From Risk to Resilience: Assessing Geophysical and Climate Vulnerability and Adaptation Strategies for Transport Infrastructure in the Middle Corridor

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Abstract

The Middle Corridor (MC) is emerging as a strategically important Eurasian transport route, yet its infrastructure faces significant risks from floods, earthquakes, and landslides. This study assesses current and future exposure and risk to railway and road networks using high-resolution hazard, infrastructure, and vulnerability data. This is followed by a corridor-wide cost–benefit analyses (CBA) to evaluate the economic justification of adaptation measures. Results show that pluvial flooding and earthquakes dominate current risks, while landslides are locally critical. Future scenarios indicate increasing flood and rainfall-triggered landslide risks, particularly in Armenia and Georgia. Targeted upgrades and protective measures can substantially reduce damages, highlighting the importance of proactive adaptation to ensure long-term climate resilience and continuity of trade along the MC.

Keywords: Middle Corridor; Climate risks; Adaptation

1. Introduction

The Middle Corridor (MC) has gained strategic importance as a Eurasian trade route, particularly since the Russia–Ukraine war increased demand for alternatives to the Trans-Siberian line. Transport volumes are rising, yet the MC currently handles only 5–10% of the Northern Corridor's capacity (Vasa & Barkanyi, 2023; Walter, 2022), reflecting persistent infrastructure, operational, and geopolitical constraints that require sustained investment and cooperation (Rentschler et al., 2025). At the same time, the impacts of natural hazards on the MC remain unaddressed, though they are critical to consider as today's infrastructure decisions will lock in risks for decades to come.

This study evaluates the exposure and risk of the MC's road and railway infrastructure to climate-related and geophysical hazards, combining asset-level data with hazard and vulnerability information. We then conduct a CBA for the MC, identifying network sections where upgrading is economically justified based on avoided direct damages.

2. Methodology

We conduct a comprehensive assessment of the current and future exposure and risk of the transport networks in the ECA region to floods, landslides and earthquakes. Using detailed railway data and hazard datasets combined with vulnerability datasets, we quantify risk in terms of Expected Annual Damage (EAD), derived from exceedance probability curves linking damages to hazard probabilities.

Flooding is represented by the Fathom V3.0 dataset, including eight return-period maps (1/5–1/1000) at 30 m resolution, with defended historical conditions and two future scenarios (SSP3, SSP5) for 2050 and 2080. Earthquake hazard follows the GIRI maps (Palau et al., 2023), expressed as Peak Ground Acceleration for five return periods (250–2,475 years, ~500 m resolution), combined with liquefaction susceptibility classes (Zorn & Koks, 2019). Landslide is based on GIRI's susceptibility maps (~90 m resolution) for current rainfall and earthquake-triggered landslides, and future rainfall-triggered landslides under SSP1-2.6 and SSP5-8.5, in combination with information on hazard-triggering conditions.

The transport network is derived from OpenStreetMap (OSM) in combination with internal data. Vulnerability estimates (Nirandjan et al., 2024) and construction values from the World Bank and Asian Transport Outlook underpin the risk modeling, expressed in constant 2020 USD.

Investing in the improvement and maintenance of infrastructure can significantly reduce the probability of damage. In this extended abstract, we present preliminary CBA results for railways in Georgia, with plans to extend the analysis to the entire MC. For flooding, we assume that the damage probability for railway tracks can be reduced from 3% to 1% through railway track upgrades.

3. Preliminary results

The MC railway is exposed to multiple hazards, with pluvial flooding accounting for the largest share (43.5%), followed by earthquakes (37.3%) and fluvial flooding (15.1%). Landslides and coastal flooding contribute only marginally. The estimated annual risk amounts to USD 34.7 million for railways and USD 92.7 million for roads (Figure 1). At the national level, flooding dominates risk in most countries, while earthquakes are the primary hazard in Uzbekistan and a major contributor in Kyrgyzstan. Landslide risk is also highest in these two countries, and is the main contributor to road risk in Kyrgyzstan.

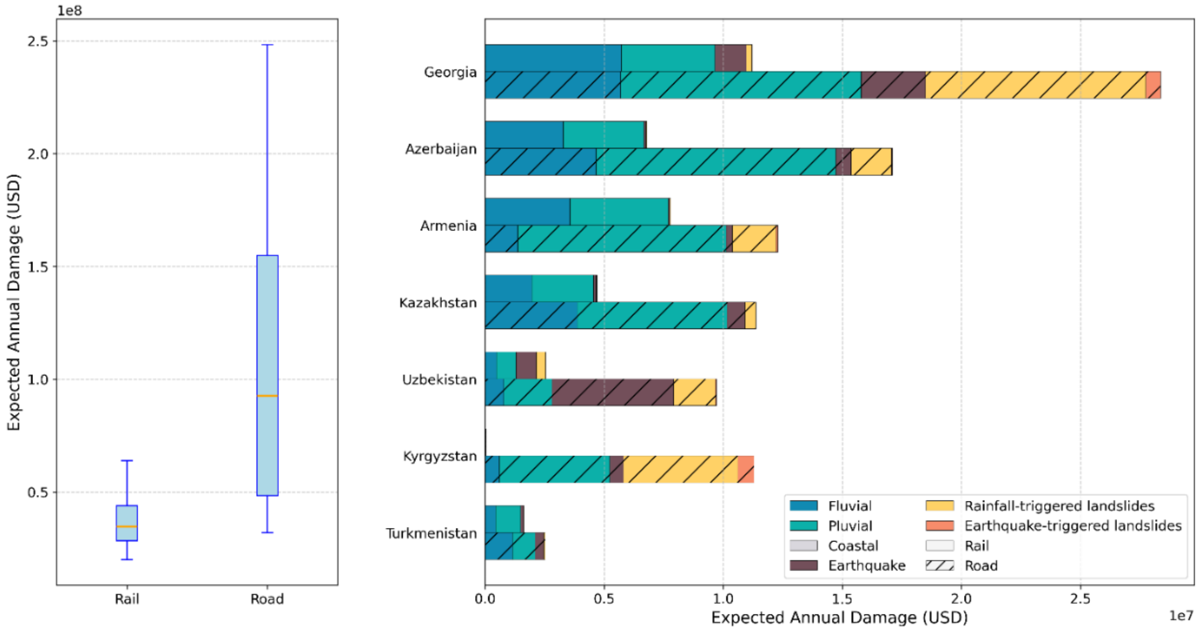

Figure 1. The EAD to the MC railway and the road network relevant for the MC from multiple hazards per country is shown in panel A. Panel B shows the absolute median risk from these hazards.

Flood-related risks, particularly due to pluvial and coastal flooding, to the MC are projected to rise under future climate scenarios. Combined road and rail flood risk amounts to USD 92.3 million under historical conditions, increasing to USD 106–111 million by 2080 under both SSP3-7.0 and SSP5-8.5. The distribution of this risk varies widely across countries and flood types (Figure 2). Rainfall-triggered landslide risks also increase. Total damages rise from USD 20.6 million historically to USD 22.0 million under SSP1-2.6 and USD 25.4 million under SSP5-8.5.

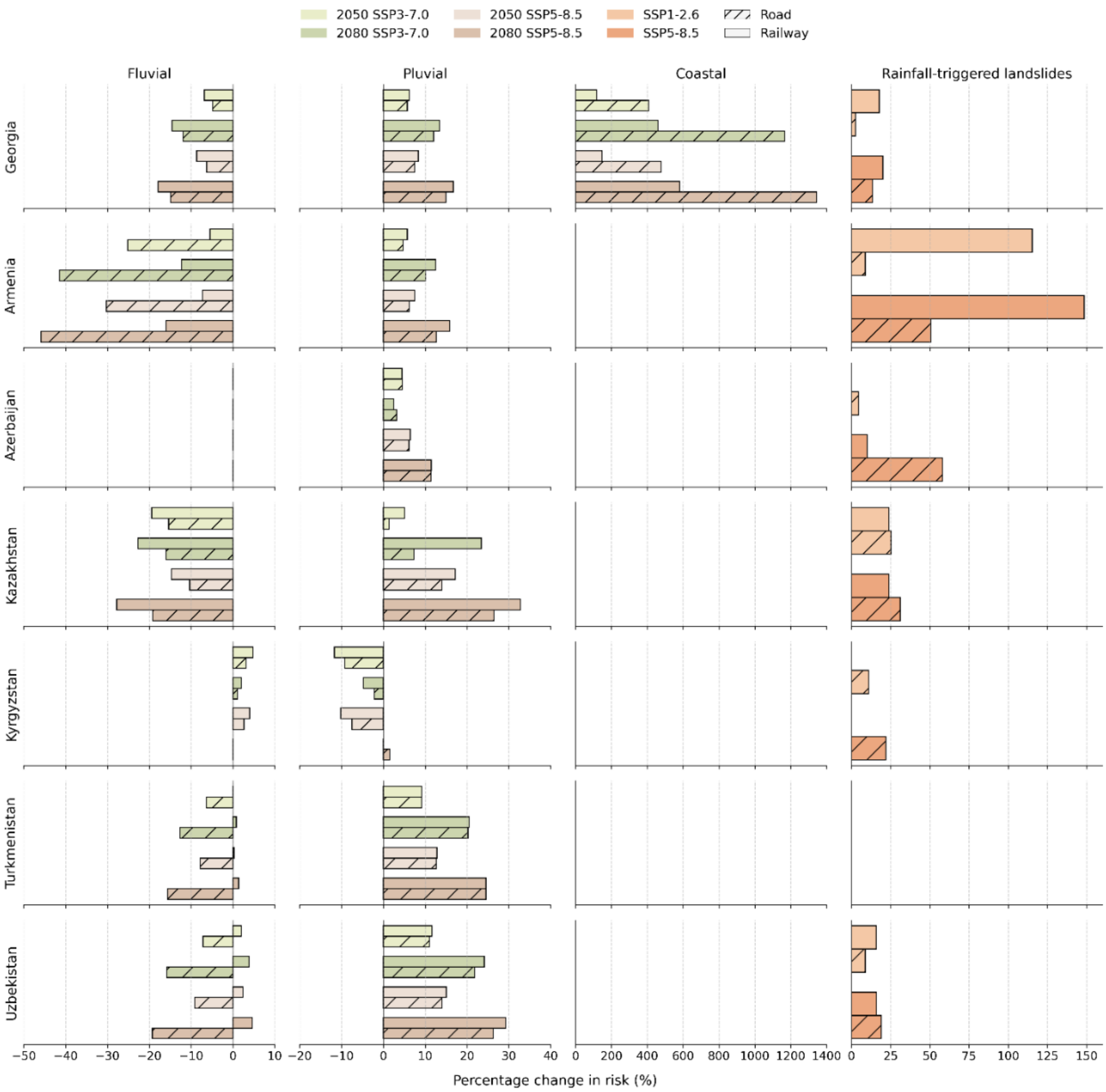

Figure 2. The relative change (%) in road and rail risk for the MC due to fluvial, pluvial, and coastal flooding, as well as rainfall-triggered landslides, across Middle Corridor countries under various future climate scenarios.

Upgrading proves economically viable for 33.4% of the Georgian railway network exposed to flooding (Figure 3). Upgrading 838 km of the railway network, where Benefit-Cost Ratio (BCR) values indicate a positive return, would require an investment of approximately USD 25.2 million and is expected to reduce annual flood-related damages to USD 10.7 million. The total discounted benefits over 15 years is USD 103.7 million.

Figure 3. Spatial distribution of railways in Georgia prioritized for improvement based on economic viability, assuming an investment of 3% of the construction costs, 6% discount rate and a lifetime of 15 years.

4. Discussion and conclusion

The MC railway and road infrastructure face substantial risks from floods, earthquakes, and landslides. Current exposure shows that pluvial flooding and earthquakes dominate the profile, while landslides are highly localized but can be critical for specific segments, particularly in Kyrgyzstan and Uzbekistan. Future climate scenarios indicate a clear upward trend in flood- and rainfall-triggered landslide risks across the MC, whereas the distribution of this risk varies widely across the countries and hazard types. Our study highlights the importance of incorporating hazard assessments into infrastructure planning, as neglecting hazard exposure and risk can lock in long-term vulnerabilities. The CBA suggest that targeted upgrades and protective interventions can substantially reduce risk, offering an economically justified path to enhancing corridor resilience. Overall, risk varies significantly across countries and hazard types, requiring context-specific strategies for effective risk management.

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