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Ranking of risk using the application of the AHP method in the risk assessment process on the Piraeus-Belgrade-Budapest railway corridor

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Abstract

The paper examines the application of the AHP method in risk assessment for the Piraeus-Belgrade-Budapest railway corridor, which is part of the "Belt and Road Initiative". The AHP method is employed to identify, analyze, and evaluate risks in five key areas: security, operational, economic, environmental, and political risks. The analysis includes the assessment of potential threats to infrastructure security, operational efficiency, economic sustainability, and environmental protection. The results are presented in a tabular format, providing insight into risk prioritization and their relative importance. This study contributes to the understanding of the complex challenges accompanying the implementation of major international infrastructure projects, offering a systematic approach to risk management and supporting decision-making within the comprehensive logistics chain connecting Asia and Europe.

Keywords: Risk assessment, AHP method, Piraeus–Belgrade–Budapest railway corridor, Belt and Road initiative.

1. Introduction

A large number of methods have been developed and are continually being developed for risk assessment. Due to the need for its quantification, multi-criteria decision-making methods have found their place in risk assessment. One of the frequently used methods in this field is the Analytic Hierarchy Process (AHP) (Saaty, 1980), which allows for a structured and systematic evaluation of various risks across multiple criteria. Within the global "Belt and Road" initiative, the Piraeus–Belgrade–Budapest railway corridor represents an important infrastructure project of strategic significance for connecting Asia and Europe. This corridor not only serves as an economic

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,,artery” but is also a geopolitically significant link supporting trade and the region's integration into broader global flows.

In this paper, the AHP method is applied in specific phases of the risk assessment process for the aforementioned railway corridor, with a focus on five groups of risks: security, operational, economic, environmental, and political. Through the analysis of these risks using the AHP method, a detailed evaluation and prioritization of risks were conducted, which is essential for risk management in such complex infrastructure projects. Proper risk management is key to the long-term success and sustainability of this ambitious project (Huang et al., 2018).

The aim of this paper is to contribute to a better understanding of the risks along the Piraeus–Belgrade–Budapest railway corridor within the "Belt and Road" initiative and to provide a foundation for decision-making that will minimize negative impacts on project implementation. This analysis highlights the need for a proactive approach to risk management, ensuring the successful implementation and integration of the corridor into the global transport network.

2. The significance of the Piraeus–Belgrade–Budapest railway corridor within the ,,Belt and Road” initiative – problem description

The Piraeus–Belgrade–Budapest railway corridor (Figure 1) is one of the key projects within China's "Belt and Road Initiative" (BRI). This corridor, which connects the port of Piraeus in Greece with Central Europe via Serbia and Hungary, is significant not only for the countries it traverses but also for the broader geopolitical and economic context. The Port of Piraeus, managed by the Chinese company COSCO[1], has become a major entry point for Chinese goods transported to Europe, while the railway network enables fast and efficient transport to the central parts of the continent.

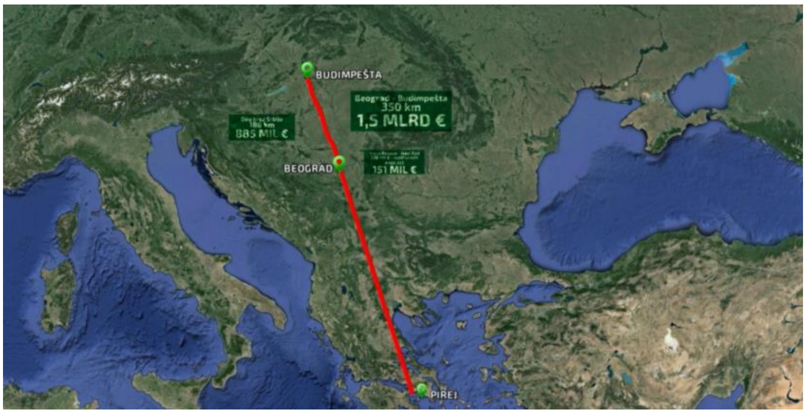

Figure 1. Piraeus–Belgrade–Budapest Railway Corridor
(Source: *https://n1info.rs/biznis/a252708-pirej-i-pruga-do-budimpeste-glavne-kapije-kine-ka-eu/)*

The "Belt and Road Initiative" aims to enhance global trade and economic connectivity through the development of infrastructure projects worldwide. In this context, the Piraeus–Belgrade–Budapest railway corridor plays a crucial role in strengthening trade links between Asia and Europe. This project accelerates the flow of goods, contributes to regional development, increases competitiveness, and improves the logistical capacities of the countries it passes through.

[1] COSCO (China Ocean Shipping Company) is a Chinese state-owned shipping and logistics company. In 2016, COSCO acquired a majority stake in the Greek Port of Piraeus, making it a central hub for Chinese exports to Southern, Eastern, and Central Europe, as well as a key point for maritime transport across the Mediterranean. This acquisition is part of China's broader strategy to strengthen its economic and trade ties with Europe through the "Belt and Road Initiative."

Beyond its economic significance, the Piraeus–Belgrade–Budapest railway corridor has substantial geopolitical implications. The development of infrastructure that connects China with European markets via the Balkans can be seen as part of China's broader strategic goal to strengthen its influence in Europe and on the global stage. At the same time, countries such as Serbia, Greece, and Hungary gain significant economic benefits and strengthen their political standing through closer cooperation with China (Gul and Ak, 2018).

In the context of the "Belt and Road Initiative," the Piraeus–Belgrade–Budapest corridor can be viewed as both a symbolic and practical example of cooperation between China and Europe. Its construction and implementation highlight China's growing role in shaping global economic and political flows, further solidifying its status as a global power (Gul, 2018). This project also underscores the importance of the Balkans as a bridge between East and West, a region that has historically played a pivotal role in connecting diverse cultures and economic zones (Ghaderi and Burdett, 2019).

The realization of this project faces numerous challenges that may jeopardize its success. Therefore, risk assessment and management are key factors that need to be carefully considered to ensure the project's long-term sustainability. The geopolitical context, differing national interests, and the need for significant infrastructure investments represent serious obstacles. Additionally, risks related to operational aspects, such as the efficiency of transportation systems, railway safety, and environmental impacts, must be thoroughly analyzed and managed. These risks require a systematic and structured approach to be identified, analyzed, and mitigated in a timely manner.

3. The Analytic hierarchy process (AHP) method

The Analytic Hierarchy Process (AHP) is used in various fields to solve complex problems through multi-criteria decision-making (Badi and Abdulshahed, 2021). This method enables the precise quantification of subjective assessments and decision-making in projects that require comprehensive analysis (Božanić et al., 2023). Its application in risk assessment allows for an objective and systematic evaluation of different risk factors.

3.1 Overview of the AHP method

The Analytic Hierarchy Process (AHP) is a well-known and widely applied multi-criteria decision-making method developed by Thomas Saaty (1980). This method enables a structured and systematic evaluation of complex problems through the hierarchical organization of goals, criteria, and options (Biswas et al., 2025; Đukić et al., 2022). AHP is used in various fields, such as risk management, strategic planning, and resource allocation, as it facilitates decision-making based on multi-criteria analysis.

The core principle of the AHP method is pairwise comparison, where elements at each level of the hierarchy are compared to one another based on specific criteria (Elraaid et al., 2024; Radovanović et al., 2023). This process provides quantitative results that allow for the ranking of options according to their importance (Pamučar et al., 2012). Since the method is well-researched and frequently applied in practice, this paper will not focus on its theoretical foundation but rather on its application in the specific context of risk assessment.

3.2 Advantages of applying the AHP method in risk assessment

The application of the AHP method in risk assessment offers numerous advantages, particularly in the context of complex infrastructure projects. First and foremost, AHP facilitates structured and systematic risk analysis, enabling decision-making based on multi-criteria evaluation (Bobar et al., 2020). This method provides a framework for quantifying subjective assessments through pairwise comparison, thereby increasing the objectivity of the decision-making process and minimizing the influence of individual biases.

One of the key advantages of using the AHP method in risk assessment is its ability to integrate and analyze heterogeneous risk factors, such as security, operational, economic, environmental, and political risks, allowing for their prioritization based on importance (Ghaderi & Burdett, 2019). This flexibility allows for application at different stages of the risk assessment process, ensuring a comprehensive analysis that encompasses both qualitative and quantitative aspects (Hu et al., 2019).

Moreover, AHP enhances the transparency and traceability of decisions, as it clearly defines the process from the establishment of criteria to the final evaluation (Qian et al., 2024). This approach facilitates communication among relevant stakeholders and enables consensus-based decision-making, which is particularly important for projects involving multiple parties. In this way, the AHP method contributes to better risk management, reduces uncertainty, and improves the chances of long-term success and sustainability of the project.

4. Identification of risks on the Piraeus-Belgrade-Budapest railway corridor within the „Belt and Road” initiative

The Piraeus–Belgrade–Budapest railway corridor, part of China’s "Belt and Road" initiative, faces significant risks that could affect its initial implementation, as well as its operational efficiency, long-term sustainability, and geopolitical stability in the region (Mladenović et al., 2024). These risks encompass all aspects of the complexity of international infrastructure projects and require careful planning and proactive management to ensure the successful realization of the project (Khalilzadeh et al., 2024). The risks can be classified into several main categories: security, operational, environmental, economic, and political, each of which has the potential to significantly impact the overall dynamics and functioning of the corridor.

4.1 Security risks

Security risks pose a serious threat to the continuity and safety of the implementation and operation of the railway corridor. In the context of such projects, security risks encompass a wide range of potential dangers that could severely jeopardize not only the physical infrastructure but also operational processes, the safety of employees and users, as well as the continuity of transportation activities. Some of the key security risks, with the note that these examples represent only a portion of possible scenarios, include:

- *Terrorist attacks:* The corridor, as an infrastructural link between Asia and Europe, could be a target for terrorist groups aiming to disrupt trade flows or destabilize political relations. An attack on the railway infrastructure could seriously endanger the transport of goods and people, with significant consequences for the economy and regional stability.
- *Theft and vandalism*: These threats particularly affect segments passing through less urbanized or politically unstable regions, where surveillance is limited. Theft of materials or equipment, as well as vandalism of infrastructure, could result in significant costs and delays in the operation of the corridor.
- *Inadequate maintenance:* Regular and quality maintenance is crucial for the safety of transport systems. If maintenance is not performed adequately or promptly, the risk of failures, accidents, and operational delays increases, potentially endangering the safety of users and the flow of goods.
- *Human error:* The human factor always presents a risk in managing complex transport systems. Operator or worker errors can lead to serious incidents, including accidents on the tracks, delays in transport, or incorrect allocation of resources.
- *Sabotage:* Deliberate acts of sabotage by local or international actors represent a significant risk, especially in politically unstable regions. Sabotage of infrastructure can be motivated by political, economic, or social reasons and could have far-reaching consequences for the corridor's operation.

4.2 Operational risks

Operational risks refer to the functional challenges that can threaten the daily operation of the railway corridor. These risks encompass a range of technical and organizational issues that can negatively affect the efficiency and reliability of transportation activities. Some of the key operational risks, with the note that these examples represent only part of the possible scenarios, include:

- *Unexpected failures:* Technical failures on trains or infrastructure, such as signaling issues or mechanical breakdowns, can cause significant delays and disruptions in the transport system. These problems can severely affect the accuracy and continuity of goods and passenger transport, leading to additional costs and delays.
- *Poor logistics organization:* Inefficient coordination between different operators, especially when international borders and varying jurisdictions are involved, can lead to bottlenecks and disrupt the corridor's functionality. Logistical problems, such as untimely deliveries or poorly coordinated schedules, can negatively impact the speed and reliability of the entire system.
- *Delivery delays:* Border controls, customs procedures, and unforeseen administrative or legal issues in the countries through which the corridor passes can result in significant delays in the transport of goods. These delays can disrupt the supply chain and cause dissatisfaction among end-users.
- *Misalignment of technical standards:* Different technical standards between the countries along the railway corridor, including discrepancies in signaling systems, track gauges, or safety protocols, can create significant operational challenges. These differences can reduce system interoperability, requiring additional resources to adjust technical aspects at each segment of the route.
- *Maintenance issues:* A lack of regular infrastructure maintenance can reduce system efficiency and increase the risk of failures, accidents, or disruptions. Inadequate maintenance can also decrease the long-term sustainability of the railway corridor, raising repair costs and the risk of serious incidents within the transport system.

4.3 Environmental risks

Environmental risks refer to the impact of the railway corridor on the environment, which can lead to long-term consequences. These risks include potential disruptions to ecosystems, pollution, and other negative effects that may arise from the construction and operation of the corridor. Some of the key environmental risks, with the understanding that these examples represent only part of the possible scenarios, include:

- *Air pollution:* Increased use of trains and transport activities can raise emissions of harmful gases, negatively affecting air quality. Prolonged exposure to these emissions can have significant consequences for the environment and human health, especially in densely populated areas.
- *Impact on local ecosystems:* The construction and operation of the corridor disrupt the ecological balance, leading to the destruction of habitats and threatening biodiversity in the regions through which the railway passes (Ilbahar et al., 2018). This disruption may cause irreversible damage to flora and fauna.
- *Noise pollution:* The passage of trains through populated areas can generate high levels of noise, which may negatively impact the quality of life for local residents. Prolonged exposure to noise pollution can cause health problems, such as stress and sleep disturbances, particularly in communities near the railway.
- *Water pollution:* During the construction or operation of the corridor, there is a risk of contaminating local water resources, including rivers and underground water supplies. Such pollution can affect both the local environment and the availability of clean water for nearby communities.
- *Climate change:* Changes in climatic conditions, such as extreme weather events, can negatively impact the operational efficiency and safety of the railway. Increased flooding, heat waves, or storms can damage infrastructure and disrupt transport services, complicating long-term sustainability planning for the corridor.

4.4 Economic risks

Economic risks refer to the financial aspects of the project and can significantly impact its long-term sustainability. These risks include market changes, fluctuations in costs and demand, as well as political and economic factors that may complicate the project's realization. Some of the key economic risks, with the understanding that these examples represent only part of the possible scenarios, include:

- *Fluctuations in material prices:* Sudden changes in the prices of construction materials can increase the project's costs and significantly jeopardize its budget. These changes may lead to cost overruns and construction delays.
- *Currency exchange rate changes:* Volatility in currency markets can negatively affect international contracts and financial transactions related to the project. A sudden drop or rise in currency value can lead to additional costs or reduced revenues, threatening the project's economic sustainability.
- *Increase in labor costs:* Unexpected increases in labor costs, whether due to inflation, increased demand for labor, or changes in legislation, can place additional pressure on the project's budget and hinder its timely and financially sustainable completion.
- *Political changes affecting financing:* Changes in governments or political relations between countries can influence the availability of financial resources and the conditions under which the project is carried out. This uncertainty can undermine financial stability, particularly if international political relations or investment priorities shift.
- *Changes in demand:* Fluctuations in the demand for goods transportation, whether due to changes in global trade flows or economic recessions, can negatively impact the corridor's economic viability. A decrease in demand may reduce revenues, while an unexpected increase in demand may overwhelm the corridor's capacity.

4.5 Political risks

Political risks refer to challenges related to geopolitical and legal aspects that can affect both the implementation of the project and its long-term functioning once the corridor is built and operational. These risks encompass potential disruptions arising from changes in international relations, political interests, and regulatory frameworks. Some of the key political risks, with the understanding that these examples represent only part of the possible scenarios, include:

- *Geopolitical tensions:* Once the corridor is operational, changes in international relations, including tensions between states, can seriously jeopardize its long-term functionality. The escalation of conflicts or economic sanctions may lead to disruptions in transport or restrictions on access to certain countries.
- *Regulatory changes:* Shifts in legislation or regulatory frameworks in the countries through which the corridor passes may affect its compliance with local regulations and rules. This could lead to operational challenges, ranging from the introduction of new customs rules to restrictions related to safety or environmental standards.
- *Conflicting national interests:* After the corridor is operational, differing political or economic interests among the countries it crosses could create obstacles to its efficient operation and development. Varying views on the use of infrastructure, transport priorities, or economic policies may lead to disagreements and slow down operations.
- *Dependence on international policies:* The corridor's operations could be heavily influenced by international policies, including sanctions, trade restrictions, or changes in strategic partnerships. Such changes may limit access to key markets or increase transportation costs.

- *Corporate influence:* The influence of large international corporations or lobbying groups could impact political decisions directly affecting the corridor's operations. The interests of powerful stakeholders may pressure governments to change laws or working conditions in favor of certain companies, potentially altering the balance of the corridor's operations.

The identification of various types of risks associated with the Piraeus–Belgrade–Budapest railway corridor, as part of the "Belt and Road" initiative, highlights the complexity of realizing such a significant infrastructure project. From the implementation phase to everyday operations, this corridor faces a range of security, operational, environmental, economic, and political challenges, each of which can significantly affect its long-term sustainability and success. Careful planning and proactive risk management are essential to mitigate potential issues and ensure that the corridor operates successfully as a vital transportation link between Asia and Europe.

5. Application of the AHP method in risk analysis and assessment on the Piraeus-Belgrade-Budapest railway corridor corridor within the ,,Belt and Road" initiative

In the following section, the AHP method was applied to systematically analyze and evaluate various types of risks associated with the Piraeus–Belgrade–Budapest railway corridor, which is part of China's "Belt and Road" initiative. The AHP method enables decision-makers to rank and prioritize risks according to their relative importance, thereby facilitating strategic decision-making related to risk management in this complex international infrastructure project.

The AHP method follows several key steps:

1. *Identification of goals and criteria* – The primary risk assessment goals are identified, and criteria are defined based on which the risks will be evaluated.
2. *Pairwise comparison between criteria and specific risks* – The criteria (security, operational, environmental, economic, and political risks) are compared with one another, and then specific risks within each group are compared, assigning scores based on their importance.
3. *Weight allocation and normalization of results* – After the pairwise comparison, weights are assigned to each criterion, which are then normalized to obtain an overall picture of each risk's relative significance.
4. *Risk ranking according to their relative importance* – Based on the assigned weights, a hierarchy of risks is created. This allows for the identification of the most critical threats that require immediate attention and those that can be addressed with fewer resources.

Through the analysis in this section, the goal is to identify the risks that most threaten the project and, based on the results, to assign priorities for their resolution (Gul, 2018). This method is not just a theoretical framework but a practical tool that provides transparent and precise insight into which risks are the most important and require urgent interventions, and which can be addressed with fewer resources or at later stages of the project.

5.1 Establishing the hierarchical structure for risk assessment

In this paper, the AHP method was applied through a hierarchical structure consisting of three levels:

- *Goal:* Assessment and ranking of risks based on their impact on the implementation and long-term sustainability of the railway corridor.
- *Criteria:* Five main categories of risks – security, operational, environmental, economic, and political risks.
- *Specific Risks:* Each risk group is divided into specific threats that were identified in Chapter 4 of this paper.

5.2 Pairwise comparison of criteria and weight assignment

The assignment of weights to risk groups and specific threats was carried out through pairwise comparison, which is the core of the AHP method. Pairwise comparison allows risks to be compared against one another, assessing them based on relative importance. The ratings are assigned on a scale from 1 to 9, where 1 indicates equal importance between two risks, while 9 signifies that one risk is significantly more important than the other.

Based on the pairwise comparison, a matrix was created representing the relative weights for each risk group (Table 1). These weights were assigned using empirical data from similar infrastructure projects, expert opinions, and a review of relevant literature.

Table 1. Pairwise comparison and weights for main risk groups

Risk group	Security risks	Operational risks	Environmental risks	Economic risks	Political risks	Weight (%)
Security risks	1	3	5	7	8	40%
Operational risks	1/3	1	3	5	7	30%
Environmental risks	1/5	1/3	1	3	5	15%
Economic risks	1/7	1/5	1/3	1	3	10%
Political risks	1/8	1/7	1/5	1/3	1	5%

5.3 Ranking of specific risks within groups

After assigning weights to the main risk groups, a pairwise comparison of specific risks within each group was conducted. This allowed for the ranking and prioritization of specific threats, providing a more precise insight into which risks should receive the most attention during the implementation and operational phases of the corridor.

Table 2. Ranking of specific risks within the main groups

Specific Risks	Risk Group	Weight (%)
Terrorist attacks	Security Risks	20%
Sabotage	Security Risks	12%
Theft and vandalism	Security Risks	8%
Technical failures	Operational Risks	15%
Poor logistics organization	Operational Risks	12%
Air pollution	Environmental Risks	10%
Fluctuations in material prices	Economic Risks	7%
Geopolitical tensions	Political Risks	5%

Table 2 presents the specific risks within each main group. For example, terrorist attacks and sabotage are identified as the greatest threats within the security risks, while technical failures and logistical inefficiencies are key operational challenges.

Based on the application of the AHP method, the risk assessment for the Piraeus–Belgrade–Budapest railway corridor provides a comprehensive overview of the risks that could threaten this infrastructure project. This approach facilitates the identification of the most significant risks and offers a detailed framework for resource allocation according to priorities, enabling better risk management. The AHP method, with its focus on risk ranking and quantification, improves the decision-making process, making it more systematic and grounded in objective data.

6. Results and discussion

The results of applying the AHP method in the risk analysis and evaluation clearly indicate that security risks, particularly terrorist attacks and sabotage, are the most significant factors that could threaten the long-term success of the Piraeus–Belgrade–Budapest railway corridor. These risks carry the highest weight because any threat targeting critical infrastructure could lead to a disruption in transport activities, with significant consequences for the economy and regional stability. Security risks, in the context of this infrastructure project, can also have geopolitical implications, as destabilization in one region could affect broader international trade flows.

Operational risks, such as technical failures and inadequate logistical organization, also rank highly in the analysis. In complex supply chains, issues with infrastructure or coordination between different operators can lead to significant delays, losses, and interruptions in the delivery of goods. The efficiency of logistics processes directly impacts the sustainability of the corridor, underscoring the need for continuous monitoring and improvement of technical and operational efficiency.

Environmental risks, such as air pollution, are becoming increasingly important in the global context of environmental preservation. The increased use of transport systems can contribute to higher emissions of harmful gases, further burdening the project's environmental sustainability. Therefore, it is necessary to integrate strategies to reduce emissions, which may include the use of environmentally friendly technologies and the implementation of international environmental protection standards.

Economic and political risks, although ranked relatively lower compared to security and operational risks, should not be overlooked. Instabilities in currency markets, changes in demand, or political shifts in the countries through which the corridor passes can have long-term consequences on the economic success of the project. For these reasons, continuous monitoring of political and economic conditions, as well as quick adaptability to changes, are crucial for the long-term sustainability of the railway corridor.

This analysis shows that proactive management of security and operational risks is of utmost importance for ensuring the continuity and long-term success of the project. Additionally, environmental risks require special attention to mitigate their negative impact, while economic and political risks are essential for the project's long-term sustainability. Through the systematic application of the AHP method, decision-makers can better understand the interrelationships of these risks and direct resources towards the most critical threats.

5. Conclusion

The paper provides an overview of the risks associated with the Piraeus–Belgrade–Budapest railway corridor, which is part of the global ,,Belt and Road” initiative. Through the application of the Analytical Hierarchy Process (AHP), risks were analyzed in five categories—security, operational, environmental, economic, and political—to facilitate their ranking and prioritization in the decision-making process.

The AHP method enabled a structured assessment, highlighting security and operational risks as the most significant factors for the long-term success of the project. Identifying and analyzing these risks provide decision-makers with clear guidelines for optimal resource allocation and timely responses to potential threats. Additionally, environmental, economic, and political factors, though ranked lower, remain crucial for the project's long-term stability and success.

The conclusion of this analysis is that a comprehensive and proactive approach to risk management enhances coordination among all stakeholders involved in the project, allowing this important infrastructure endeavor to integrate into the global network with minimal obstacles.

Thanks to the application of the AHP method, it was possible to clearly determine which groups of risks should be treated as priorities to minimize their negative effects. This method helps direct resources and activities towards those risks with the greatest impact.

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