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Research Article

ASSESSMENT METHODOLOGY FOR THE SEISMIC RISK OF ANGREN-POP TRANSPORTATION STRUCTURES

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ABSTRACT
This article aims to develop a methodology for assessing the seismic risk of roads and railways in the Angren-Pop area, taking into account hazardous geological processes.

Keywords: *Hazardous geological processes, seismic vulnerability, vulnerability function, linear structures, seismic hazard, seismic impact.*

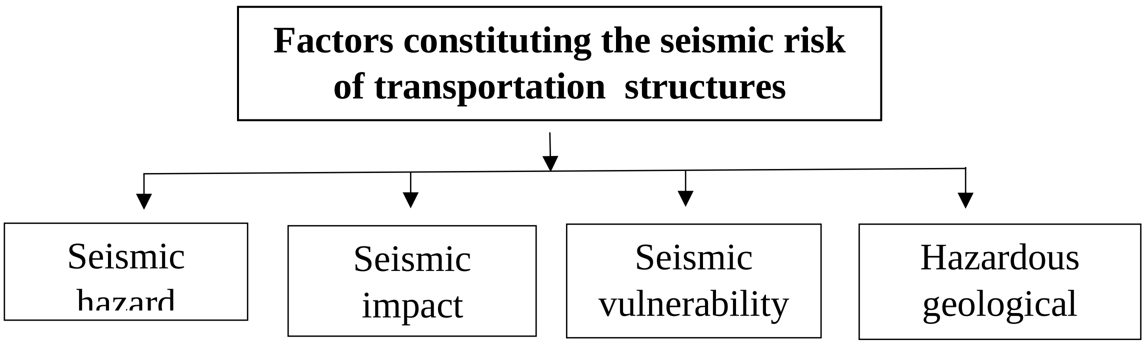
INTRODUCTION

Roads and railways are essential components of any nation's infrastructure system. These transport routes serve as key elements of economic, social, and cultural development, facilitating trade, logistics, and tourism between different countries and regions. Therefore, ensuring the comprehensive safety of areas where roads and railways are located is crucial. In particular, it is necessary to prevent potential damage caused by strong earthquakes and develop measures to mitigate their impact. Thus, assessing the seismic risk of roads and railways holds significant importance, and the first step involves developing an appropriate methodology.

Main Part: Globally, the damages caused by strong earthquakes to areas where roads and railways are located are assessed based on primary (e.g., road cracking, asphalt destruction, deformation or dislocation of railway tracks) and secondary factors (Figure 1) such as hazardous exogenous geological processes triggered by the earthquake. These damages are evaluated in terms of economic and social loss. Taking into account that the Angren-Pop transportation infrastructure is selected as the study area and considering the frequent occurrence of hazardous geological processes in this region, the following four factors were identified (Table1).

Figure 1. Primary and secondary damages to roads and railways caused by earthquakes.

Table 1. Factors constituting the seismic risk of transportation structures



Seismic Hazard-is an indicator representing the likelihood of damage to an area or structure under the influence of an earthquake. It is determined based on the intensity, duration, and frequency of seismic vibrations, as well as the geological conditions of the region. This concept plays a crucial role in assessing the level of seismic risk in a particular area.

Seismic Impact-refers to the movements, vibrations, or stresses occurring in areas with roads and railways as a result of seismic forces.

It is essential to study the geological conditions of the study area, as the propagation speed of seismic waves varies across different types of soil.

Based on the geological conditions of the area, the foothill regions are characterized by Quaternary period deposits formed through proluvial processes. Loess rocks from the Middle Quaternary period (pQ_{II}) are widespread within 15-20 km of roads and railways. The terrain consists of uneven and sloping surfaces. Additionally, the lower Quaternary period ($aQ_{I}gl$) comprises alluvial deposits of loess rocks, with layer thicknesses ranging from 10 to 15 meters. The slope of the terrain generally directs toward the river. The area aligns with the III-IV terraces of the Chirchiq and Ohangaron rivers. The thickness of the loess rocks at the boundary, which includes loam, sand, and gravel, reaches up to 15-20 meters. Groundwater levels are typically deeper than 10-15 meters (Shermatov M.Sh.1979).

The current Quaternary period ($apQ_{IV}sd$) features gravel and gravelly deposits formed through alluvial and alluvial-proluvial processes, situated on the terraces of the Ohangaron, Shavazsoy, Qoraboy, and Dukent rivers. The Tashkent erosional-accumulative cycle ($apQ_{II}ts$) is present on mountain slopes with complex conditions, consisting of rubble layers.

In the deeper parts of the terraces, coarse-grained rocks accumulate due to river and stream sedimentation. Magmatic rocks are also widely distributed, with layer thicknesses ranging from 2-5 meters to 25-30 meters. The groundwater table varies seasonally between 1-2 meters and 25-30 meters. The area is situated in an 8-point seismic zone, and the seismic amplification due to complex engineering-geological conditions is rated between 0 and 0.5 points (Shermatov M.Sh.1979).

In the mountainous part of the region, the main geological formations consist of magmatic rocks from the Paleozoic period, including quartz porphyry, sandstone, and limestone.

Seismic vulnerability of linear structures-such as roads and railways-is defined by the cost of damage caused during an earthquake and the expenses required for repair, relative to the initial construction costs. The vulnerability coefficient ranges from 0 (no damage) to 1 (complete reconstruction) (El-Maissi A. M., *et al.*, 2022).

To determine the seismic vulnerability of roads and railways, it is necessary to develop seismic vulnerability functions. Several methods are available for developing these functions, as described below.

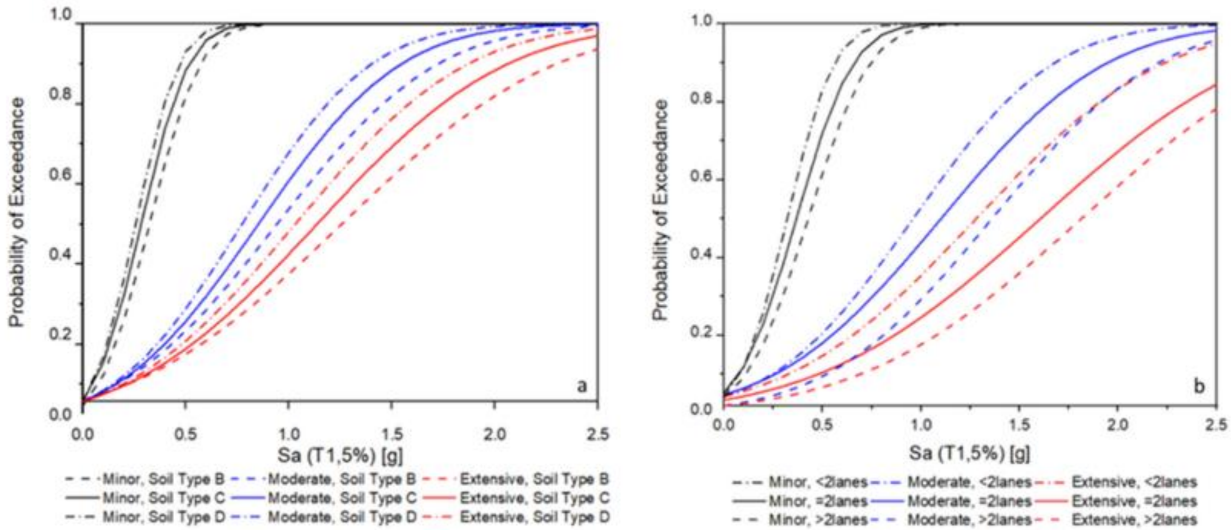


Figure 2. Numerical fragility functions for different roadway assets (a) type of soil and (b) road width (El-Maissi *et al.,* 2022).

Analytical method. The analytical method involves calculations and analyses performed using computer software by architects who are knowledgeable about the construction structures of roads and railways as well as the underlying soil layers. This method allows for the determination of seismic vulnerability through analytical evaluation.

Empirical method. This method is based on post-earthquake macroseismic studies, which evaluate the amount of damage caused to roads and railways by seismic events.

Expert evaluation method. This method involves gathering opinions from experienced professionals through surveys or questionnaires. Each expert provides their assessments and suggestions based on their knowledge and practical experience in testing different structures. However, the reliability of the results can be uncertain, as they depend heavily on the subjective experience of the experts. This method is typically used when analytical and empirical methods are unavailable due to the complexity of calculations or the lack of empirical data (El-Maissi *et al.,* 2020; Anbazhagan *et al.*, 2012.].

Hybrid Method. The hybrid method combines the data and analyses from the three aforementioned methods. It allows for the development of seismic vulnerability functions for roads and railways, even when data from one method is insufficient. In most cases, this approach integrates analytical and empirical data to achieve comprehensive results (El-Maissi *et al.,* 2020; Anbazhagan *et al.*, 2012).

When selecting a method, the completeness, accuracy, and reliability of the collected data must be carefully considered. In this research, the empirical method is used to compile and analyze results from macroseismic studies, leading to the development of a seismic vulnerability function. The relationship between seismic impact and the vulnerability coefficient of linear structures is defined as the vulnerability function.

By knowing the construction costs of roads and railways, and determining the peak acceleration of the ground during an earthquake, the expected damage can be assessed.

The seismic vulnerability function of roads and railways enables the identification of potential damages in specific sections and evaluates secondary impacts caused by hazardous geological processes.

In the Angren-Pop area, the potential damage and seismic vulnerability must consider the influence of hazardous geological processes (HGPs), such as landslides, rockfalls, and debris flows, due to the mountainous terrain and steep slopes (Figure 3).

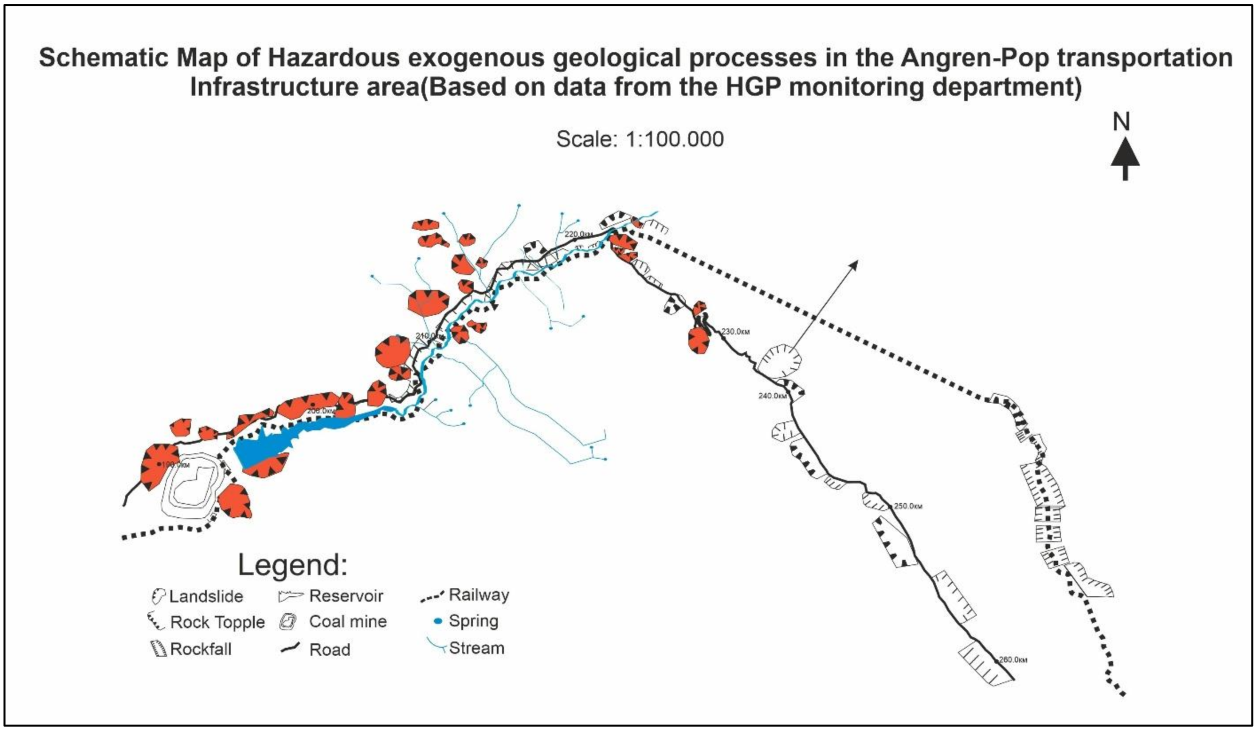


Figure 3. Schematic Map of Hazardous Geological Processes in the Angren-Pop transportation Infrastructure Area (Suvonov Yu. *et al.,* 2020).

In general, hazardous geological processes (HGP) can be classified into several types based on the lithological composition, formation conditions, volume, slope, and other parameters of the affected mass. For the study area, the most common types include rock topples, landslides, and rockfalls. Differentiating between these types requires collecting and analyzing data on the lithology, volume, and slope angles of the displaced or shifted masses, which are then systematically organized.

Using this organized data, it becomes possible to calculate the stability of landslides and the jump distances of rockfalls resulting from earthquakes. The primary goal of these calculations is to assess the hazard levels of landslides, the potential damage distances, and the economic losses quantitatively in the event of a strong earthquake.

Considering the above-mentioned factors and the components of seismic risk for linear structures, a methodology for assessing the seismic risk of the Angren-Pop transportation infrastructure is presented in the following table.

Moreover, this analysis provides valuable insights for infrastructure planning and protection. For example:

Risk Reduction Strategies: Understanding the distribution and characteristics of HGPs allows for the design of protective structures, such as retaining walls, drainage systems, or slope stabilization measures, to minimize the risk of damage to transportation infrastructure.

Seismic Vulnerability Assessment: By evaluating the potential effects of seismic waves on different geological conditions, engineers can improve the structural resilience of roads and railways (Ismailov *et al.,* 2021).

Emergency Preparedness and Planning: Accurate hazard maps and risk assessments help in developing evacuation plans and prioritizing areas for immediate response after an earthquake.

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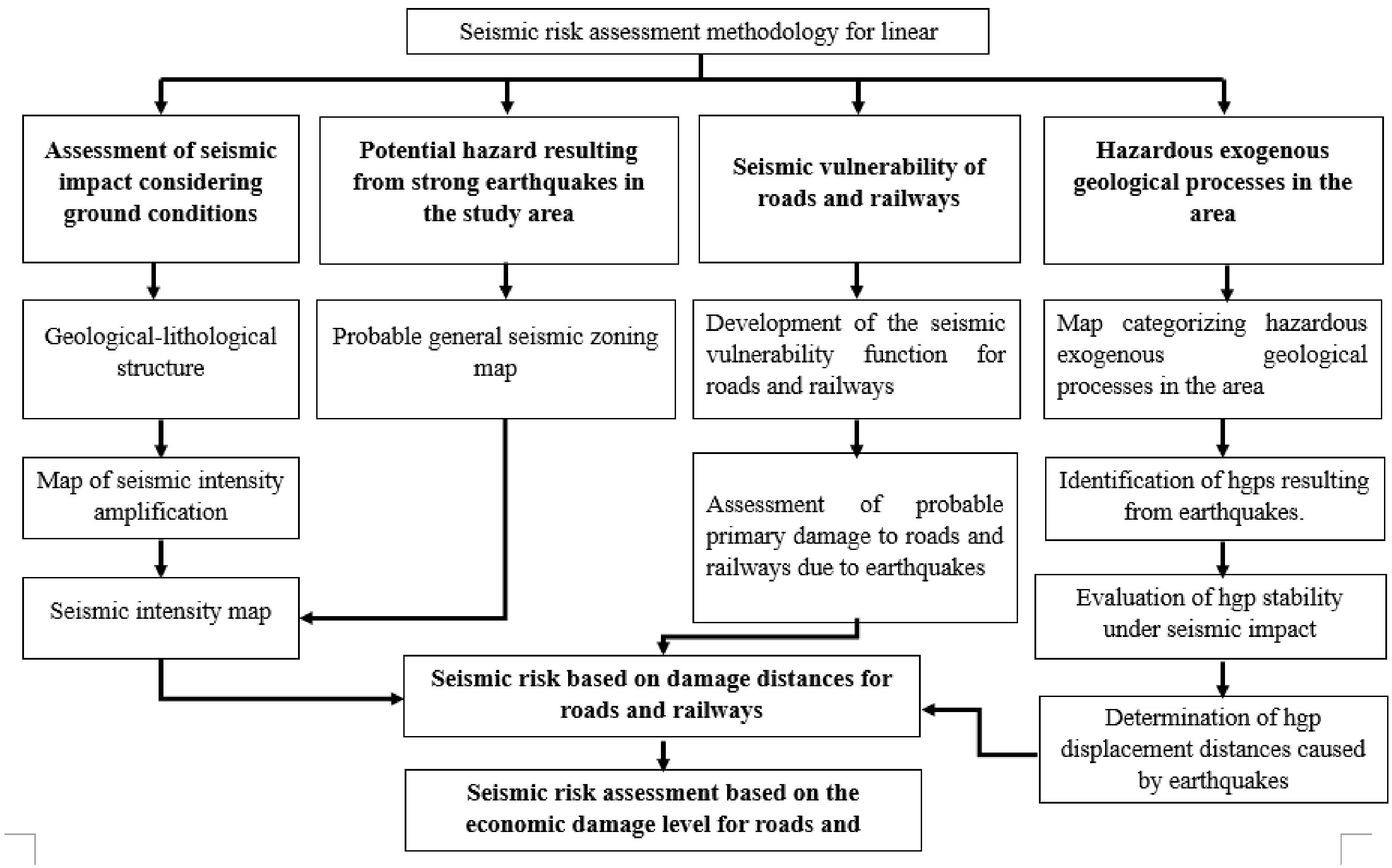
Table 2. Seismic risk assessment methodology for roads and railways



Conclusion The proposed methodology enables the assessment of the seismic risk in the Angren-Pop transportation infrastructure area by evaluating the damage caused by primary and secondary factors in terms of quantity and severity.

A database is created through each stage of the process, and using specialized software, the damage for every kilometer of roads and railways is visualized with varying color codes to achieve detailed results.

In general, seismic risk maps for roads and railways are developed. These maps provide insights into the potential damage caused by primary and secondary factors resulting from strong earthquakes in the region. By identifying areas with higher or lower risk, appropriate measures can be implemented to prevent significant losses.

Each stage's results require the development of specific measures to protect infrastructure from seismic hazards.

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