothill intersections or slopes, and distance from slopes)
- Assessing the population density in proximity and the distance from the road/railway.

3 Summarizing conclusions on the following aspects

- Identifying the dominant hazard(s) requiring adaptation measures
- Determining spatial limitations
- Evaluating road/railway RoW (e.g., single or dual carriageway, single or double-track railway)
- Analysing existing or planned transportation infrastructure
- Counting intersections with water bodies
- Assessing existing major structures (bridges, tunnels).

Adaptation measures have been systematically categorized based on identified hazards, encompassing:



[6] The analysis of spatial conditions was performed by leveraging advanced tools such as QGIS data, Google Earth and Open Street maps.

3.3 Investment costs of critical sections per RP

Investment Assessment Overview:

- Part of the Project's CBA and Criticality Assessment.
- Directly tied to planned adaptation measures for road and rail networks against climate change.

Components of Investment Assessment:

- Evaluates both investment costs and maintenance expenditures.
- Assesses avoided maintenance costs to calculate project benefits.
- Represents expenses linked to maintenance activities if adaptation scenarios are not implemented.

Investment Scenarios:

- Defined based on sub-link vulnerability scores and ground conditions analysis.
- Each sub-link has a specific investment scenario with predetermined adaptation measures.
- Evaluates investment value of chosen measures to determine future costs up to 2030 and 2050.
- The proposed adaptation measures for the analysed sections have been carefully crafted.

Length Estimation and Normalization:

- Estimates potential hazard occurrence length within the link.
- Normalizes lengths with corrective factors for flood, snow drift, and landslides.

Hazard Impact Assessment:

- Uses vulnerability scores to identify predominant hazards for each link.
- Conducts investment evaluation considering all identified hazards.

Estimation Basis:

- Investment estimates are determined per-kilometre unit for road and railway infrastructure.
- Relies on sector experience and expert estimation.

The Catalogue of proposed adaptation measures has been presented in Appendix B of the Report.

3.4 Criticality Assessment – Outputs

3.4.1 Road sections

The most critical segments of the road TEN-T network assessed though the criticality assessment, as per methodology presented, are on the following figure and contains **up to 40 most vulnerable sub-links per RP (20 per each timespan, 2030 and 2050**). Based on these sub-links, **the 10 most critical road sections** have been identified and presented per each RP in Appendix A for which investment estimations were conducted

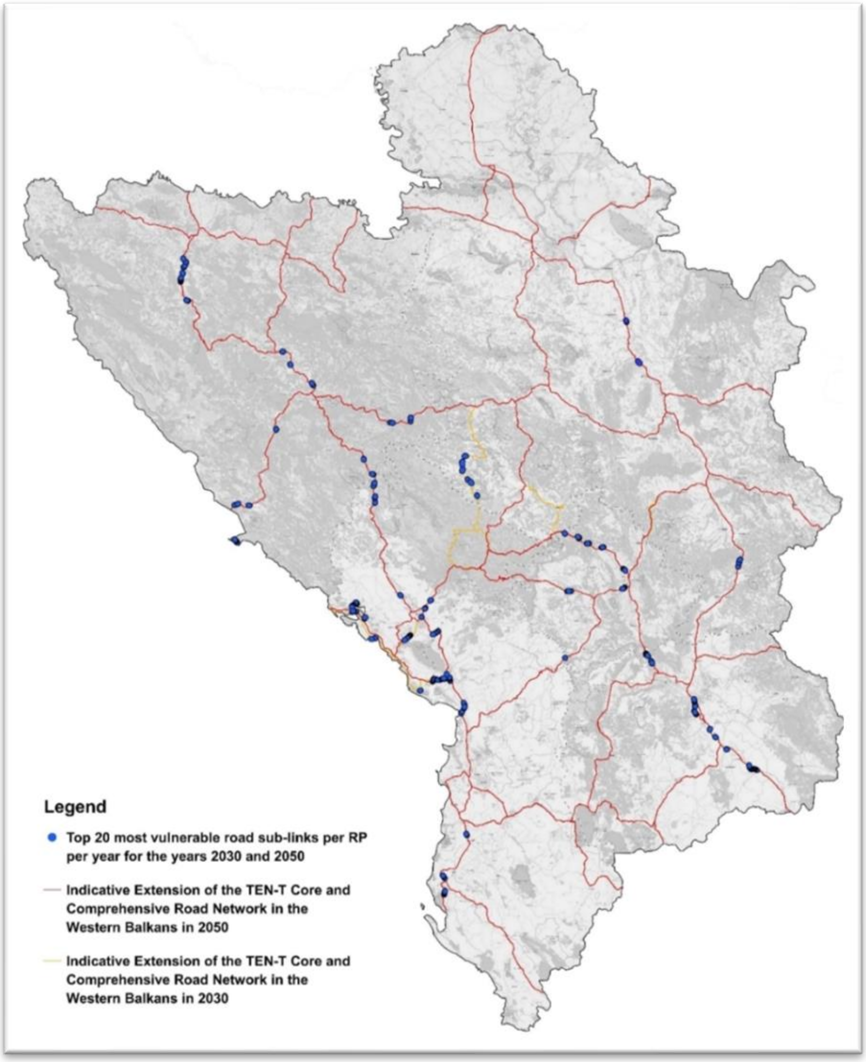


Figure 18 Top 20 most vulnerable road sections in 2030 and top 20 most vulnerable road sections in 2050

3.4.2 Railway sections

The most critical segments of the railway TEN-T network assessed though the criticality assessment, as per methodology are presented on the following figure and contains **up to 40 most vulnerable sub-links per RP (20 per each timespan, 2030 and 2050)**. Based on these sub-links, **the 10 most critical railway sections** have been identified and presented per each RP in Appendix A for which investment estimations were conducted.

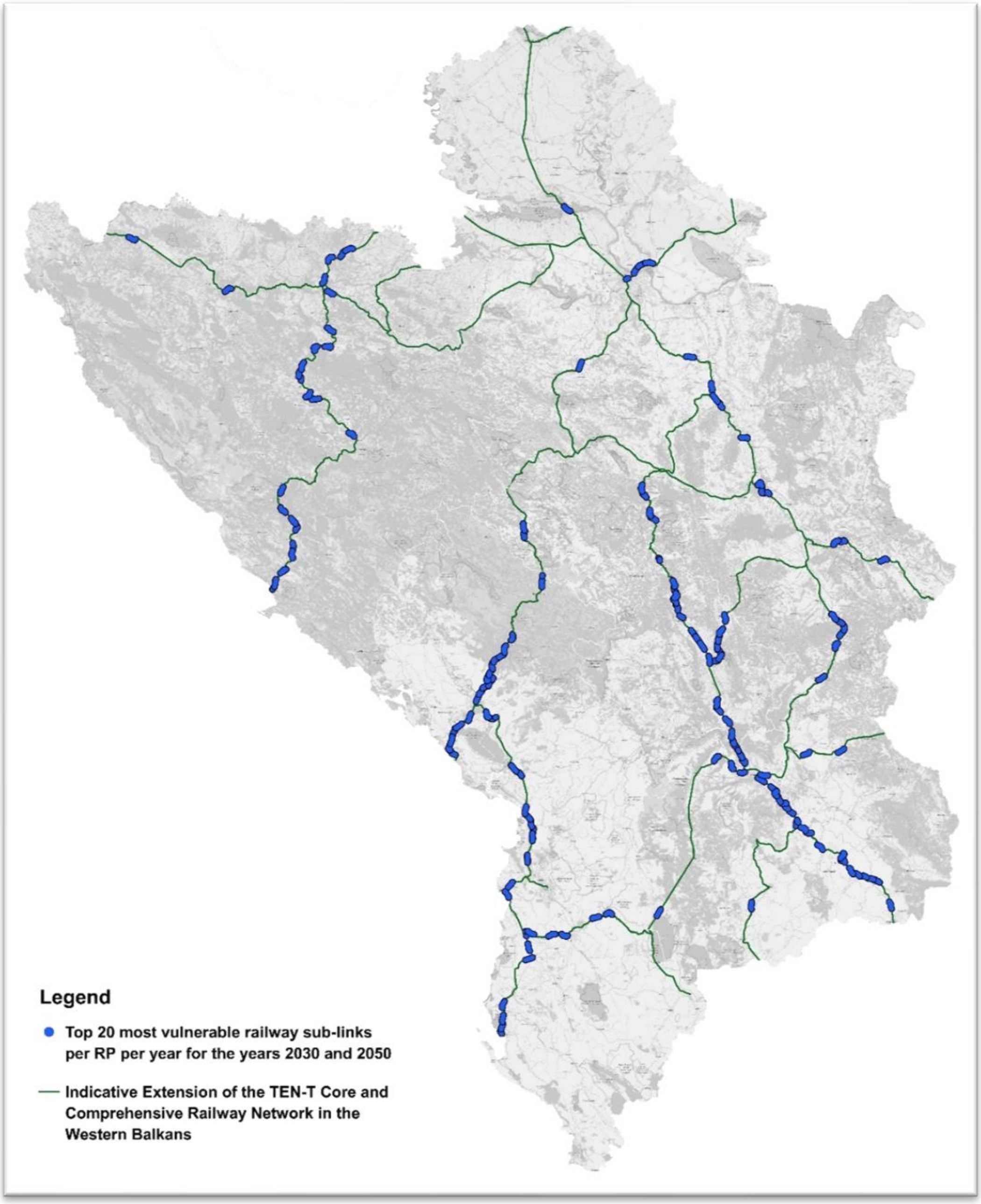


Figure 19 Top 20 most vulnerable railway sections in 2030 and top 20 most vulnerable railway sections in 2050

Conclusions

4. Concluding remarks

The assignment's overall findings indicate the Region's significant vulnerability to climate change and the need for enhancement. This has been confirmed by both, developed models for near and far climate projections (Figure 20) and actual road and railway conditions reported during the workshops by RPs' stakeholders.

When assessing the networks by link definition it seems that in 2030 both rails and roads are to face considerable coverage of high and very high vulnerability to hazards. Very high and high vulnerability classes combined will affect up to 43.5% or 1743 km of railway network and 44% or 2323 km of roads. The multi-hazard approach (Figure 20) somewhat conceals the local influences and highlights the areas affected by multiple hazards, but in reality, a single hazard can do as much damage. In 2050 projection the links will not be as much affected by multiple hazards, but within, as indicated before, a single hazard type can become crucial.

The sub-link network definition reveals considerable overestimation that is introduced in the link case. As much as 25% of rails and 19% of roads are covered with high and very high vulnerability classes in the first climate projection (2030), which are maintained in the second (2050). In the railway case, the proportions between very high and high classes remain more-or-less constant, whereas a significant change is evident in proportions between these classes in the roads case.

In the case of the road network, a drop in exposure to all hazards combined is evident in 2050 in comparison to 2030. The primary bias that distorts expected increase is likely the increase of temperature (due to GHGE) which affects two major hazards that, landslides and snowdrifts. Higher temperatures inevitably reduce the snow cover extent in 2050, meaning that snowdrift is likely to be reduced with time. Besides snow, the high temperatures increase indirectly affects the landslides, as it causes an overall drop of rainfall.

The overlap between 2030 and 2050 multi-hazard estimation shows steady trends, indicating that about 40 to 50% of the road and rail network will keep the same vulnerability class in 2050 as in 2030. The remaining percentage is mainly exhibiting decrease of vulnerability class by one order of magnitude, rarely two.

However, the assessment's limitations concerning future conditions, particularly hazards and climate, are noteworthy. While global trends align with increased daily temperatures, reduced annual precipitation, and rising sea levels due to GHGE, most hazards are linked to local rather than global trends. These hazards do not necessarily correlate with averaged climate conditions and their parameters, on contrary. Even though the drop of average rainfall is on course, the sudden and extreme variations of precipitation are by far more influential on landslides, floods, and all other relevant hazards. Unfortunately, we cannot look that far into future when these extreme conditions are in question, and we can only base our models on averaged parameter projections, for now.

When breaking down multi-hazards into five constitutive types, it can be generalized that the flood vulnerability is expected to slightly increase in 2050 compared to the 2030 scenario. As said, the landslide hazards are more prone to localized effects, but the patterns of local increase are clear (mountainous and remote areas are most prone). The hazard seems to slightly increase in 2050. The sea surge hazard is localized in RPs connected to the sea and isn't as prevalent as other hazards.

Figure 20 Road and railway network vulnerability class distribution (very low – dark green, low – light green, moderate – yellow, high – orange, very high - red) for 2030 (inner circle) and 2050 (outer circle) for link and sub-link network definition, based on multi-hazard (combined all five hazard types).

Next steps

After discussions, the proposed steps aim to support RPs in integrating activities related to climate-resilient transport infrastructure into their daily operations.

Raising awareness

There's been institutional progress in raising awareness about the impact of climate change on the transportation infrastructure. However, more efforts are required to ensure that all decisions and procedures align with the sector's actual needs. One of the steps would involve presenting the study to the technical and operational personnel of the Authorities.

Procedural issues

Integrating climate change-related requirements into the design stage procedures is crucial to enhance preparedness.

Downscaling of study results to the level of single RPs

Further developing the vulnerability assessment model for each specific RP. Explore how the vulnerability and criticality assessments, adaptation measures, and other outcomes presented in the workshops can be practically applied in the ongoing projects and future planning of road and railway infrastructure. Recognize the specific concerns raised by participants from Montenegro, Bosnia and Herzegovina, Kosovo, and other regions regarding the applicability of the study results to their local conditions. Consider developing more localized models and analyses to address region-specific hazards. To validate results, additional input data is essential. Exploring the option of continuously integrating operational data into the model could provide real-time updates, facilitating comprehensive and timely analyses.

Project Extension or Follow-Up Initiatives

Evaluate the possibility of extending the project scope or initiating follow-up projects to address specific concerns raised during the workshops. This could involve more in-depth studies in certain regions or additional training sessions.

Dissemination of Workshop Outcomes

Share the workshop outcomes with a broader audience, including relevant ministries, institutions, and organizations involved in transportation infrastructure planning. This can be done through publications, presentations, or targeted dissemination efforts.

List of Abbreviations

Abbreviation list	Meaning
AoI	Area of Interest
D	Deliverable
EU	European Union
EUR	Euro
Exp	Exposure
GHGE	Green House Gass Emission
GIS	Geographic Information System
H	High
ICJ	International Court of Justice
IR	Inception Report
KE	Key Expert
KoM	Kick off Meeting
L	Low
M	Medium
MoM	Minutes of Meeting
PD	Project Director
PM	Project Manager
RP	Regional Party
Sen	Sensitivity
SSMS	Sustainable and Smart Mobility Strategy
TA	Technical Assistance
TCT	Transport Community Treaty Permanent Secretariat
TL	Team Leader
ToR	Terms of Reference
UNSCR	United Nations Security Council resolution
VH	Very High
VL	Very Low
VOC	Vehicle operation costs
VoT	Value of time
Vul	Vulnerability
WB	Western Balkan

Appendices

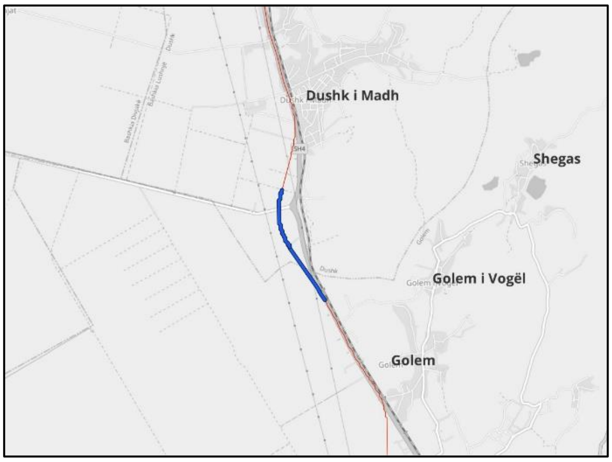
Appendix A

The top 10 ranked critical sections

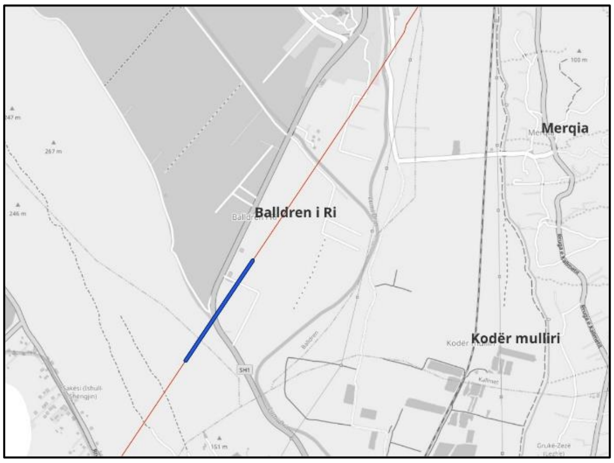
A.1 Road Sections

A.1.1 Albania

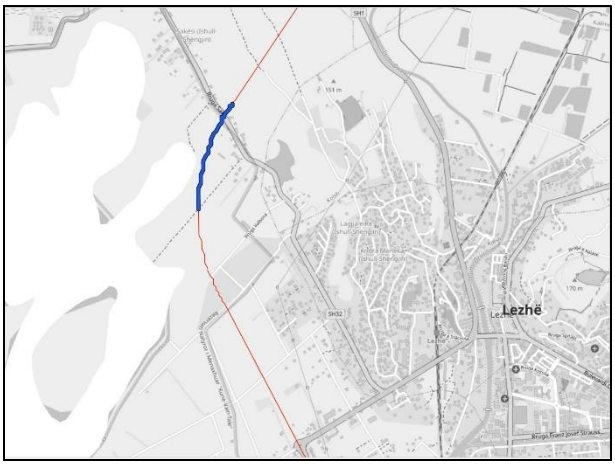
The top 10 ranked critical road sections in Albania are presented in the following figures:



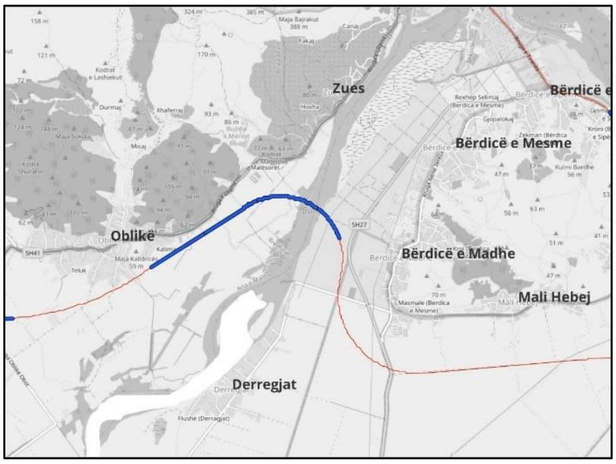
Rank 1 - Rrogozhine – Lushnje, Corridor VIII



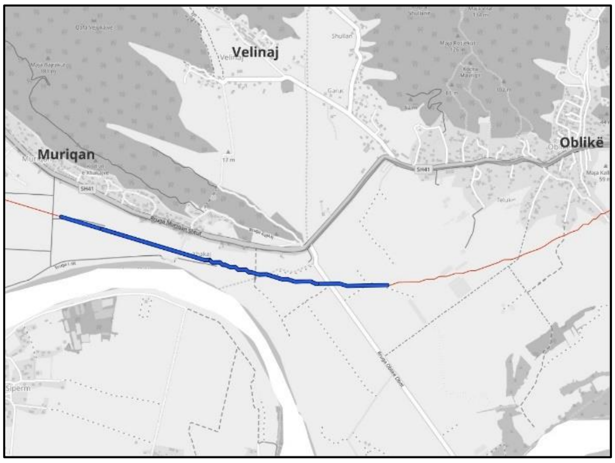
Rank 2 - Shkoder – Lezhe, Route 2b



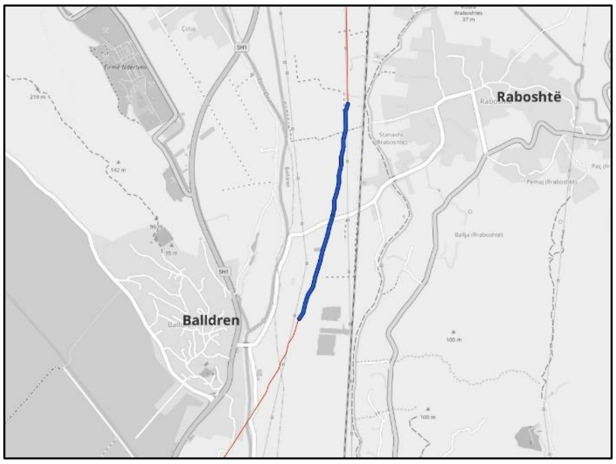
Rank 3 - Shkoder – Lezhe, Route 2b



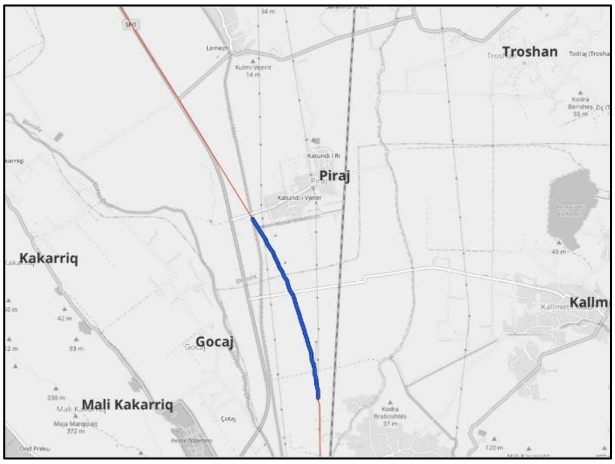
Rank 4 - BCP Muriqan - Lezhe, Route 1



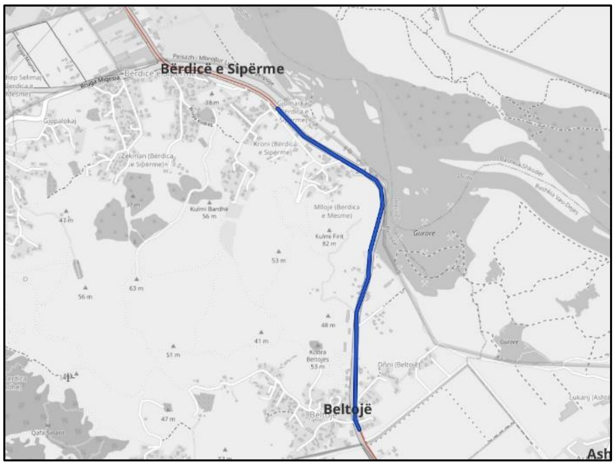
Rank 5 - BCP Muriqan - Lezhe, Route 1



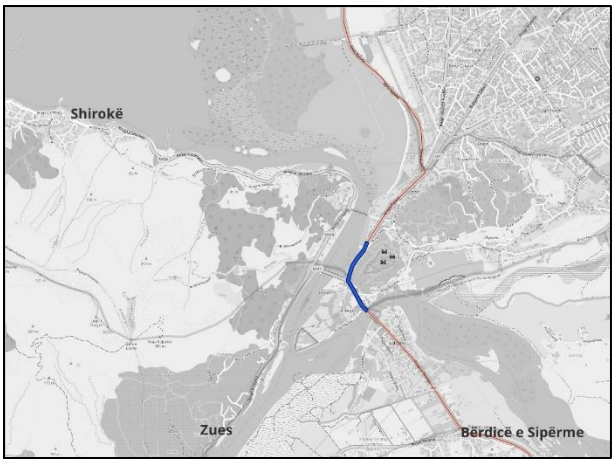
Rank 6 - Shkoder – Lezhe, Route 2b



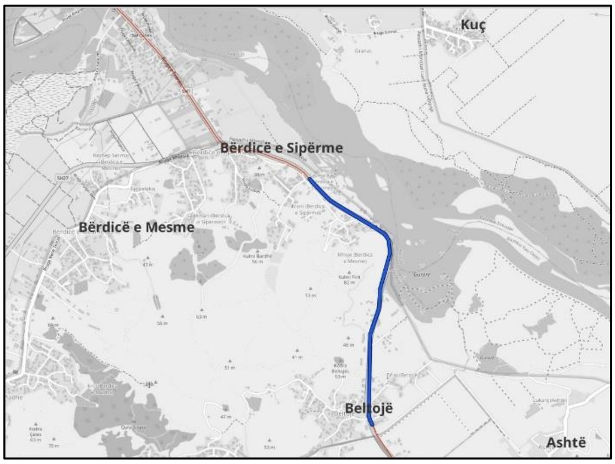
Rank 7 - Shkoder – Lezhe, Route 2b



Rank 8 - Shkoder – Lezhe, Route 2b



Rank 9 - Shkoder – Lezhe, Route 2b



Rank 10 - Shkoder – Lezhe, Route 2b

In the next table, investment cost[7] for road sections are represented for RP Albania.

[7] **Assumptions related to investment cost tables:**

1. Length of sub links within vulnerable sections are used for the assessment of road length highly exposed to hazard
2. Correction factors are applied to different hazard types when assessing road affected length (if couldn't been measured from maps):
   - 0.4 for landslide
   - 0.8 for flood and sea surge
   - 0.8 for snow drift
3. Singular scenario has been formulated to estimate landslide investments, consolidating diverse remediation measures' average costs, while there are five scenarios for floods and one for snow drift.
4. Temperature rise related measures are treated as distinct components of maintenance expenses and are not encompassed within of investment costs.

Legend for adaptation measures (AM) scenario:

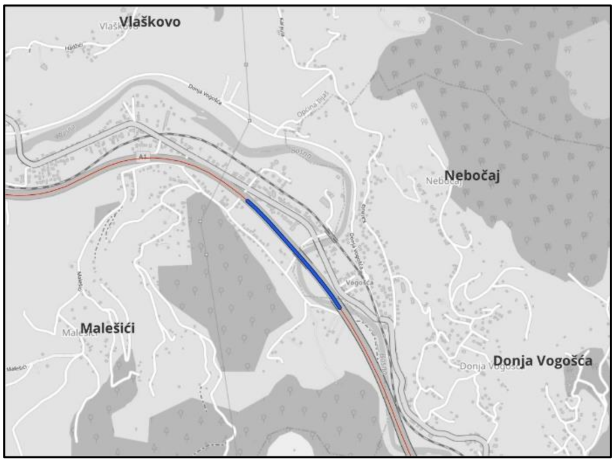
L -landslide, F - flood, T - temperature, S – snow drift

Table 1 Investment cost (road) outcomes for RP Albania

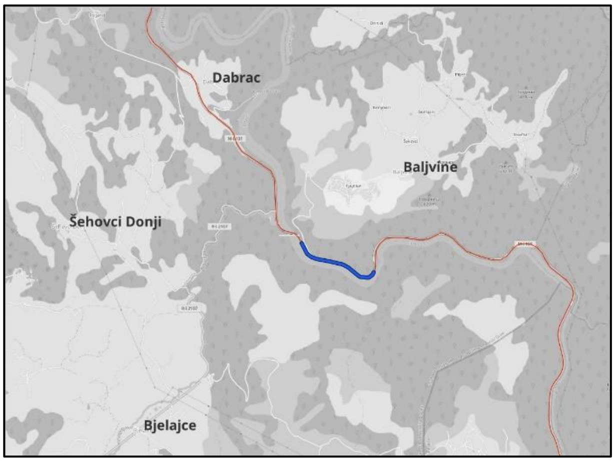
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Rrogozhine – Lushnje	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**1,780,640**
		S	0.718	0.8	100,000	**57,440**	
Rank 2: Shkoder – Lezhe	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**1,723,200**
Rank 3: Shkoder – Lezhe	2.154	F1	2.154	0.8	3,000,000	**5,169,600**	**5,169,600**
Rank 4: BCP Muriqan - Lezhe	1.436	F3	1.436	0.8	4,200,000	**4,824,960**	**4,939,840**
		S	1.436	0.8	100,000	**114,880**	
Rank 5: BCP Muriqan - Lezhe	2.154	F3	2.5	1	4,200,000	**10,500,000**	**10,500,000**
Rank 6: Shkoder – Lezhe	2.154	F3	2.154	1	4,200,000	**9,046,800**	**9,046,800**
Rank 7: Shkoder – Lezhe	0.718	F3	2	1	4,200,000	**8,400,000**	**8,716,000**
		L	0.1	1	3,160,000	**316,000**	
Rank 8: Shkoder – Lezhe	0.718	F3	1	1	4,200,000	**4,200,000**	**4,200,000**
Rank 9: Shkoder – Lezhe	1.436	F3	2.1	1	4,200,000	**8,820,000**	**8,820,000**
Rank 10: Shkoder – Lezhe	2.154	F3	2.9	1	4,200,000	**12,180,000**	**12,180,000**

A.1.3 Bosnia and Herzegovina

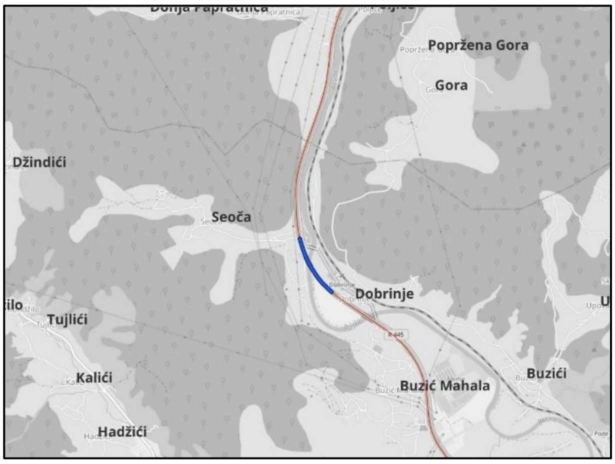
The top 10 ranked critical road sections in Bosnia and Herzegovina are presented in the following figures:



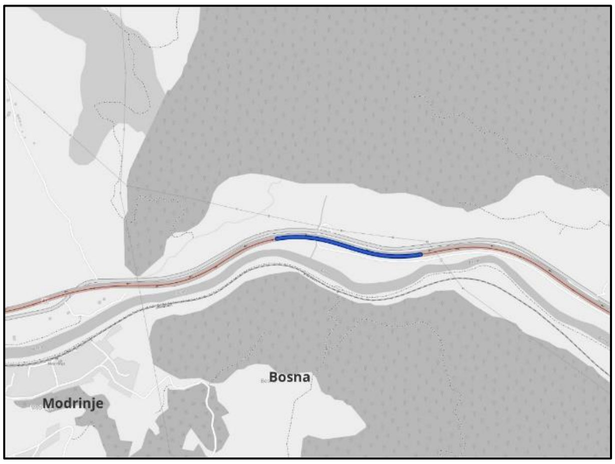
Rank 1: Josanica – Semizovac, Route 2b



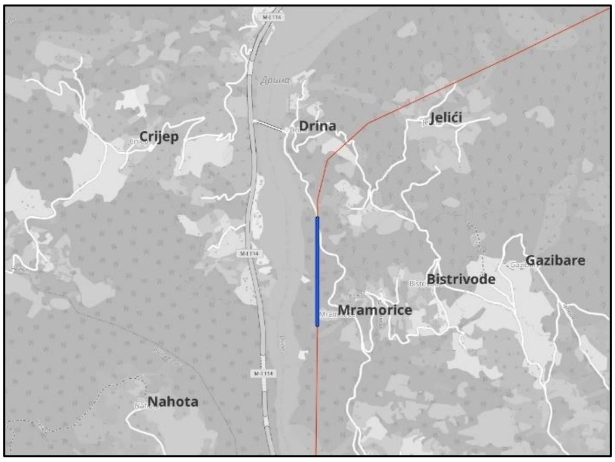
Rank 2: Banja Luka - Jajce, Route 2a



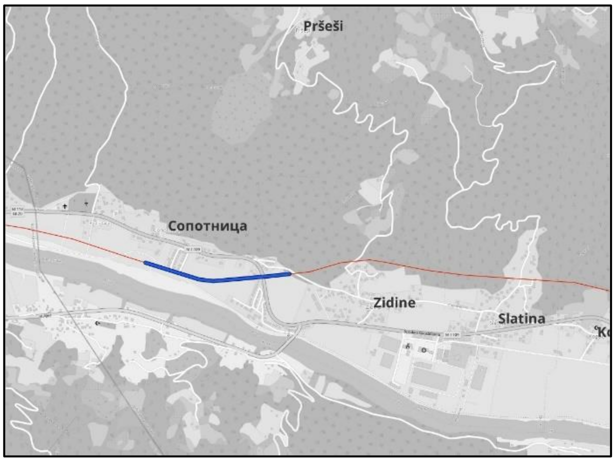
Rank 3: Lasva - Visoko, Corridor



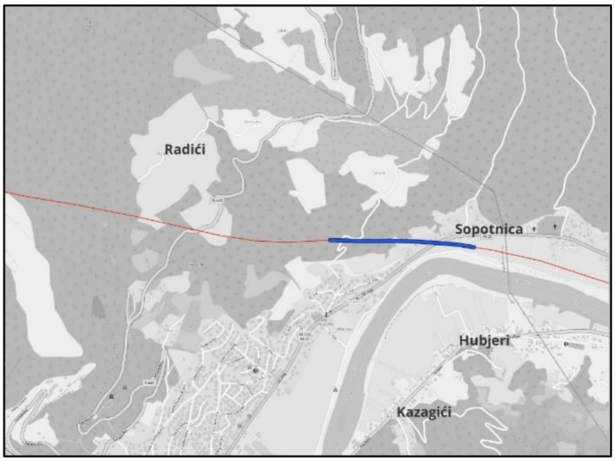
Rank 4: Lasva - Visoko, Corridor Vc



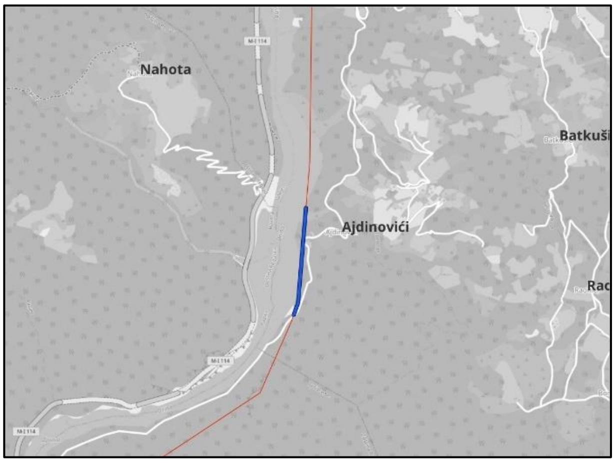
Rank 5: Ustipraca - Medjedja, Route 3



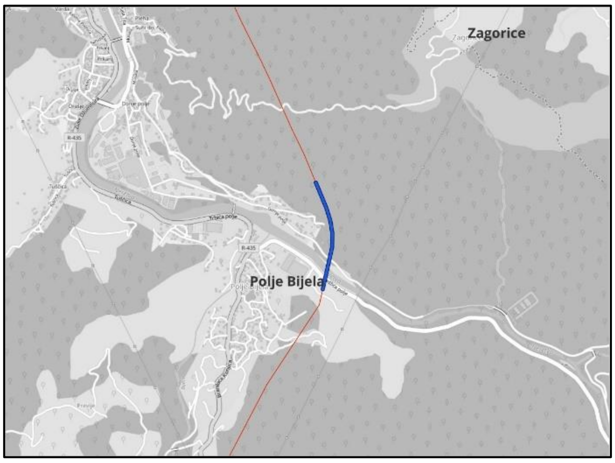
Rank 6: Mesici - Ustipraca, Route 3



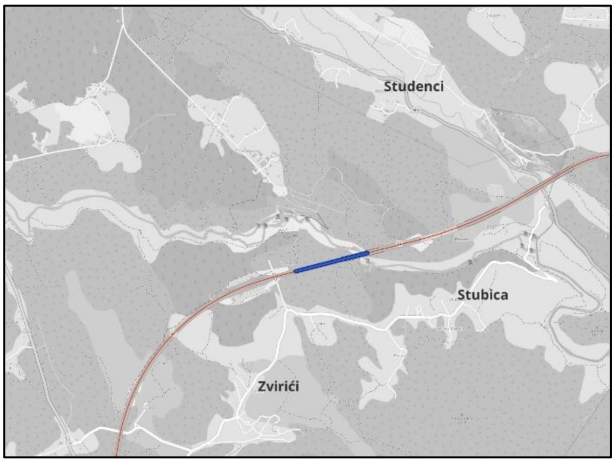
Rank 7: Mesici - Ustipraca, Route 3



Rank 8: Ustipraca - Medjedja, Route 3



Rank 9: Tarcin - Konjic, Corridor Vc



Rank 10: Capljina - Doljani, Corridor Vc

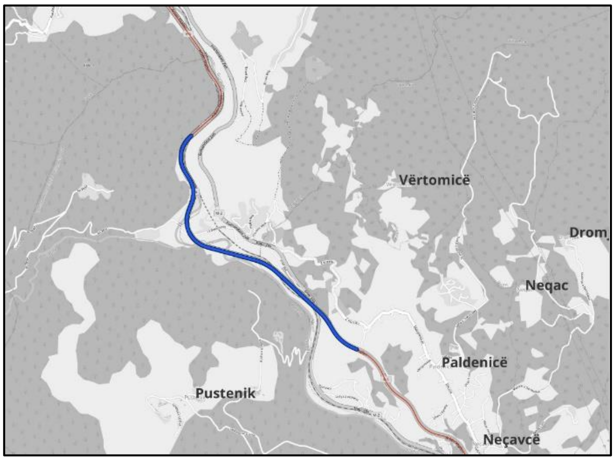
In the next table, investment cost[7] for road sections are represented for RP Bosnia and Herzegovina.

Table 2 Investment cost (road) outcomes for RP Bosnia and Herzegovina

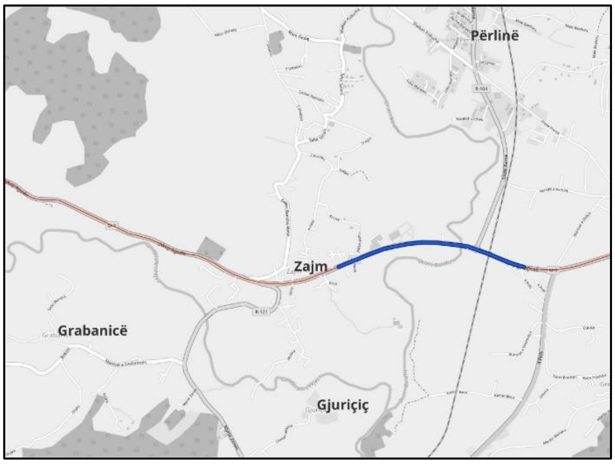
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Josanica – Semizovac	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**2,025,717**
		L	0.239	0.4	3,160,000	**302,517**	
Rank 2: Banja Luka - Jajce	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**1,723,200**
Rank 3: Lasva - Visoko	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**2,176,976**
		L	0.359	0.4	3,160,000	**453,776**	
Rank 4: Lasva - Visoko	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**2,267,731**
		L	0.431	0.4	3,160,000	**544,531**	
Rank 5: Ustipraca - Medjedja	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**1,995,466**
		L	0.215	0.4	3,160,000	**272,266**	
Rank 6: Mesici - Ustipraca	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**2,630,752**
		L	0.718	0.4	3,160,000	**907,552**	
Rank 7: Mesici - Ustipraca	0.718	F1	0.215	1	3,000,000	**646,200**	**646,200**
Rank 8: Ustipraca - Medjedja	1.436	F1	1.436	0.8	1,500,000	**1,723,200**	**2,630,752**
		L	1.436	0.4	1,580,000	**907,552**	
Rank 9: Tarcin - Konjic	0.718	L	0.718	0.4	3,160,000	**907,552**	**907,552**
Rank 10: Capljina - Doljani	0.718	F3	1.000	1	4,200,000	**4,200,000**	**4,200,000**

A.1.4 Kosovo

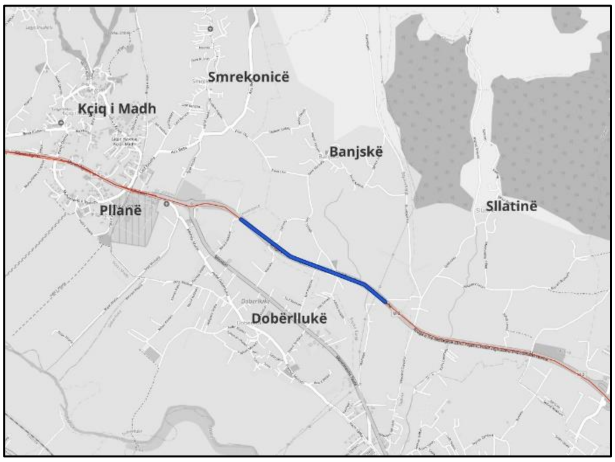
The top 10 ranked critical road sections in Kosovo are presented in the following figures:



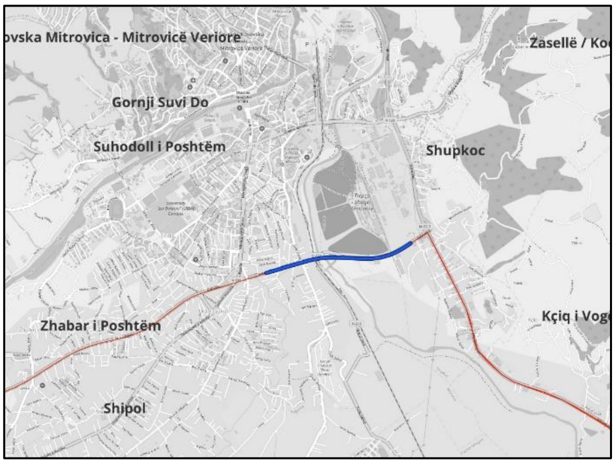
Rank 1: Kacanik – Jankovic (BCP Hani i Elezit), Route 6a



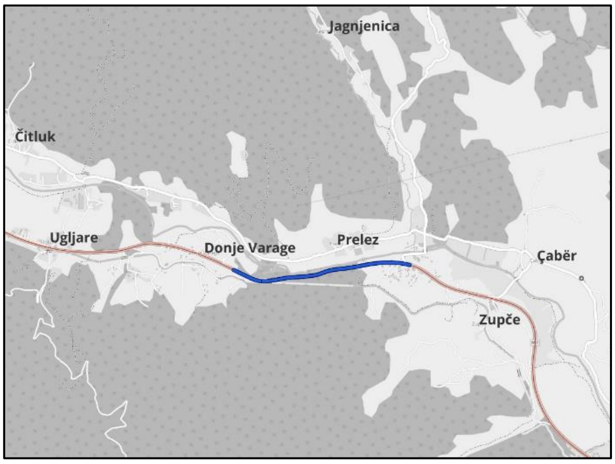
Rank 2: Klinavac - Glogovac, Route 6b



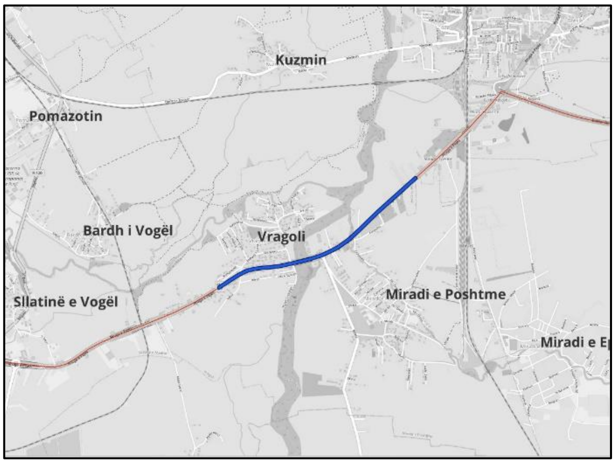
Rank 3: Kacanik – Jankovic (BCP Hani i Elezit), Route 6a



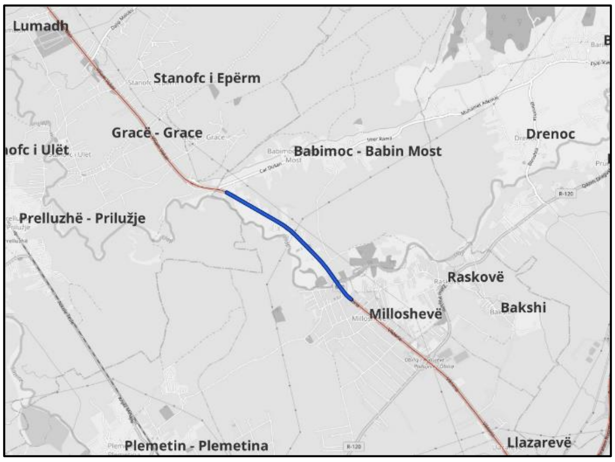
Rank 4: Mitrovica – Vucitrn (Pristina), Route 6a



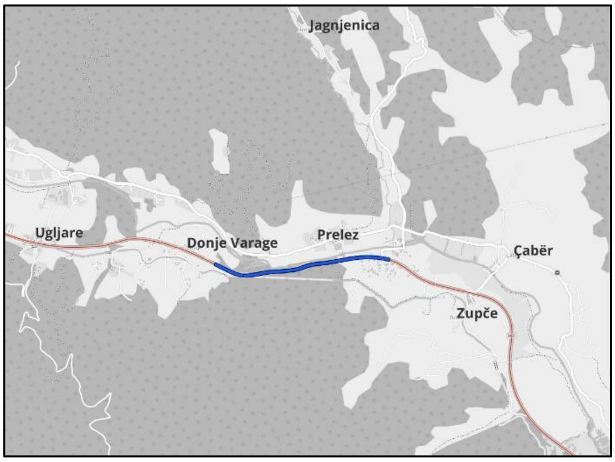
Rank 5: Banje - Mitrovica, Route 6a



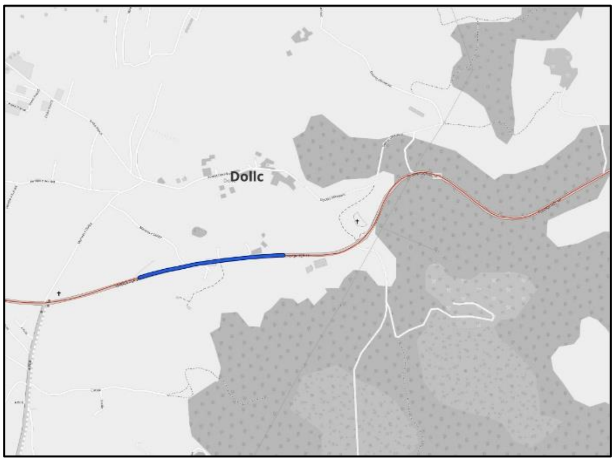
Rank 6: Pristina - Pec, Route 6b



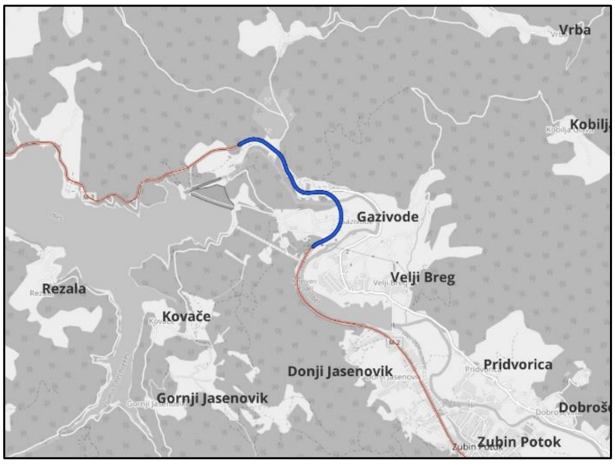
Rank 7: Vucitrn - Pristina, Route 6b



Rank 8: Banje - Mitrovica, Route 6a



Rank 9: Klinavac - Glogovac, Route 6b



Rank 10: Banje - Mitrovica, Route 6a

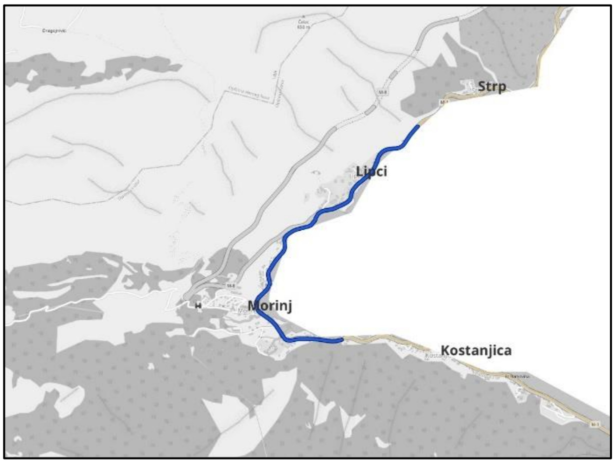
In the next table, investment cost[7] for road sections are represented for RP Kosovo.

Table 3 Investment cost (road) outcomes for RP Kosovo

Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Kacanik – Jankovic (BCP Hani i Elezit)	1.436	F1	1.436	0.8	1,500,000	**1,723,200**	**1,723,200**
Rank 2: Klinavac - Glogovac	1.436	F1	1.436	0.8	1,500,000	**1,723,200**	**2,630,752**
		L	1.436	0.4	1,580,000	**907,552**	
Rank 3: Kacanik – Jankovic (BCP Hani i Elezit)	0.718	T	0.718	1	n.a.	**n.a.**	**n.a**
Rank 4: Mitrovica – Vucitrn (Pristina)	2.154	F1	2.154	1	3,000,000	**6,462,000**	**6,462,000**
Rank 5: Banje - Mitrovica	2.154	F1	1.077	0.8	3,000,000	**2,584,800**	**3,401,597**
		L	0.6462	0.4	3,160,000	**816,797**	
Rank 6: Pristina - Pec	2.154	F1	2.154	0.8	1,500,000	**2,584,800**	**2,584,800**
Rank 7: Vucitrn - Pristina	1.436	F1	1.436	0.8	3,000,000	**3,446,400**	**3,446,400**
Rank 8: Banje - Mitrovica	1.436	F2	2.5	1	10,000,000	**25,000,000**	**25,000,000**
Rank 9: Klinavac - Glogovac	2.154	F1	2.154	0.8	3,000,000	**5,169,600**	**5,169,600**
Rank 10: Banje - Mitrovica	1.436	L	1.149	0.4	3,160,000	**1,452,083**	**1,452,083**

A.1.5 Montenegro

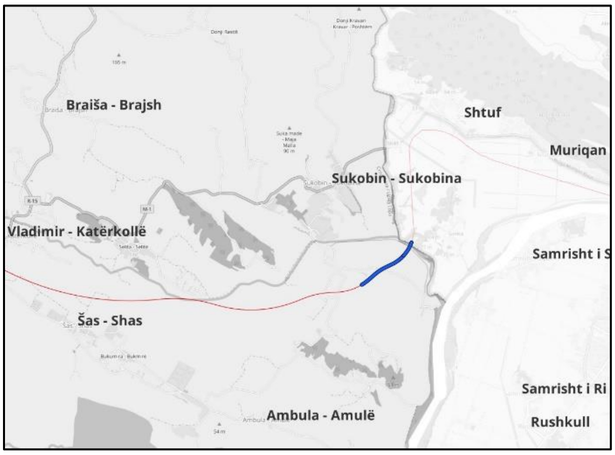
The top 10 ranked critical road sections in Montenegro are presented in the following figures:



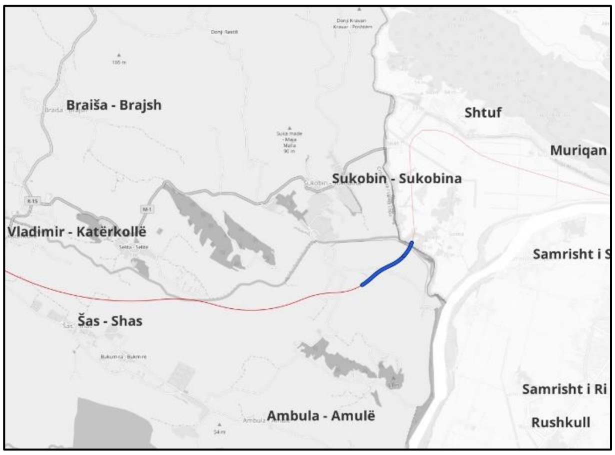
Rank 1: Kamenari - Raskrsnica E65 (Lipci), Route 1

Rank 2: Podgorica - Tuzi, Route 2b

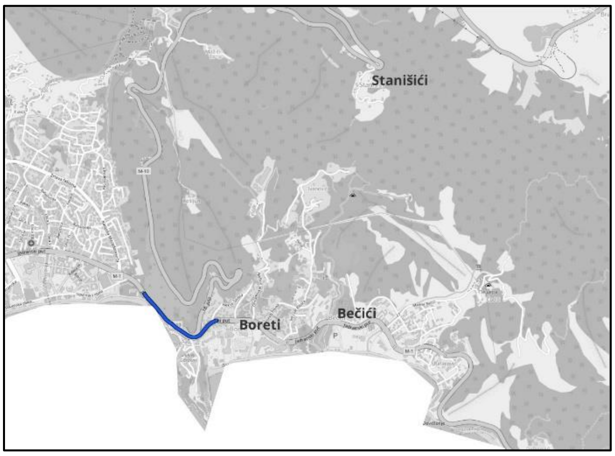
Rank 3: Raskrsnica E65 (Lipci) – Tivat (Kotor), Route 1



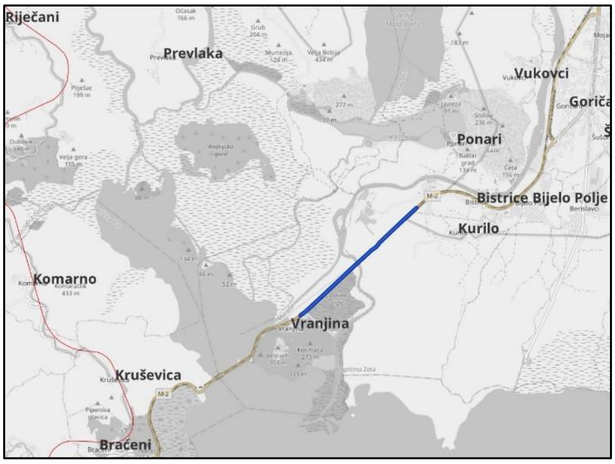
Rank 4: Bar – BCP Sukobin, Route 1



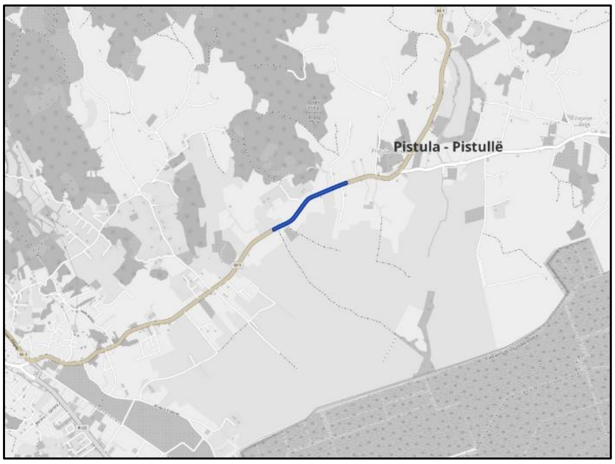
Rank 5: Bar – BCP Sukobin, Route 1



Rank 6: Budva - Petrovac, Route 1

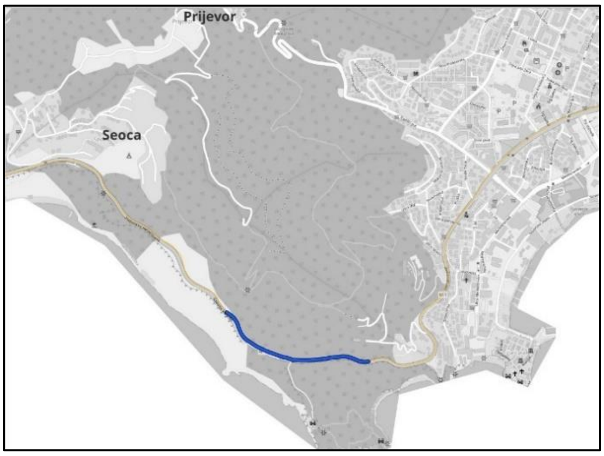


Rank 7: Podgorica - Virpazar, Route 4



Rank 8: Bar – BCP Sukobin, Route 1

Rank 9: Podgorica - Tuzi, Route 2b



Rank 10: Tivat (Airport) - Budva, Route 1

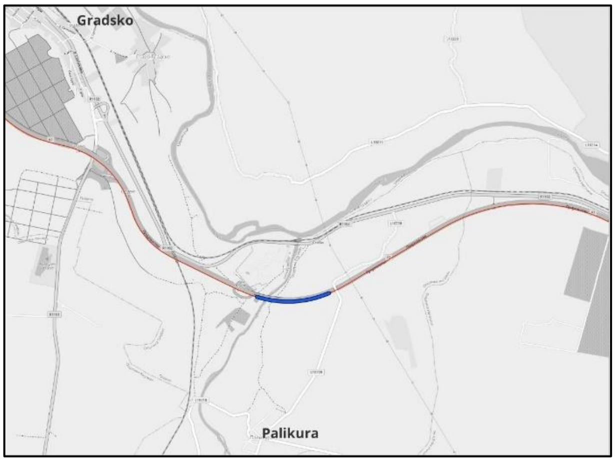
In the next table, investment cost[7] for road sections are represented for RP Montenegro.

Table 4 Investment cost (road) outcomes for RP Montenegro

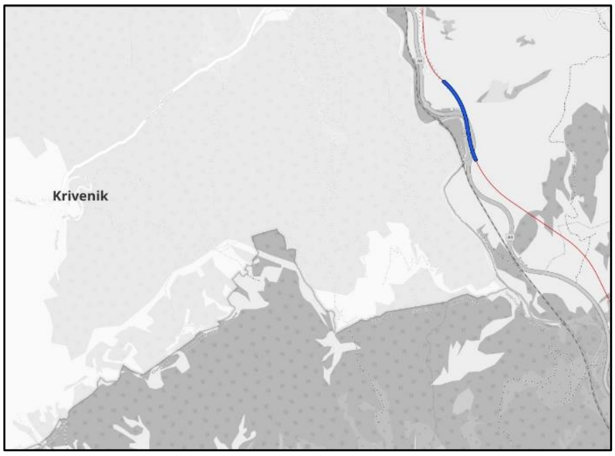
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Kamenari - Raskrsnica E65 (Lipci)	0.718	T	0.718	1	n.a.	**n.a.**	**n.a**
Rank 2: Podgorica - Tuzi	0.718	T	0.718	1	n.a.	**n.a.**	**n.a**
Rank 3: Raskrsnica E65 (Lipci) – Tivat (Kotor)	0.718	L	0.479	0.4	3,160,000	**605,035**	**605,035**
Rank 4: Bar – BCP Sukobin	3.59	F4	3.590	4.2	4,000,000	**60,312,000**	**60,312,000**
Rank 5: Bar – BCP Sukobin	2.872	F5	2.872	1	4,000,000	**11,488,000**	**12,758,573**
		L	2.010	0.4	1,580,000	**1,270,573**	
Rank 6: Budva - Petrovac	1.436	F5	0.479	0.8	4,000,000	**1,531,733**	**1,531,733**
Rank 7: Podgorica - Virpazar	0.718	F1	0.718	0.8	1,500,000	**861,600**	**919,040**
		S	0.718	0.8	100,000	**57,440**	
Rank 8: Bar – BCP Sukobin	0.28	F3	0.700	1	4,200,000	**2,940,000**	**2,940,000**
Rank 9: Podgorica - Tuzi	0.718	F3	1.200	1	4,200,000	**5,040,000**	**5,040,000**
Rank 10: Tivat (Airport) - Budva	2.154	F5	1.436	1	4,000,000	**5,744,000**	**5,744,000**

A.1.6 North Macedonia

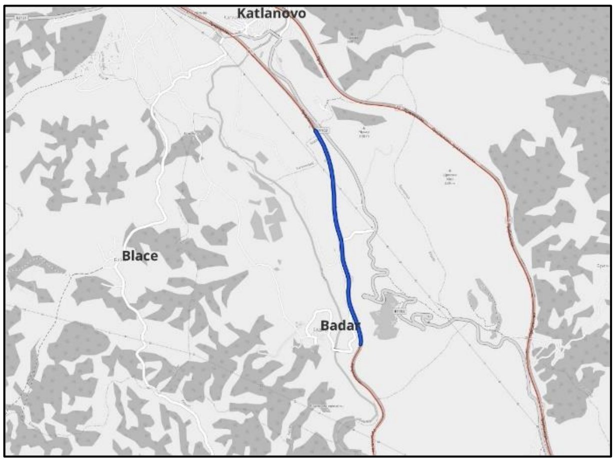
The top 10 ranked critical road sections in North Macedonia are presented in the following figures:



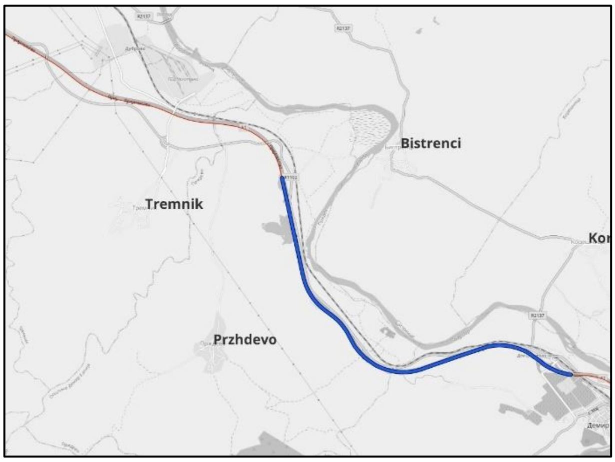
Rank 1: Gradsko - Negotino, Corridor X



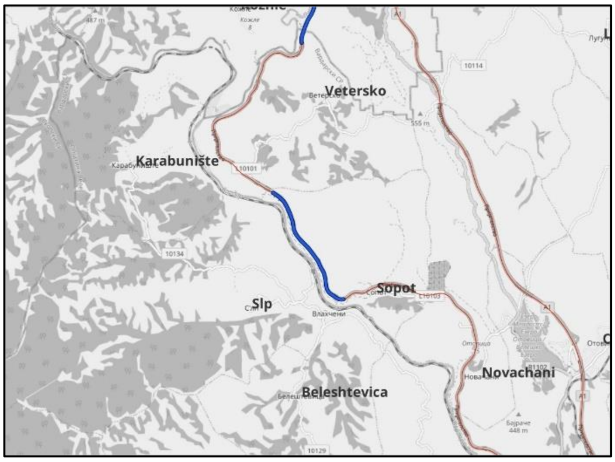
Rank 2: Blace – Stenkovac (Skopje), Route 6a



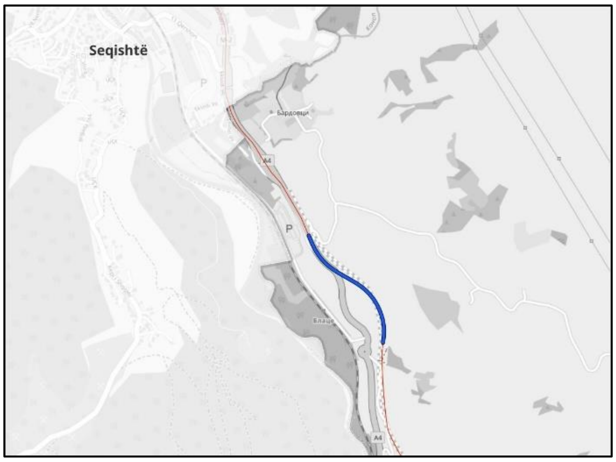
Rank 3: Miladinovci (Skopje) - Veles, Corridor X



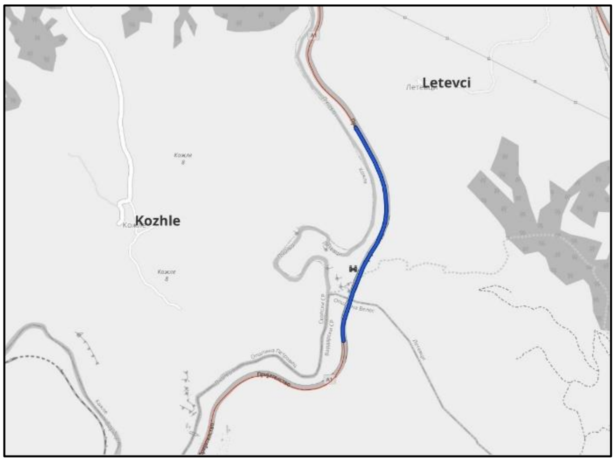
Rank 4: Negotino – Demir Kapija, Corridor X



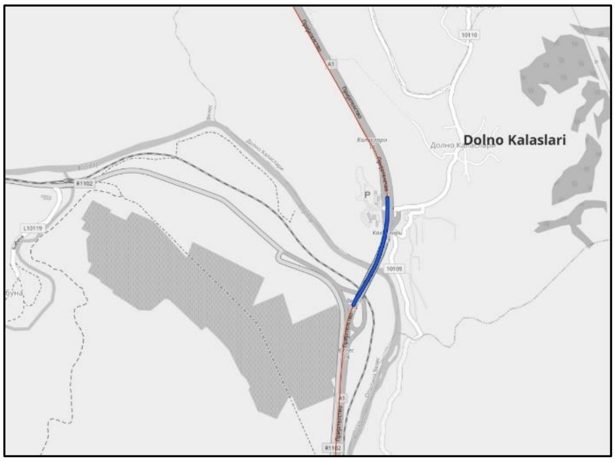
Rank 5: Miladinovci (Skopje) - Veles, Corridor X



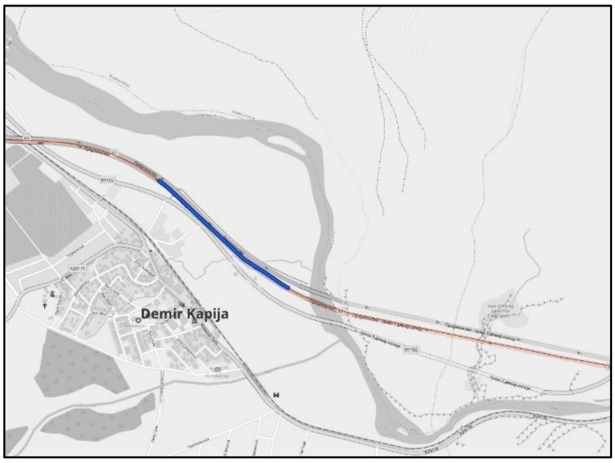
Rank 6: Blace – Stenkovac (Skopje), Route 6a



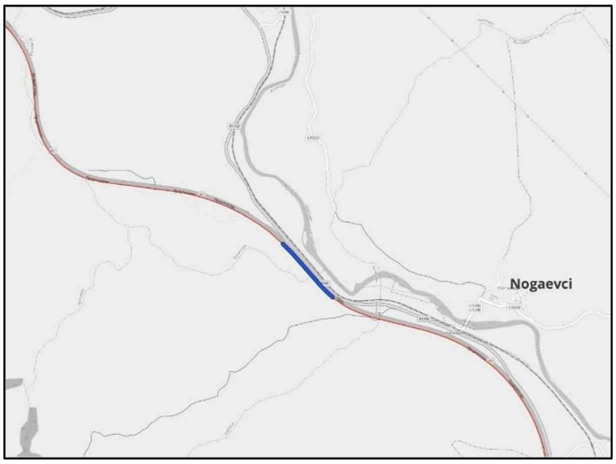
Rank 7: Miladinovci (Skopje) - Veles, Corridor X



Rank 8: Veles - Gradsko, Corridor X



Rank 9: Demir Kapija - Udovo, Corridor X



Rank 10: Veles - Gradsko, Corridor X

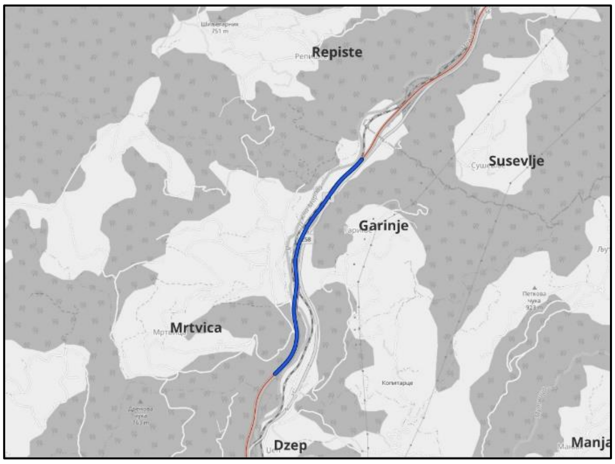
In the next table, investment cost[7] for road sections are represented for RP North Macedonia.

Table 5 Investment cost (road) outcomes for RP North Macedonia

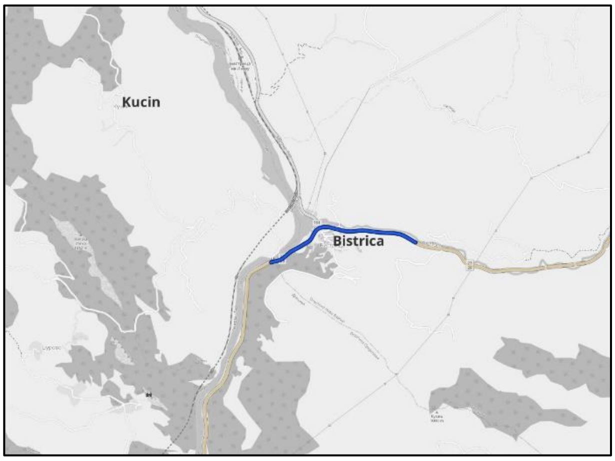
<table>
<tr><th>Section</th><th>Link length (km)</th><th>Adaptation measures scenario (L, F, T, S)</th><th>Highly exposed length (km)</th><th>Correction factor applied</th><th>Cost per 1 km (EUR)</th><th>Estimated Investment Cost per AM scenario (EUR)</th><th>Total Investment Cost (EUR)</th></tr>
<tr><td>Rank 1: Gradsko - Negotino</td><td>2.872</td><td>F1</td><td>2.872</td><td>0.8</td><td>1,500,000</td><td>3,446,400</td><td>3,446,400</td></tr>
<tr><td>Rank 2: Blace – Stenkovac (Skopje)</td><td>1.436</td><td>F4</td><td>1.700</td><td>1</td><td>4,000,000</td><td>6,800,000</td><td>6,800,000</td></tr>
<tr><td>Rank 3: Miladinovci (Skopje) - Veles</td><td>2.154</td><td>F</td><td>2.154</td><td>0.8</td><td>1,500,000</td><td>2,584,800</td><td>2,584,800</td></tr>
<tr><td rowspan="2">Rank 4: Negotino – Demir Kapija</td><td rowspan="2">0.718</td><td>F1</td><td>0.718</td><td>0.8</td><td>3,000,000</td><td>1,723,200</td><td rowspan="2">2,630,752</td></tr>
<tr><td>L</td><td>0.718</td><td>0.4</td><td>3,160,000</td><td>907,552</td></tr>
<tr><td rowspan="2">Rank 5: Miladinovci (Skopje) - Veles</td><td rowspan="2">0.718</td><td>F1</td><td>0.718</td><td>0.8</td><td>3,000,000</td><td>1,723,200</td><td rowspan="2">2,630,752</td></tr>
<tr><td>L</td><td>0.718</td><td>0.4</td><td>3,160,000</td><td>907,552</td></tr>
<tr><td>Rank 6: Blace – Stenkovac (Skopje)</td><td>0.718</td><td>F1</td><td>0.718</td><td>0.8</td><td>3,000,000</td><td>1,723,200</td><td>1,723,200</td></tr>
<tr><td>Rank 7: Miladinovci (Skopje) - Veles</td><td>6.462</td><td>F4</td><td>7.000</td><td>1</td><td>8,400,000</td><td>58,800,000</td><td>58,800,000</td></tr>
<tr><td>Rank 8: Veles - Gradsko</td><td>0.718</td><td>F4</td><td>1.000</td><td>1</td><td>8,400,000</td><td>8,400,000</td><td>8,400,000</td></tr>
<tr><td>Rank 9: Demir Kapija - Udovo</td><td>0.718</td><td>F4</td><td>1.000</td><td>1</td><td>8,400,000</td><td>8,400,000</td><td>8,400,000</td></tr>
<tr><td>Rank 10: Veles - Gradsko</td><td>0.718</td><td>F4</td><td>1.000</td><td>1</td><td>8,400,000</td><td>8,400,000</td><td>8,400,000</td></tr>
</table>

A.1.7 Serbia

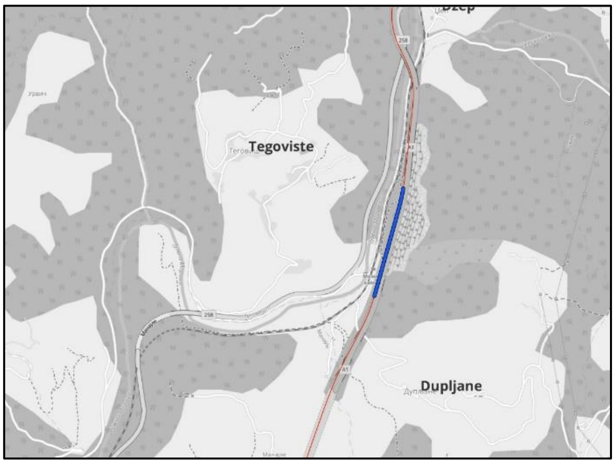
The top 10 ranked critical road sections in Serbia are presented in the following figures:



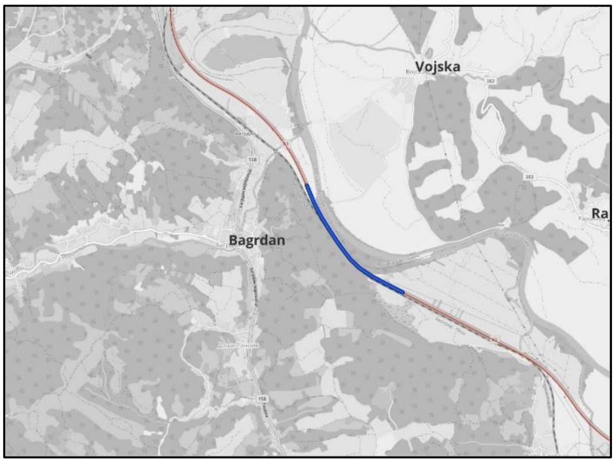
Rank 1: Grdelica – Vladicin Han, Corridor X



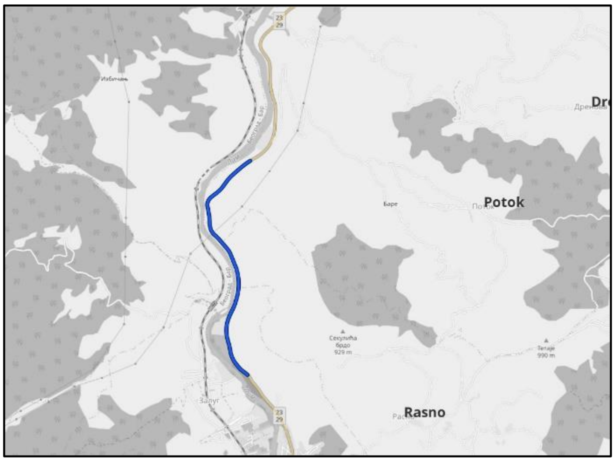
Rank 2: Bistrica - Prijepolje, Route 4



Rank 3: Grdelica – Vladicin Han, Corridor X

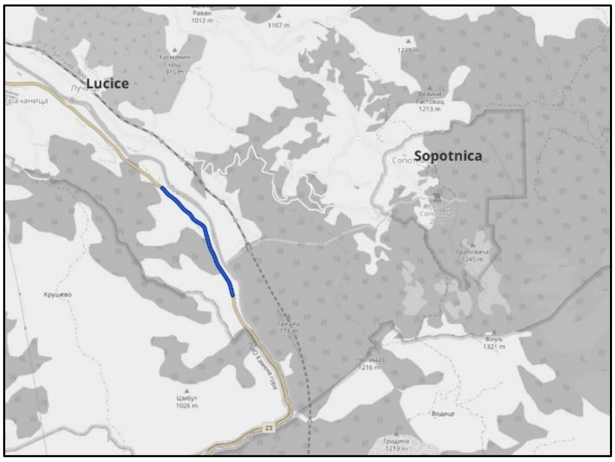


Rank 4: Nova Varos - Bistrica, Route 4

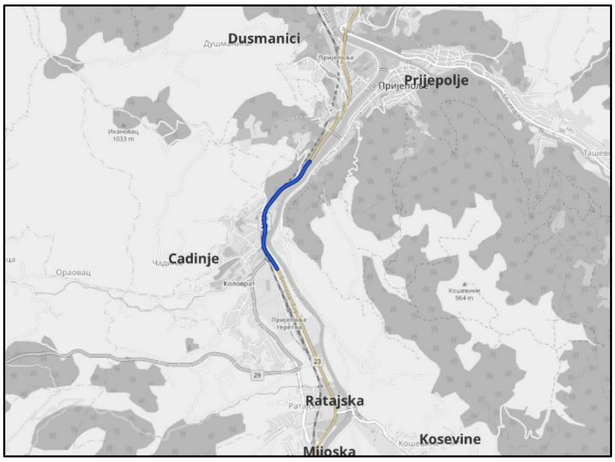


Rank 5: Batocina - Jagodina, Corridor X

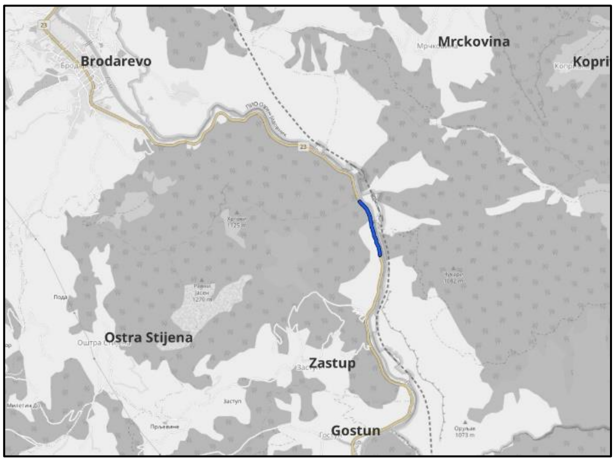
Rank 6: Bistrica - Prijepolje, Route 4



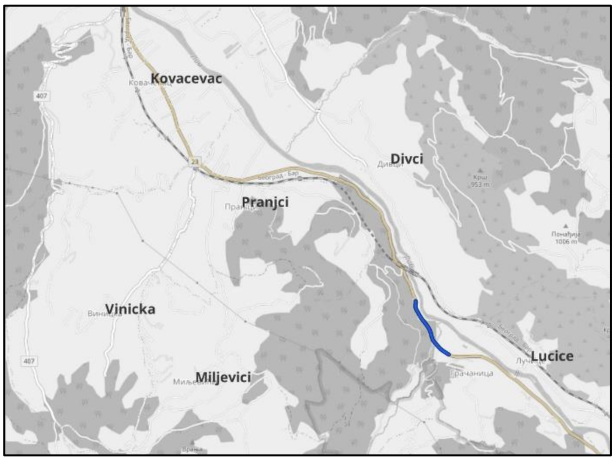
Rank 7: Velika Plana - Markovac, Corridor X



Rank 8: Prijepolje - Gostun, Route 4



Rank 9: Prijepolje - Gostun, Route 4



Rank 10: Prijepolje - Gostun, Route 4

In the next table, investment cost[7] for road sections are represented for RP Serbia.

Table 6 Investment cost (road) outcomes for RP Serbia

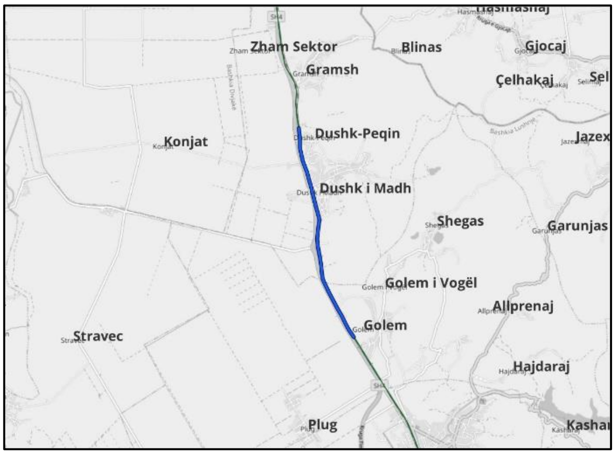
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Grdelica – Vladicin Han	2.872	L	1.436	0.4	1,580,000	**907,552**	**907,552**
Rank 2: Bistrica - Prijepolje	1.436	L	1.436	0.4	1,580,000	**907,552**	**907,552**
Rank 3: Grdelica – Vladicin Han	2.872	F2	1.436	1	20,000,000	**28,720,000**	**30,995,200**
		L	1.8	0.4	3,160,000	**2,275,200**	
Rank 4: Nova Varos - Bistrica	0.718	F1	0.718	0.8	3,000,000	**1,723,200**	**3,145,200**
		L	0.45	1	3,160,000	**1,422,000**	
Rank 5: Batocina - Jagodina	1.436	L	1.436	0.4	1,580,000	**907,552**	**907,552**
Rank 6: Bistrica - Prijepolje	0.718	L	0.718	0.4	1,580,000	**453,776**	**453,776**
Rank 7: Velika Plana - Markovac	0.718	L	0.4308	0.4	1,580,000	**272,266**	**272,266**
Rank 8: Prijepolje - Gostun	2.154	F1	2.154	0.8	3,000,000	**5,169,600**	**5,341,920**
		S	2.154	0.8	100,000	**172,320**	
Rank 9: Prijepolje - Gostun	1.436	F1	1.436	0.8	3,000,000	**3,446,400**	**3,561,280**
		S	1.436	0.8	100,000	**114,880**	
Rank 10: Prijepolje - Gostun	1.436	L	1.436	0.4	1,580,000	**907,552**	**907,552**

A.2 Rail Sections

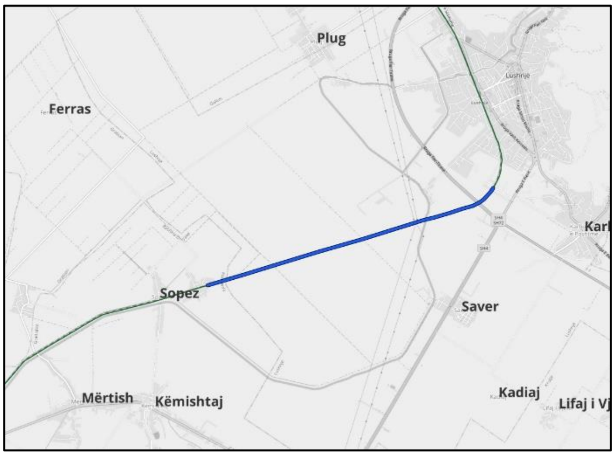
A.2.1 Albania

The top 10 ranked critical railway sections in Albania are presented in the following figures:

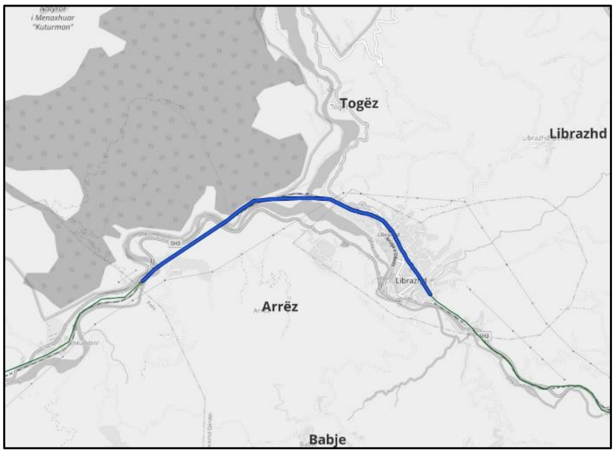
Rank 1: BCP Muriqan – Vore (Shkoder – Vore), Route 2



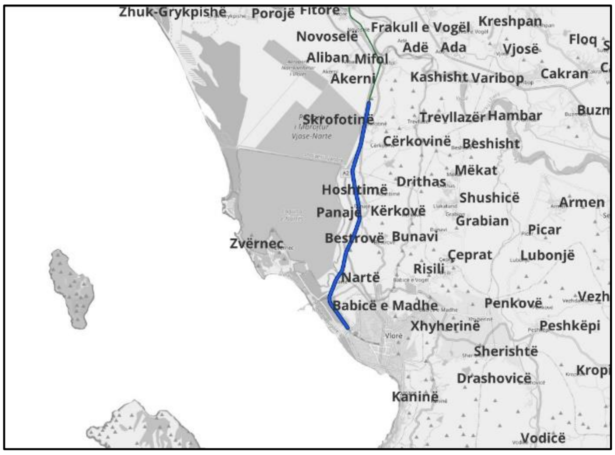
Rank 2: Rrogozhine - Vlore, Corridor VIII



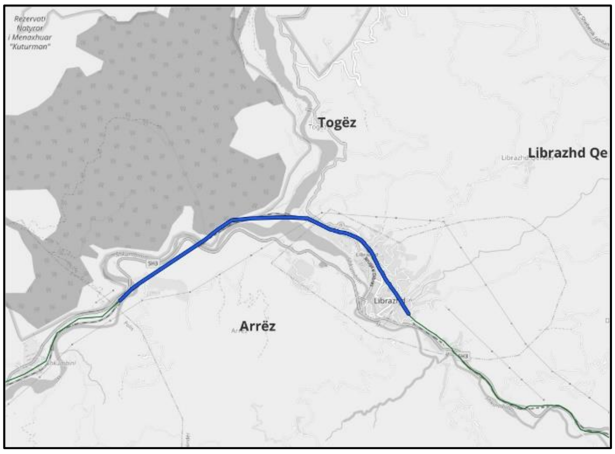
Rank 3: Rrogozhine - Vlore, Corridor VIII



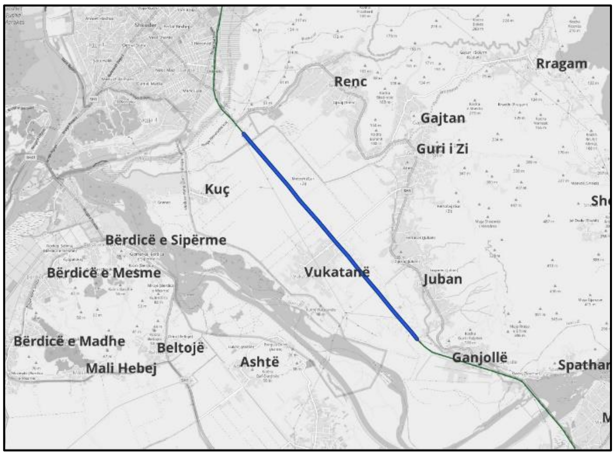
Rank 4: Rrogozhine - MKD Border (Elbasan – Lin), Corridor VIII



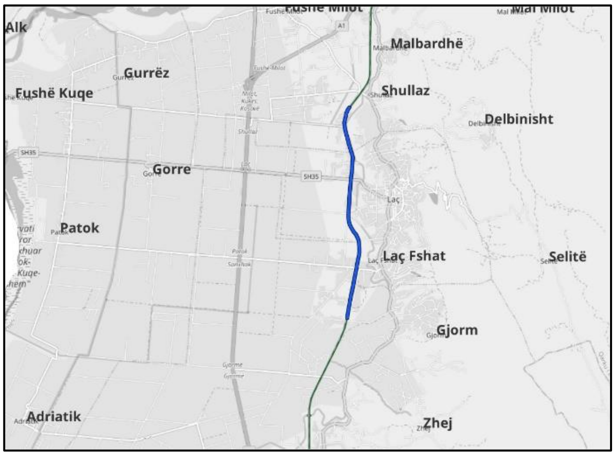
Rank 5: Rrogozhine - Vlore, Corridor VIII



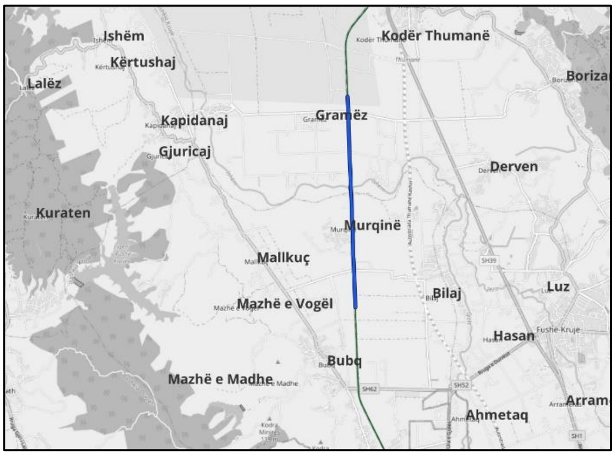
Rank 6: Rrogozhine - MKD Border (Rrogozhine – Elbasan), Corridor VIII



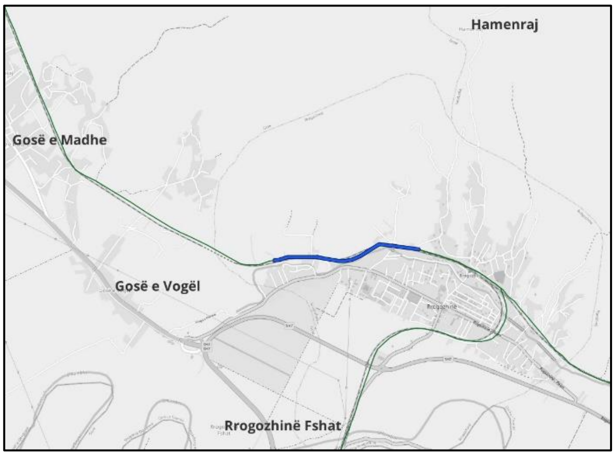
Rank 7: BCP Muriqan – Vore (Shkoder – Vore), Route 2



Rank 8: BCP Muriqan – Vore (Shkoder – Vore), Route 2



Rank 9: Tirana - Rrogozhine (Shkozet – Rrogozhine), Corridor VIII



Rank 10: Tirana – Rrogozhine, Corridor VIII

In the next table, investment cost[8] for rail sections are represented for RP Albania.

[8] **Assumptions related to investment cost tables:**

1. Length of sub links within vulnerable sections are used for the assessment of road length highly exposed to hazard
2. Correction factors are applied to different hazard types when assessing road affected length (if couldn't been measured from maps):
   - 0.4 for landslide
   - 0.8 for flood and sea surge
   - 0.8 for snow drift
3. Singular scenario has been formulated to estimate landslide investments, consolidating diverse remediation measures' average costs, while there are five scenarios for floods and one for snow drift.
4. Temperature rise related measures are treated as distinct components of maintenance expenses and are not encompassed within of investment costs.

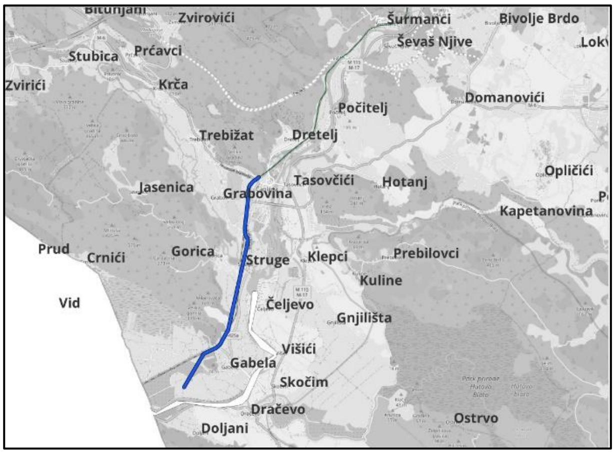
Legend for adaptation measures (AM) scenario:
L -landslide, F - flood, T - temperature, S – snow drift

Table 7 Investment cost (rail) outcomes for RP Albania

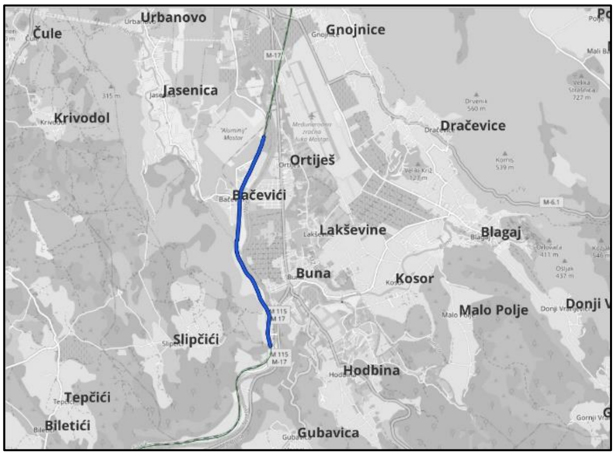
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: BCP Muriqan – Vore (Shkoder – Vore)	13.163	F4	9.872	1	5,200,000	**51,335,700**	**57,752,663**
		F1	3.291	1	1,950,000	**6,416,963**	
Rank 2: Rrogozhine - Vlore	3.59	F4	2.872	1	5,200,000	**14,934,400**	**16,334,500**
		F1	0.718	1	1,950,000	**1,400,100**	
Rank 3: Rrogozhine - Vlore	3.59	F4	3.590	0.8	5,200,000	**14,934,400**	**14,934,400**
Rank 4: Rrogozhine - MKD Border (Elbasan – Lin)	3.59	F4	2.992	1	5,200,000	**15,556,667**	**15,556,667**
Rank 5: Rrogozhine - Vlore	3.59	F5	3.590	1	5,200,000	**18,668,000**	**18,668,000**
Rank 6: Rrogozhine - MKD Border (Rrogozhine – Elbasan)	3.59	F5	3.590	1	5,200,000	**18,668,000**	**18,668,000**
Rank 7: BCP Muriqan – Vore (Shkoder – Vore)	3.59	F4	1.436	1	5,200,000	**7,467,200**	**10,857,309**
		F1	1.795	0.8	1,950,000	**2,800,200**	
		L	0.718	0.4	2,054,000	**589,909**	
Rank 8: BCP Muriqan – Vore (Shkoder – Vore)	10.77	F4	8.616	1	5,200,000	**44,803,200**	**44,803,200**
Rank 9: Tirana - Rrogozhine (Shkozet – Rrogozhine)	1.046	F1	1.046	1	1,950,000	**2,039,700**	**2,039,700**
Rank 10: Tirana – Rrogozhine	3.59	F4	0.898	1	5,200,000	**4,667,000**	**9,917,375**
		F1	2.693	1	1,950,000	**5,250,375**	

A.2.2 Bosnia and Herzegovina

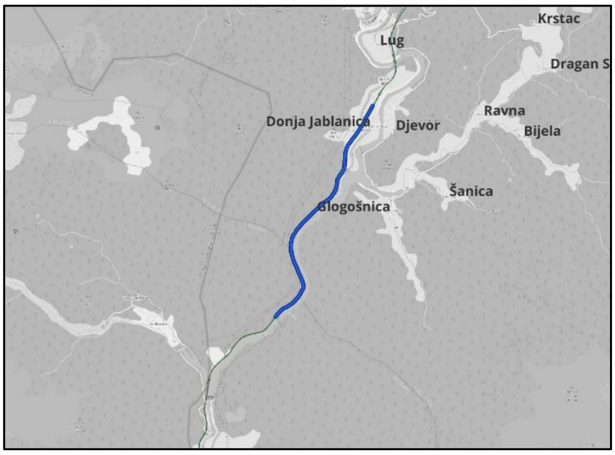
The top 10 ranked critical railway sections in Bosnia and Herzegovina are presented in the following figures:



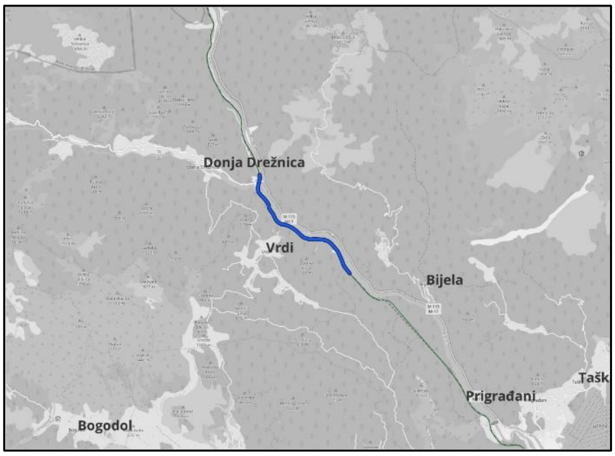
Rank 1: Sarajevo – Capljina, Corridor Vc



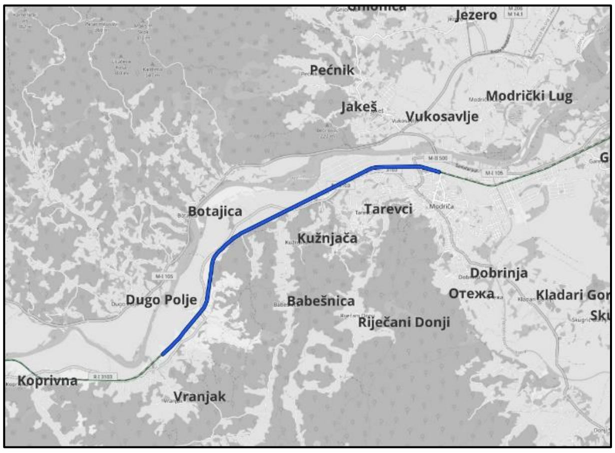
Rank 2: Sarajevo – Capljina, Corridor Vc



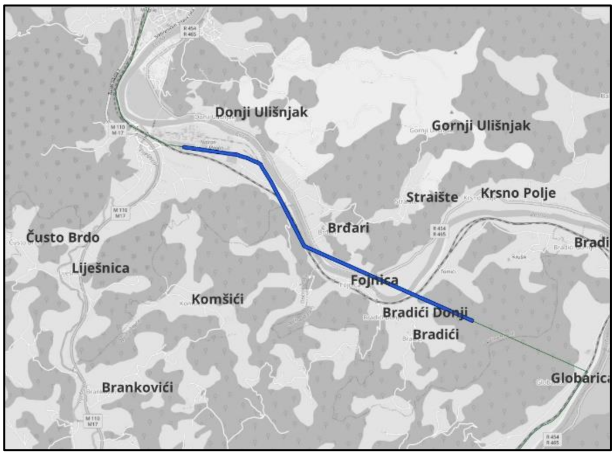
Rank 3: Sarajevo – Capljina, Corridor Vc



Rank 4: Sarajevo – Capljina, Corridor Vc

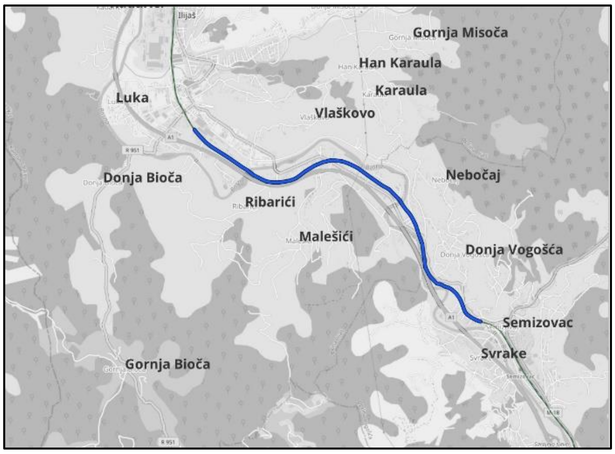


Rank 5: Bosanski Samac – Doboj, Corridor Vc

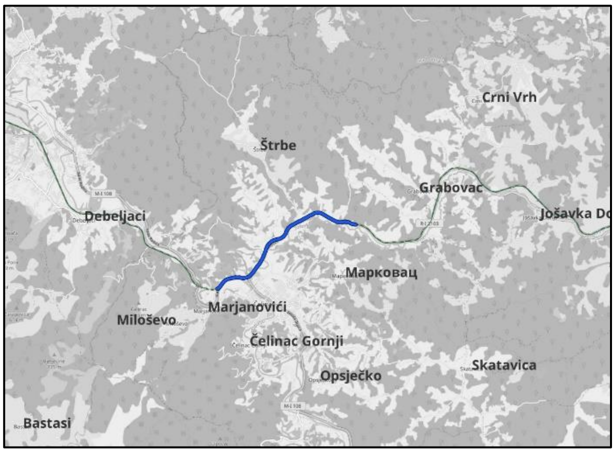


Rank 6: Doboj - Sarajevo (Doboj – Jelina), Corridor Vc

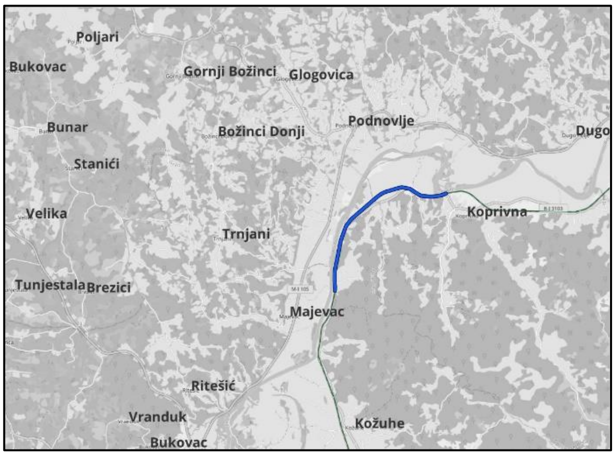
Rank 7: Doboj – Sarajevo (Doboj – Jelina), Corridor Vc



Rank 8: Doboj – Sarajevo (Jelina – Sarajevo), Corridor Vc



Rank 9: Banja Luka – Doboj Corridor Vc



Rank 10: Bosanski Samac – Doboj, Corridor Vc

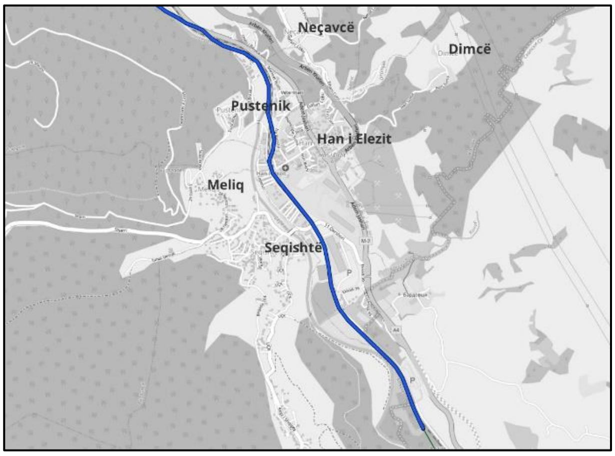
In the next table, investment cost[8] for rail sections are represented for RP Bosnia and Herzegovina.

Table 8 Investment cost (rail) outcomes for RP Bosnia and Herzegovina

Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Sarajevo – Capljina	3.59	F4	0.850	1	5,200,000	**4,420,000**	**9,763,000**
		F1	2.740	1	1,950,000	**5,343,000**	
Rank 2: Sarajevo – Capljina	3.59	F1	3.590	1	1,950,000	**7,000,500**	**7,000,500**
Rank 3: Sarajevo – Capljina	3.59	F1	3.231	1	1,950,000	**6,300,450**	**8,660,085**
		L	2.872	0.4	2,054,000	**2,359,635**	
Rank 4: Sarajevo – Capljina	7.18	F1	7.180	1	1,950,000	**14,001,000**	**19,900,088**
		L	7.180	0.4	2,054,000	**5,899,088**	
Rank 5: Bosanski Samac – Doboj	5.203	F4	2.081	1	5,200,000	**10,822,240**	**16,909,750**
		F1	3.122	1	1,950,000	**6,087,510**	
Rank 6: Doboj - Sarajevo (Doboj – Jelina)	3.59	F4	1.795	1	5,200,000	**9,334,000**	**12,834,250**
		F1	1.795	1	1,950,000	**3,500,250**	
Rank 7: Doboj – Sarajevo (Doboj – Jelina)	3.59	F4	3.590	0.8	5,200,000	**14,934,400**	**14,934,400**
Rank 8: Doboj – Sarajevo (Jelina – Sarajevo)	3.59	F1	3.590	1	1,950,000	**7,000,500**	**8,180,318**
		L	1.436	0.4	2,054,000	**1,179,818**	
Rank 9: Banja Luka – Doboj	9.807	F1	7.836	0.8	1,950,000	**12,224,628**	**26,002,059**
		F4	1.100	1	5,200,000	**5,720,000**	
		L	4.904	0.4	4,108,000	**8,057,431**	
Rank 10: Bosanski Samac – Doboj	7.18	F1	7.180	1	1,950,000	**14,001,000**	**14,001,000**

A.2.3 Kosovo

The top 10 ranked critical railway sections in Kosovo are presented in the following figures:

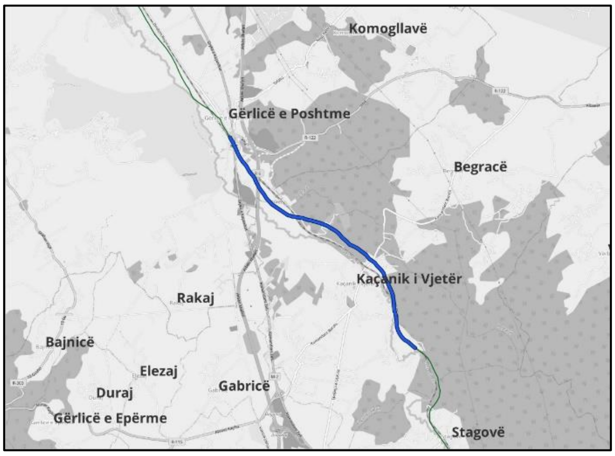


Rank 1: Fushë Kosovë - BCP Hani i Elezit, Route 10

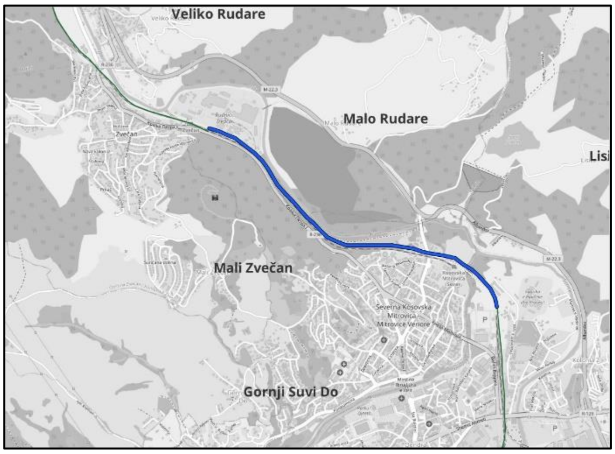
Rank 2: Common crossing point with Serbia – Leshak – Fushë Kosovë, Route 10

Rank 3: Fushë Kosovë - BCP Hani i Elezit, Route 10

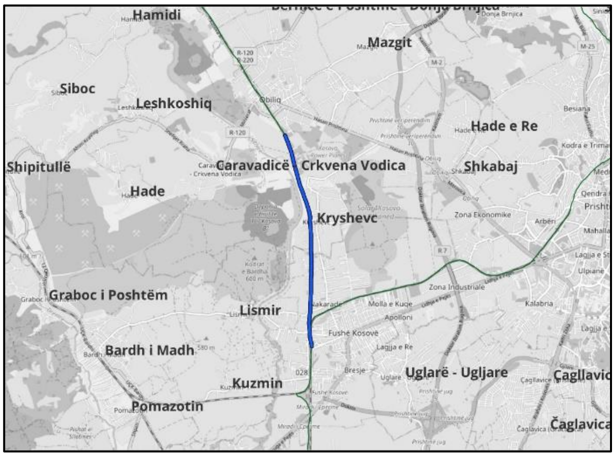
Rank 4: Common crossing point with Serbia – Leshak – Fushë Kosovë, Route 10



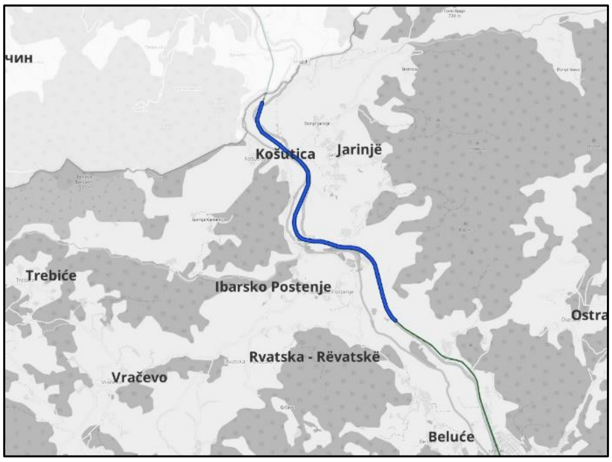
Rank 5: Fushë Kosovë - BCP Hani i Elezit, Route 10



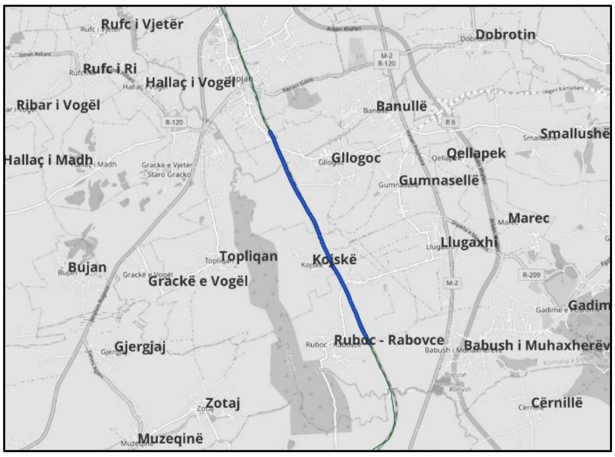
Rank 6: Common crossing point with Serbia – Leshak – Fushë Kosovë, Route 10



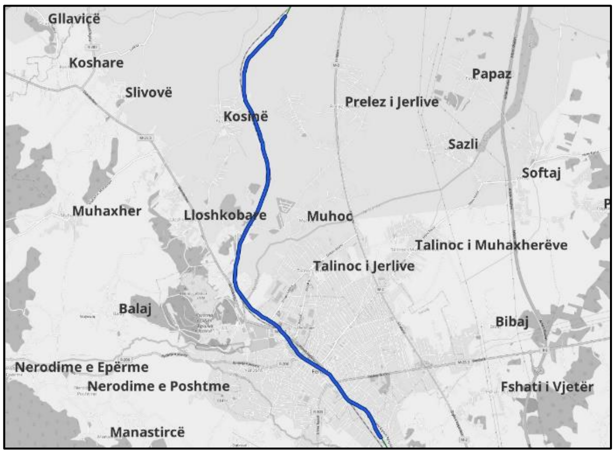
Rank 7: Common crossing point with Serbia – Leshak – Fushë Kosovë, Route 10



Rank 8: Common crossing point with Serbia – Leshak – Fushë Kosovë, Route 10



Rank 9: Fushë Kosovë - BCP Hani i Elezit, Route 10



Rank 10: Fushë Kosovë - BCP Hani i Elezit, Route 10

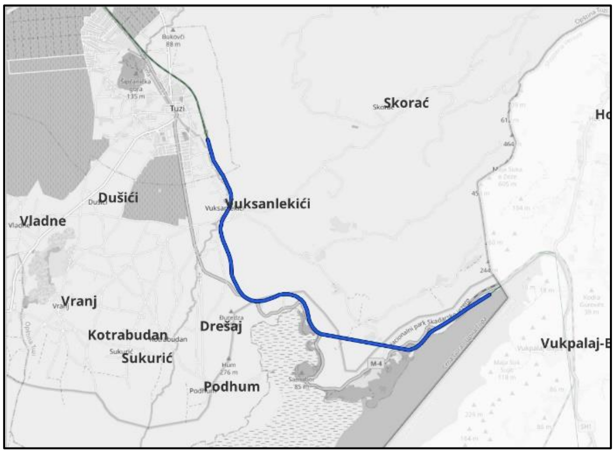
In the next table, investment cost[8] for rail sections are represented for RP Kosovo.

Table 9 Investment cost (rail) outcomes for RP Kosovo

Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Fushë Kosovë - BCP Hani i Elezit	10.77	T	10.77	1	n.a.	**n.a.**	**n.a**
Rank 2: Common crossing point with Serbia – Leshak – Fushë Kosovë	7.18	T	7.18	1	n.a.	**n.a.**	**n.a**
Rank 3: Fushë Kosovë - BCP Hani i Elezit	3.59	T	3.59	1	n.a.	**n.a.**	**n.a**
Rank 4: Common crossing point with Serbia – Leshak – Fushë Kosovë	3.59	T	2.59	1	n.a.	**n.a.**	**n.a**
Rank 5: Fushë Kosovë - BCP Hani i Elezit	10.77	F5	3.500	1	5,200,000	**18,200,000**	**18,200,000**
Rank 6: Common crossing point with Serbia – Leshak – Fushë Kosovë	17.95	F1	14.360	0.8	1,950,000	**22,401,600**	**31,250,232**
		L	10.770	0.4	2,054,000	**8,848,632**	
Rank 7: Common crossing point with Serbia – Leshak – Fushë Kosovë	3.59	L	1.616	0.4	2,054,000	**1,327,295**	**1,327,295**
Rank 8: Common crossing point with Serbia – Leshak – Fushë Kosovë	14.36	F4	8.616	0.8	5,200,000	**35,842,560**	**40,561,830**
		L	5.744	0.4	2,054,000	**4,719,270**	
Rank 9: Fushë Kosovë - BCP Hani i Elezit	2.048	F5	1.300	1	5,200,000	**6,760,000**	**8,599,935**
		F1	0.748	0.8	1,950,000	**1,166,880**	
		L	0.819	0.4	2,054,000	**673,055**	
Rank 10: Fushë Kosovë - BCP Hani i Elezit	3.59	L	1.436	0.4	2,054,000	**1,179,818**	**1,179,818**

A.2.4 Montenegro

The top 10 ranked critical railway sections in Montenegro are presented in the following figures:



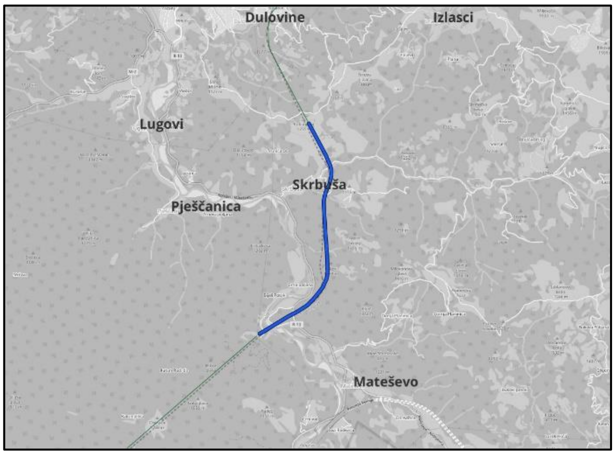
Rank 1: Podgorica - BCP Bozaj (Podgorica – Tuzi), Route 2

Rank 2: Podgorica – Bar (Virpazar – Bar), Route 4

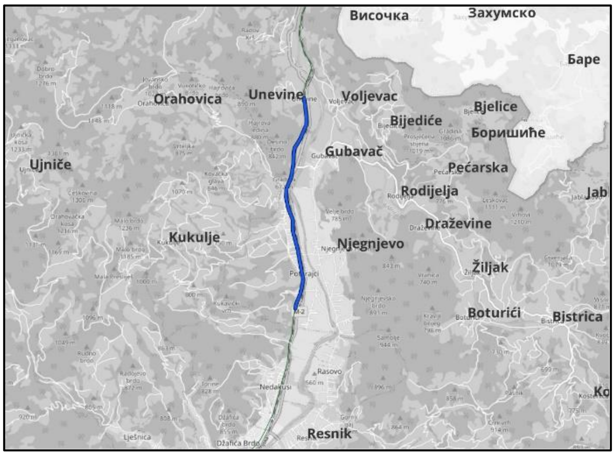
Rank 3: Podgorica – Bar (Podgorica – Virpazar), Route 4

Rank 4: BCP Dobrakovo – Podgorica (Kolasin – Podgorica), Route 4

Rank 5: Podgorica – Bar (Virpazar – Bar), Route 4

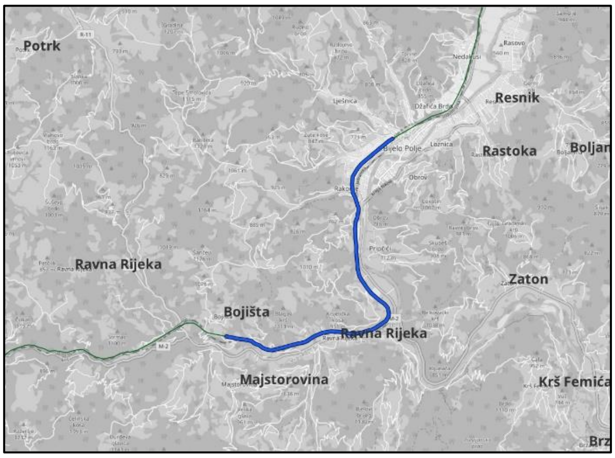


Rank 6: BCP Dobrakovo – Podgorica (Kolasin – Podgorica), Route 4

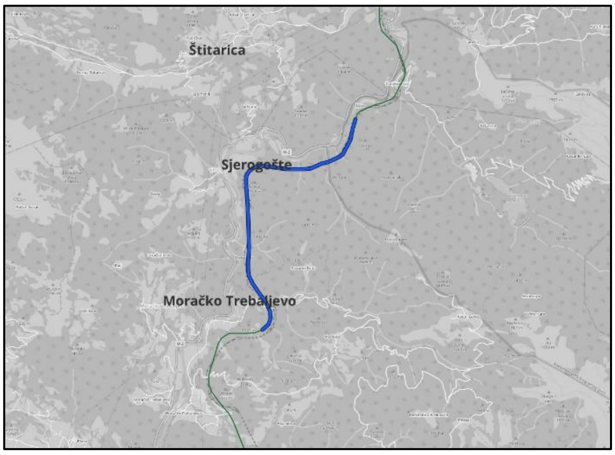


Rank 7: BCP Dobrakovo – Podgorica (Bijelo Polje – Mojkovac), Route 4

Rank 8: BCP Dobrakovo – Podgorica (Bijelo Polje – Mojkovac), Route 4



Rank 9: BCP Dobrakovo – Podgorica (Bijelo Polje – Mojkovac), Route 4



Rank 10: BCP Dobrakovo – Podgorica (Mojkovac – Trebaljevo), Route 4

In the next table, investment cost[8] for rail sections are represented for RP Montenegro.

Table 10 Investment cost (rail) outcomes for RP Montenegro

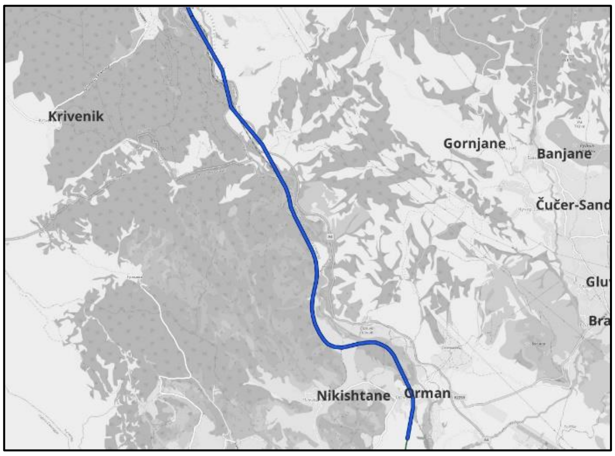
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Podgorica - BCP Bozaj (Podgorica – Tuzi)	39.49	F2	5.000	1	10,000,000	**50,000,000**	**50,000,000**
Rank 2: Podgorica – Bar (Virpazar – Bar)	8.239	F4	8.239	0.8	5,200,000	**34,274,240**	**34,274,240**
Rank 3: Podgorica – Bar (Podgorica – Virpazar)	3.59	F4	3.231	1	5,200,000	**16,801,200**	**16,801,200**
Rank 4: BCP Dobrakovo – Podgorica (Kolasin – Podgorica)	3.59	F1	1.890	0.8	1,950,000	**2,948,400**	**11,788,400**
		F5	1.700	1	5,200,000	**8,840,000**	
Rank 5: Podgorica – Bar (Virpazar – Bar)	0.6	F1	0.600	1	1,950,000	**1,170,000**	**1,170,000**
Rank 6: BCP Dobrakovo – Podgorica (Kolasin – Podgorica)	7.18	F4	1.508	0.8	5,200,000	**6,272,448**	**7,532,538**
		F1	0.646	1	1,950,000	**1,260,090**	
Rank 7: BCP Dobrakovo – Podgorica (Bijelo Polje – Mojkovac)	7.53	F5	2.259	1	5,200,000	**11,746,800**	**11,746,800**
Rank 8: BCP Dobrakovo – Podgorica (Bijelo Polje – Mojkovac)	3.04	F1	0.300	1	1,950,000	**585,000**	**585,000**
Rank 9: BCP Dobrakovo – Podgorica (Bijelo Polje – Mojkovac)	3.954	F1	1.000	1	1,950,000	**1,950,000**	**1,950,000**
Rank 10: BCP Dobrakovo – Podgorica (Mojkovac – Trebaljevo)	10.77	F5	3.231	1	5,200,000	**16,801,200**	**16,801,200**

A.2.5 North Macedonia

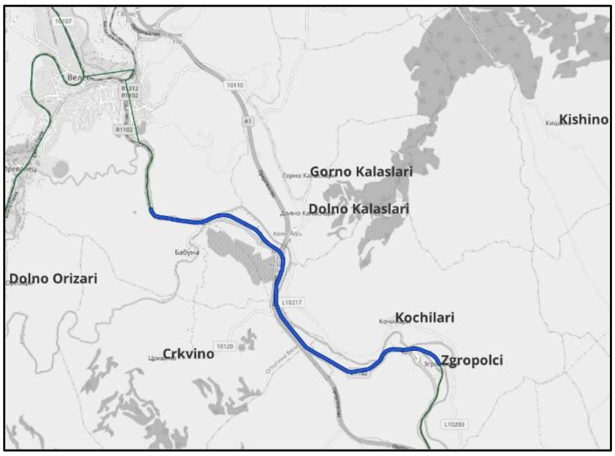
The top 10 ranked critical railway sections in North Macedonia are presented in the following figures:

Rank 1: Skopje - Veles (Trubarevo - Veles), Corridor X

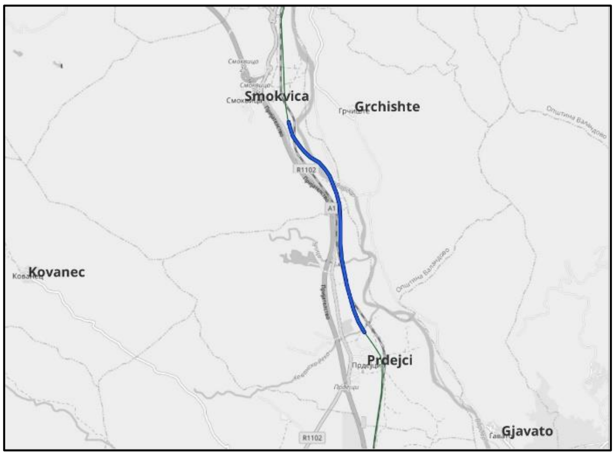
Rank 2: Veles - GRE Bordrer (Veles - Gevgelija), Corridor X



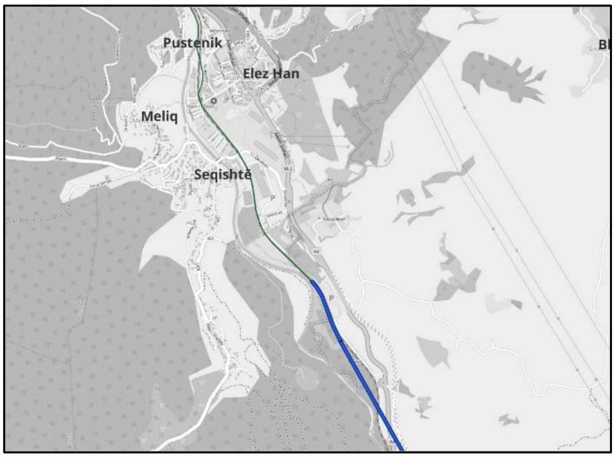
Rank 3: BCP Blace - Skopje (Blace - Gjorce Petrov), Route 10



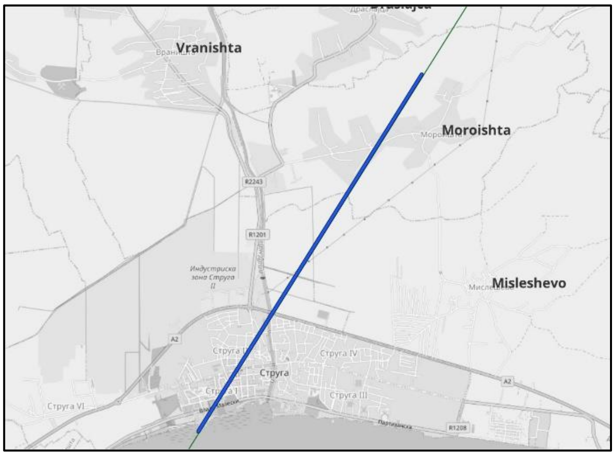
Rank 4: Veles - GRE Bordrer (Veles - Gevgelija), Corridor X

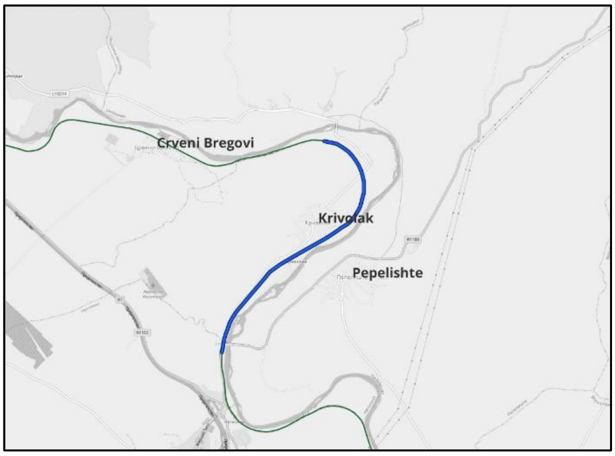


Rank 5: Veles - GRE Bordrer (Veles - Gevgelija), Corridor X



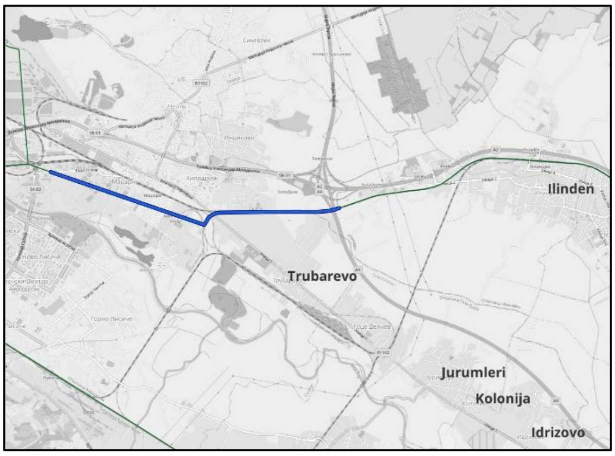
Rank 6: BCP Blace - Skopje (Blace - Gjorce Petrov), Route 10

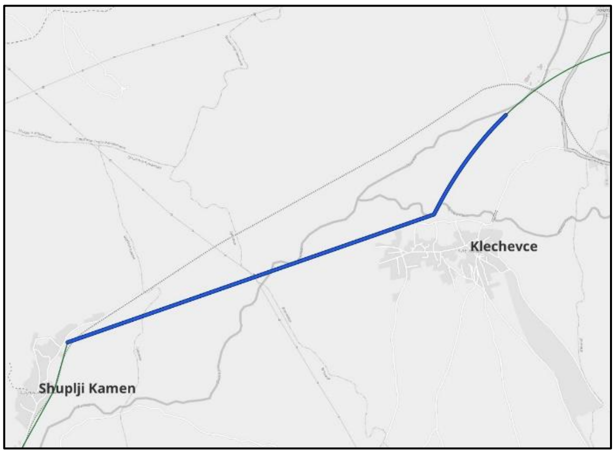




Rank 7: Skopje - ALB Border (Gjorce Petrov - Kicevo), Corridor VIII

Rank 8: Veles - GRE Bordrer (Veles - Gevgelija), Corridor X





Rank 9: Kumanovo - Skopje (Kumanovo - Trubarevo), Corridor X

Rank 10: Kumanovo - BLG Border (Dobrosane - Dovezence), Corridor VIII

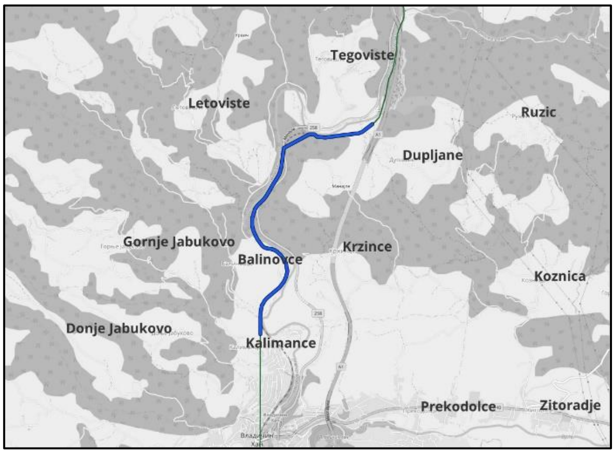
In the next table, investment cost[8] for rail sections are represented for RP North Macedonia.

Table 11 Investment cost (rail) outcomes for RP North Macedonia

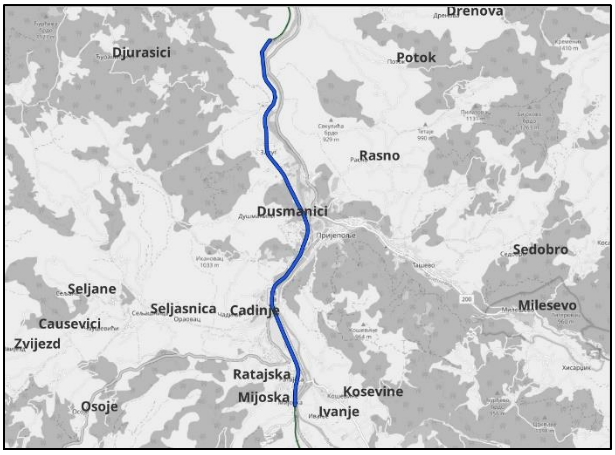
Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Skopje - Veles (Trubarevo - Veles)	2.59	F	2.331	0.8	5,200,000	**9,696,960**	**9,696,960**
Rank 2: Veles - GRE Bordrer (Veles - Gevgelija)	3.59	F1	2.872	0.8	1,950,000	**4,480,320**	**4,480,320**
Rank 3: BCP Blace - Skopje (Blace - Gjorce Petrov)	20.54	F4	10.270	0.8	5,200,000	**42,723,200**	**49,473,466**
		L	8.216	0.4	2,054,000	**6,750,266**	
Rank 4: Veles - GRE Bordrer (Veles - Gevgelija	7.18	F4	7.180	0.8	5,200,000	**29,868,800**	**29,868,800**
Rank 5: Veles - GRE Bordrer (Veles - Gevgelija)	7.18	F4	1.795	1	5,200,000	**9,334,000**	**16,054,480**
		F1	4.308	0.8	1,950,000	**6,720,480**	
Rank 6: BCP Blace - Skopje (Blace - Gjorce Petrov)	3.59	F4	3.231	1	5,200,000	**16,801,200**	**16,801,200**
Rank 7: Skopje - ALB Border (Gjorce Petrov - Kicevo)	7.18	F4	6.462	0.8	5,200,000	**26,881,920**	**26,881,920**
Rank 8: Veles - GRE Bordrer (Veles - Gevgelija)	1.267	F1	1.500	1	1,950,000	**2,925,000**	**2,925,000**
Rank 9: Kumanovo - Skopje (Kumanovo - Trubarevo)	3.59	F4	2.872	1	5,200,000	**14,934,400**	**14,934,400**
Rank 10: Kumanovo - BLG Border (Dobrosane - Dovezence)	0.602	F4	0.542	1	5,200,000	**2,817,360**	**2,817,360**

A.2.6 Serbia

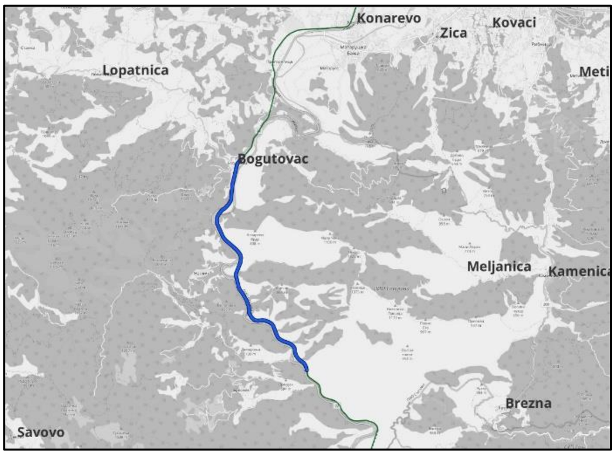
The top 10 ranked critical railway sections in Serbia are presented in the following figures:



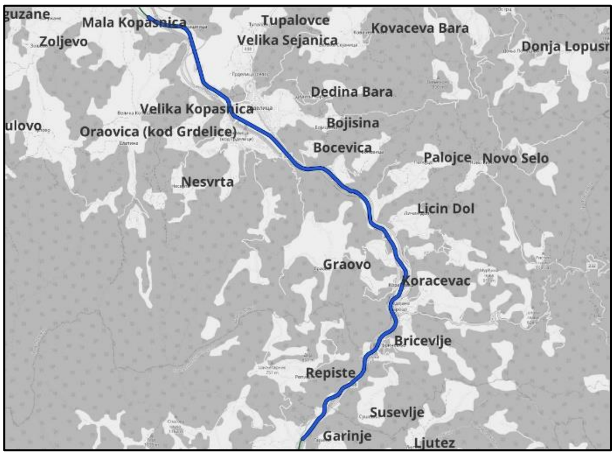
Rank 1: Nis - BCP Presevo (Nis - Presevo), Corridor X



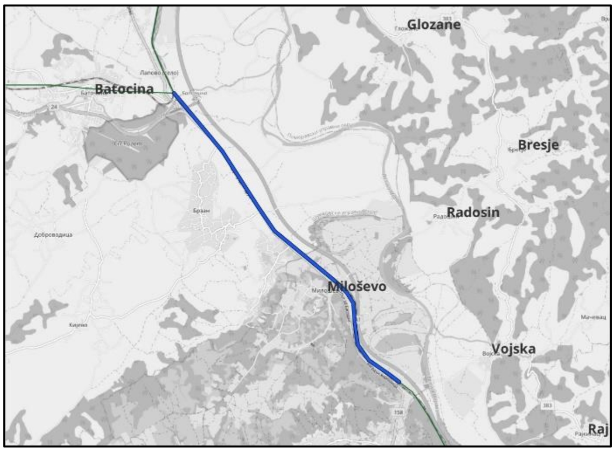
Rank 2: Uzice - BCP Gostun (Pozega - Vrbnica), Route 4



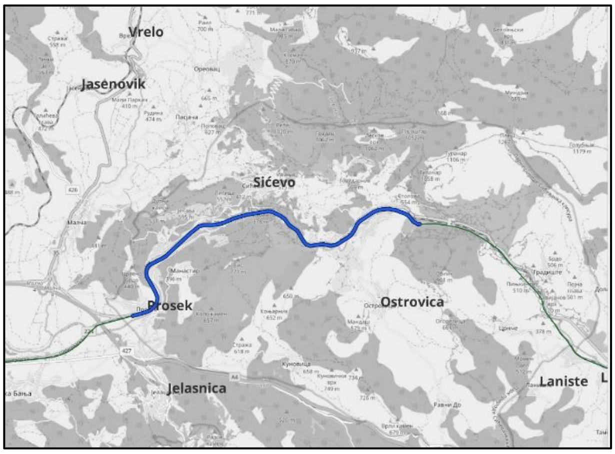
Rank 3: Kraljevo - Rudnica Kraljevo - Raska), Route 10



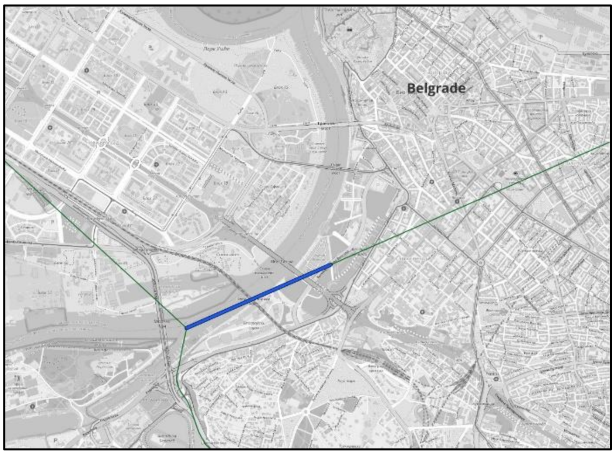
Rank 4: Nis - BCP Presevo (Nis - Presevo), Corridor X



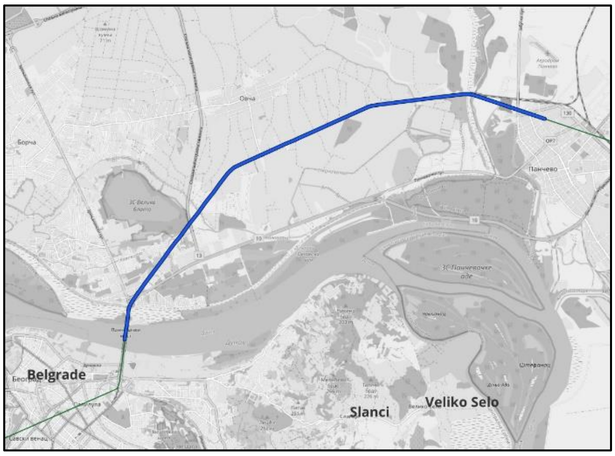
Rank 5: Beograd - Stalac (Lapovo - Stalac), Corridor X



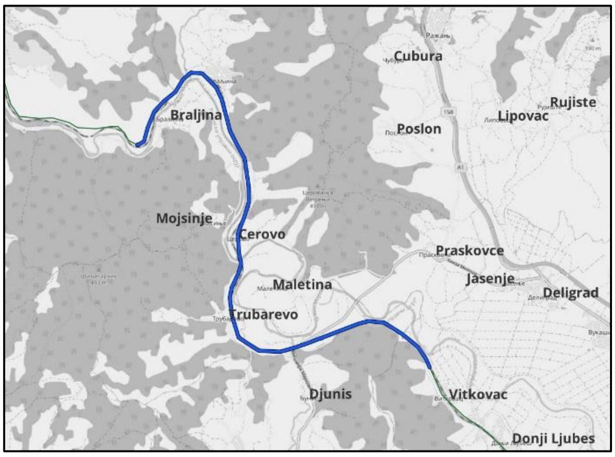
Rank 6: Nis - BCP Gradina (Nis - Dimitrovgrad), Corridor Xc



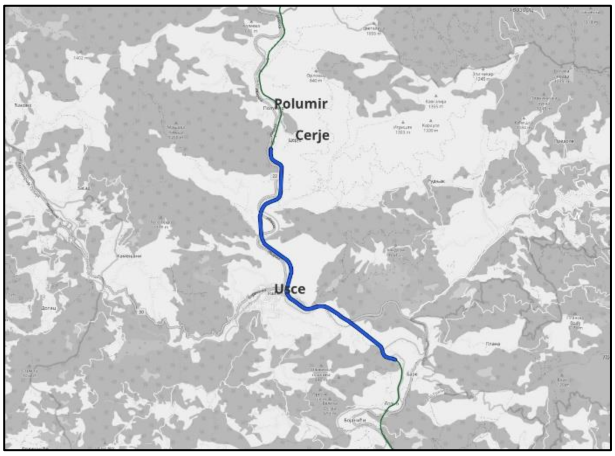
Rank 7: Beograd - BCP Vatin (Beograd - Krnjaca), Route 4



Rank 8: Beograd - BCP Vatin (Krnjaca - Pancevo), Route 4



Rank 9: Stalac - Nis, Route 4



Rank 10: Kraljevo - Rudnica (Kraljevo - Raska), Route 10

In the next table, investment cost[8] for rail sections are represented for RP Serbia.

Table 12 Investment cost (rail) outcomes for RP Serbia

Section	Link length (km)	Adaptation measures scenario (L, F, T, S)	Highly exposed length (km)	Correction factor applied	Cost per 1 km (EUR)	Estimated Investment Cost per AM scenario (EUR)	Total Investment Cost (EUR)
Rank 1: Nis - BCP Presevo (Nis - Presevo)	7.18	F1	5.744	0.8	1,950,000	**8,960,640**	**13,090,002**
		L	5.026	0.4	2,054,000	**4,129,362**	
Rank 2: Uzice - BCP Gostun (Pozega - Vrbnica)	7.18	L	1.197	0.4	2,054,000	**983,181**	**983,181**
Rank 3: Kraljevo - Rudnica Kraljevo - Raska)	14.36	F4	2.872	1	5,200,000	**14,934,400**	**36,634,083**
		F1	8.616	0.8	1,950,000	**13,440,960**	
		L	10.052	0.4	2,054,000	**8,258,723**	
Rank 4: Nis - BCP Presevo (Nis - Presevo)	10.77	F4	8.616	1	5,200,000	**44,803,200**	**44,803,200**
Rank 5: Beograd - Stalac (Lapovo - Stalac)	7.18	F4	5.744	1	5,200,000	**29,868,800**	**29,868,800**
Rank 6: Nis - BCP Gradina (Nis - Dimitrovgrad)	7.18	F4	1.436	1	5,200,000	**7,467,200**	**18,835,265**
		F1	5.170	0.8	1,950,000	**8,064,576**	
		L	4.021	0.4	2,054,000	**3,303,489**	
Rank 7: Beograd - BCP Vatin (Beograd - Krnjaca)	3.59	F4	2.872	1	5,200,000	**14,934,400**	**16,999,081**
		L	2.513	0.4	2,054,000	**2,064,681**	
Rank 8: Beograd - BCP Vatin (Krnjaca - Pancevo)	3.59	F4	2.154	1	5,200,000	**11,200,800**	**14,001,000**
		F1	1.436	1	1,950,000	**2,800,200**	
Rank 9: Stalac - Nis	10.77	F4	4.308	1	5,200,000	**22,401,600**	**32,482,320**
		F1	6.462	0.8	1,950,000	**10,080,720**	
Rank 10: Kraljevo - Rudnica (Kraljevo - Raska)	7.18	F4	7.000	1	5,200,000	**36,400,000**	**36,400,000**

Appendix B

Catalogue of proposed adaptation measures

Building on the insights gained from the analysis performed and the conclusions drawn in Step 3 of the hazard analysis, the proposed adaptation measures for the analysed sections have been carefully crafted.

In terms of implementing adaptive measures, both roads and railways share similarities as infrastructures. All the measures outlined can be effectively applied to address vulnerabilities in both contexts.

B.1 Landslides

In addressing the challenges posed by landslides and rockfalls, a range of specific measures has been identified. These measures can be individually customized to meet the unique requirements and complexities of the situation, and they can also be integrated and adapted as needed. Below, individual measures are presented, accompanied by practical examples illustrating their implementation in real-world scenarios. This comprehensive approach ensures a versatile and effective strategy for managing the risks associated with landslides and rockfalls.

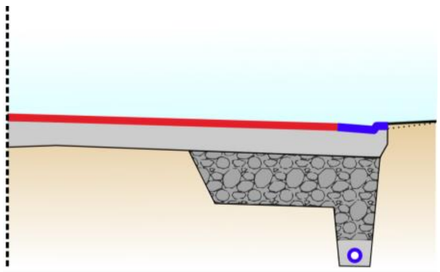
Subsurface drainage and subbase reinforcement

Subsurface drainage and subbase reinforcement are implemented when groundwater poses a threat to road/rail stability and increases the risk of localized landslides.

Main works to include:

- Demolition of existing road/ rail structure within the specified width (as per the cross-section) to facilitate the installation of planned works; separation of bounded and non-bonded materials, utilize specialized machinery for precise demolition
- Dismantling of existing road/rail equipment within the construction work zone
- Excavation for subbase reinforcement to required depths
- Excavation for drainage trench
- Preparation of subbase material for placement of new subbase reinforcement layer including required compaction
- Installation of drainage pipe(s)
- Backfilling of drainage trench with suitable materials and compaction to avoid settling
- Instalment of new subbase reinforcement layer
- Construction of road/ rail structure: rebuild layers to the original specifications
- Reinstallation of road/rail equipment

Schematic example:



Estimated investment cost [EUR/m][9]	
Road	**Rail**
1,000	1,300

Slope remodelling (excavations)

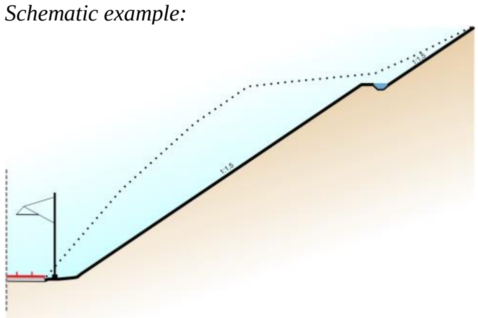
Slope remodelling through excavations is advisable when the natural stability of the slope could be compromised, especially if it's not necessarily steep but of considerable height, which might present challenges. Implementing gentler inclines with stepped excavations is recommended in such situations.

Main works to include:

- Modification of the slope's contours through grading and excavation to achieve a more stable profile

Estimated investment cost [EUR/m][9]	
Road	**Rail**
700	900

Schematic example:



Subsurface drainage and subbase reinforcement, plus retaining wall of different height

Subsurface drainage and subbase reinforcement, coupled with retaining walls of varying heights, are employed when the road/rail vulnerability necessitates additional support beyond drainage measures. This includes fortifying the roadbed by installing retaining walls.

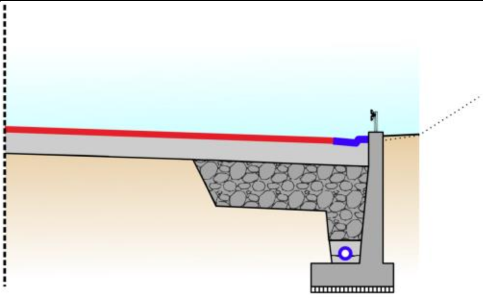
Main works to include:

- Demolition of existing road/ rail structure within the specified width (as per the cross-section) to facilitate the installation of planned works; separation of bounded and non-bonded materials, utilize specialized machinery for precise demolition
- Dismantling of existing road/rail equipment within the construction work zone
- Excavation for subbase reinforcement to required depths
- Excavation for drainage trench and retaining wall construction

Schematic example:

[9] The approximate estimated investment values for the proposed type of work have been presented. This is presentation of investment value for double carriageway/ track.

- Preparation of subbase material for placement of new subbase reinforcement layer as well as for new retaining structure, including required compaction
- Concrete and reinforcement work for installation of a new retaining wall
- Installation of drainage pipe(s)
- Backfilling of drainage trench with suitable materials and compaction to avoid settling
- Instalment of new subbase reinforcement layer
- Construction of road/ rail structure: rebuild layers to the original specifications
- Reinstallation of road/rail equipment



Estimated investment cost [EUR/m][9]	
Road	**Rail**
1,500	2,000

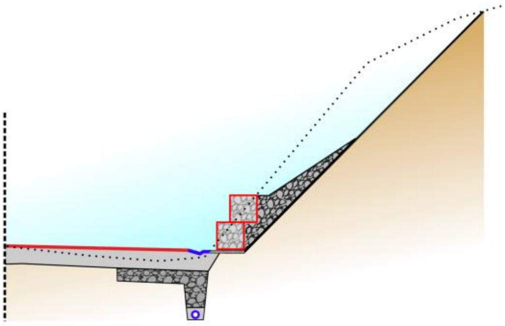
Subsurface drainage and subbase reinforcement, plus gabion wall of different height

Subsurface drainage and subbase reinforcement, along with gabion walls of varying heights, are utilized when, besides establishing proper roadbed/railbed drainage, it is necessary to protect the road/rail from minor material sliding (smaller volumes of earth material) that pose a threat from the slopes.

Main works to include:

- Demolition of existing road/ rail structure within the specified width (as per the cross-section) to facilitate the installation of planned works; separation of bounded and non-bonded materials, utilize specialized machinery for precise demolition
- Dismantling of existing road/rail equipment within the construction work zone
- Excavation for subbase reinforcement to required depths
- Excavation for drainage trench
- Preparation of subbase material for placement of new subbase reinforcement layer, including required compaction
- Installation of drainage pipe(s)
- Backfilling of drainage trench with suitable materials and compaction to avoid settling
- Instalment of new subbase reinforcement layer
- Construction of road/ rail structure: rebuild layers to the original specifications
- Installation of gabion walls
- Reinstallation of road/rail equipment

Schematic example:



Estimated investment cost [EUR/m][9]	
Road	**Rail**
1,250	1,600

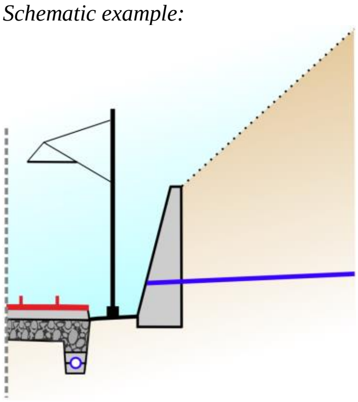
Subsurface drainage and drilled drainage in the existing retaining wall

Subsurface drainage and drilled drainage within the existing retaining wall are employed when slope instability and localized material slippage are caused by the slope groundwater, which, due to the wall's construction, cannot naturally dissipate. This measure aims to protect the wall, ensuring its durability, while stabilizing the soil behind it and reducing pressure on the wall.

Main works to include:

- Demolition of existing road/ rail structure within the specified width (as per the cross-section) to facilitate the installation of planned works; separation of bounded and non-bonded materials, utilize specialized machinery for precise demolition
- Dismantling of existing road/rail equipment within the construction work zone
- Excavation for subbase reinforcement to required depths
- Excavation for drainage trench
- Preparation of subbase material for placement of new subbase reinforcement layer, including required compaction
- Installation of drainage pipe(s)
- Backfilling of drainage trench with suitable materials and compaction to avoid settling
- Instalment of new subbase reinforcement layer
- Construction of road/ rail structure: rebuild layers to the original specifications
- Implementation of drilled drainage in the existing retaining wall: carefully drill drainage openings ensuring optimal drainage pathways within the retaining wall
- Reinstallation of road/rail equipment

Schematic example:



Estimated investment cost [EUR/m][9]	
Road	**Rail**
1,200	1,600

Gabions only

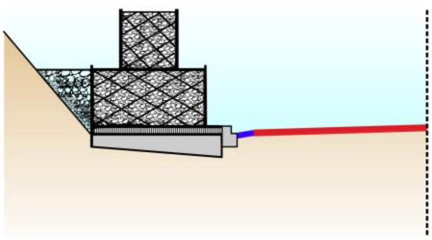
Gabions are used exclusively when the road/railway is threatened by minor material slides from the slope (smaller volumes of earth material).

Main works to include:

- Preparatory earthworks for installing gabions
- Subgrade preparation and compaction
- Installation of gabion walls

Estimated investment cost [EUR/m][9]	
Road	**Rail**
400	500

Schematic example:



Removing unstable parts of the slope (rocks) and instalment of protective mash

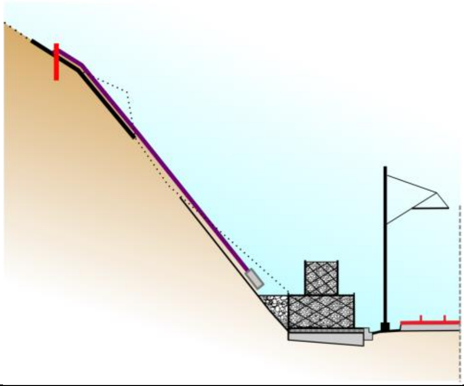
Removing unstable parts of the slope (rocks) and installing protective mesh is recommended when the slope is generally stable but has localized larger rock fragments that might shift and potentially endanger the road/railway.

Main works to include:

- Excavation unstable sections of the slope
- Preparatory works and minor slope reshaping as required
- Placing protective mash
- Tightening and weighting the mash for stability

Estimated investment cost [EUR/m][9]	
Road	**Rail**
2,500	3,200

Schematic example:



Removing unstable parts of the slope (rocks) and instalment of protective anchored mash

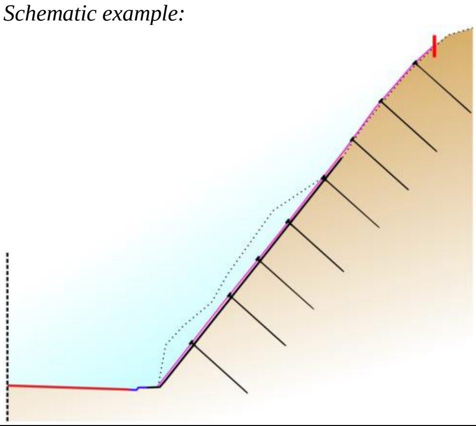
Removing unstable parts of the slope (rocks) and installing protective anchored mesh is necessary when the slope is conditionally stable and requires additional reinforcement by anchoring the mesh.

Main works to include:

- Excavation unstable sections of the slope
- Preparatory works and minor slope reshaping as required
- Placing protective mash
- Tightening and weighting the mash for stability
- Anchors installation

Estimated investment cost [EUR/m][9]	
Road	**Rail**
3,600	4,700

Schematic example:



Removing unstable parts of the slope (rocks) and instalment of protective mash plus rockfall barriers

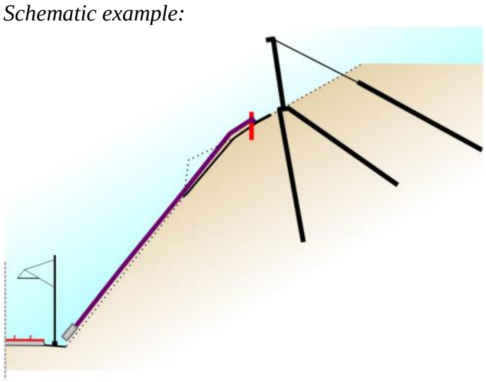
Removing unstable parts of the slope (rocks) and installing protective mesh, along with rockfall barriers, is crucial when, alongside conditionally stable slopes, there's a risk of larger rockfall from heights above the engineered slope of the road/railway.

Main works to include:

- Excavation unstable sections of the slope
- Preparatory works and minor slope reshaping as required
- Placing protective mash
- Tightening and weighting the mash for stability
- Installation of flexible rockfall protection barrier

Estimated investment cost [EUR/m][9]	
Road	**Rail**
2,700	3,500

Schematic example:



Slope anchoring stabilisation measures

Slope anchoring stabilization measures are employed when it's necessary to reinforce unstable excavated slopes along the road/railway.

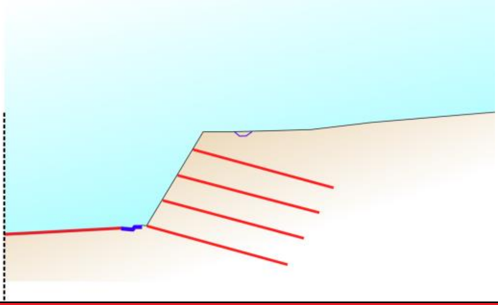
Main works to include:

- Excavation works and slope reshaping
- Installation of anchors as required

Schematic example:

Estimated investment cost [EUR/m][9]	
Road	**Rail**
5,000	6,500

-



Slope anchoring stabilisation measures with concrete reinforcement support

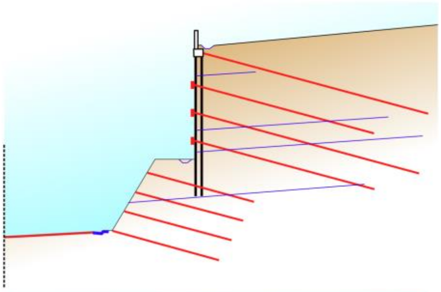
Slope anchoring stabilization measures with concrete reinforcement support are essential for larger (higher) unstable excavated slopes, where additional supportive reinforced measures are necessary.

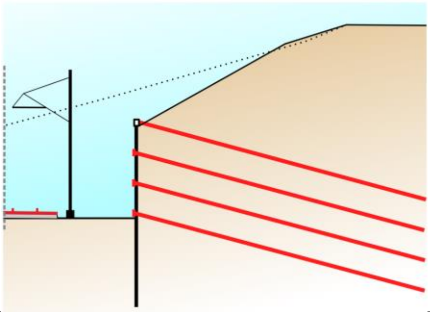
Main works to include:

- Excavation works and slope reshaping
- Installation of anchors as required
- Concrete reinforcement (for example, pile curtain)

Estimated investment cost [EUR/m][9]	
Road	**Rail**
12,000	15,600

Schematic example:





B.2 Floods

Flood protection strategies are essential for ensuring the long-term resilience of road and rail networks. While elevating the road/ rail axle is often the most effective solution, practical limitations such as spatial constraints and challenging terrain can make this approach unfeasible. In such scenarios, it becomes imperative to explore alternative protective measures within the existing road or railway infrastructure. Additionally, regulating watercourses can play a significant role in flood prevention.

Following measures recommendations stem from a comprehensive desktop analysis, taking into account the intricacies of the site, including both spatial and terrain-related constraints.

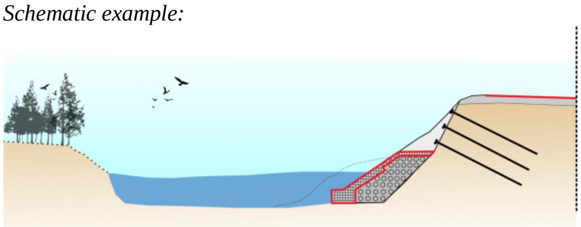
Flood protection measures

Flood protection measures are implemented when the proximity of a watercourse jeopardizes slopes and/or the structure of roads/railways, as well as at the intersection of roads/railways and watercourses.

Main works to include:

- Excavation works
- Instalment of flood barriers, such as flood protection embankments
- Protection of slopes
- Protection of road/rail structures
- River regulation under bridge zone
- Construction of new superstructure
- Construction of new substructure
- Enhancement of drainage system
- Disassembly and reassembly of road or railway equipment upon completion of the construction works

Schematic example:



Estimated investment cost [EUR/km][9]	
Road	**Rail**
3,000,000	3,000,000

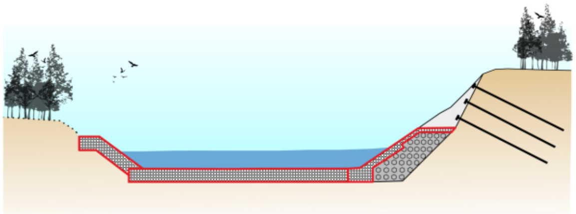
River regulation

River regulation occurs when spatial conditions allow for the regulation of a riverbed over a certain length to protect transportation infrastructure.

Main works to include:

- Preparatory works
- Excavation works
- Stone/ concrete works of riverbed and banks
- Installation of protection measures of river banks as required (such as anchoring or concrete reinforcement)

Schematic example:



Estimated investment cost [EUR/km][9]	
Road	**Rail**
20,000,000	

Elevated Road/ Rail (planned construction)

Elevation adjustment, lifting of road or railway axle, at the stage of modifying the project documentation is a measure undertaken when the planned infrastructure is in the process of acquiring necessary legal documentation. This scenario arises when standard design practices have been applied, and climate change parameters have not been accounted for. In such cases, modifications to the project documentation become necessary to incorporate elevation changes, ensuring alignment with the evolving requirements and enhancing the infrastructure's resilience in the face of future climate challenges.

Estimated investment cost [EUR/km][9]	
Road	**Rail**
4,200,000	5,200,000

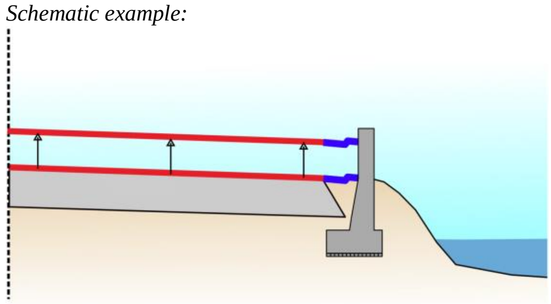
Elevated Road/ Rail (reconstruction)

In situations where there is determined spatial feasibility to elevate the grade of the road or railway, factoring in climate change parameters, this necessitates a comprehensive reconstruction spanning the entire planned length. This involves the overhaul of all associated structures and equipment, ensuring alignment with the evolving environmental considerations.

-

Estimated investment cost [EUR/km][9]	
Road	**Rail**
8,400,000	10,400,000

Schematic example:



Full reconstruction

When environment conditions make it impossible to apply any of the previously mentioned flood protection measures. It involves maximizing the protection of the road or railway bed from water infiltration, necessitating the use of geotextiles and other waterproofing measures. Such measures entail a complete reconstruction of the road or railway.

Estimated investment cost [EUR/km][9]	
Road	**Rail**
8,400,00	10,400,00

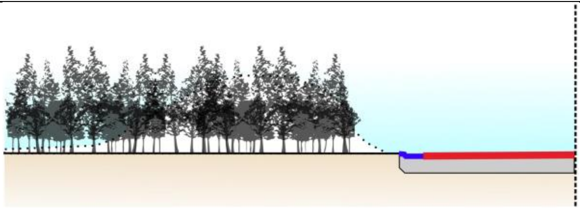
B.3 Snowdrift

While the vulnerability analysis did not prominently highlight snowdrift as a major hazard, specific locations within the TENT network, particularly in flat terrains, have underscored the significance of this concern. In response to these identified areas, the proposed measures concentrate on bolstering protection along the linear infrastructure. Addressing potential snowdrift challenges at these specific sites is crucial to ensuring the overall resilience of the network.

Planting vegetation

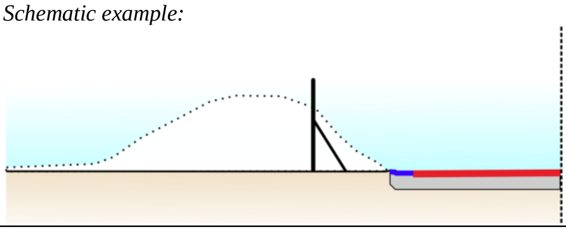
Tailoring the vegetation strategy to the strength of dominant winds along the designated road/ rail section is crucial. Planting vegetation unilaterally or bilaterally in a carefully planned arrangement is necessary to counter snowdrifts effectively. The choice of plant species should be informed by the region's climate, snowfall patterns, and wind intensity. Opting for indigenous plants is optimal, as they are naturally

Schematic example:

adapted to local conditions, ensuring not only effective snow break but also bolstering the overall ecological balance and resilience of the area. This measure further contributes to improving the landscape along the linear infrastructure.	

Estimated investment cost [EUR/km][9]	
Road	**Rail**
100,000	

Installation of snow barriers

When planting vegetation is not feasible, an alternative option for protecting roads/railways from snowdrifts involves installing barriers designed to reduce wind force and retain snowdrifts outside the roadway area. Similar to the previous scenario, these barriers are strategically placed unilaterally or bilaterally along the road/railway, depending on the direction of prevailing winds. Investment cost considered is the same as for vegetation planting.	*Schematic example:* 

B.4 Temperature rise

The increase in temperature is recognized as a specific hazard. Its significant impact is notably observed on the condition of asphalt layers in roads and rails in railways. To counter this effect, the replacement or rehabilitation of these elements must be carried out more frequently than standard engineering practices suggest.

During instances of low temperatures combined with strong winds, rail icing can significantly disrupt railway operations, especially in challenging terrains with steeper gradients. Often, conventional sanding methods prove ineffective. In such cases, considering the installation of advanced rail heating systems becomes crucial.