Identification of economic risks of investment projects of mainline railway transport infrastructure construction

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Abstract. Study of the issues of identification, analysis, and comparative assessment of the risks of violations of the safety of the main railway transport infrastructure. The aim of the study: is to develop a methodology for the identification of economic risks of investment projects of construction of mainline infrastructure of railway transport. The object of the study: railway transport enterprises involved in all stages of the life cycle of the mainline infrastructure of railroad transport. The subject of the study: tools and procedures for the identification of economic risks of violations of the security of trunk railway transport infrastructure. In the turbulent global economy, the effectiveness of project management is based on the perception of the human factor as the main in the formation of aggregate uncertainty. Large infrastructure companies should pay special attention to the identification, analysis, and assessment of project risks. One of the key figures in Russia's transport communication, influencing not only domestic traffic flows, but also international logistics chains, is JSC "Russian Railways". Disruptions of the transportation process due to the realization of risks at the main infrastructure facilities of JSC "Russian Railways" predetermine economic consequences both for consumers of services, operators, and infrastructure owners.

1 Relevance of the study

The world management practice is gradually coming to the project management models from the classical hierarchical management. According to observations of Antonio Nieto-Rodriguez [1] "already by 2025 in all industries and sectors of the economy, top managers will spend not less than 60% of their time on projects: to select, prioritize, direct the implementation".

Projects act as a guarantor of value creation and implementation of changes. Both Asian countries (e.g., China, and South Korea) and most Western countries (e.g., Germany) provide about 40% of the turnover through projects [1].

It is project work that builds its vector toward society, the team, and the individual. All kinds of technology also work for the implementation of projects, because with their help it

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is possible to make more effective decisions. This type of management has proven itself through the team's coordinated work for outcomes.

In the turbulent global economy, the effectiveness of project management is based on the perception of the human factor as the main in the formation of aggregate uncertainty.

Large infrastructure companies should pay special attention to the identification, analysis, and assessment of project risks.

One of the key figures in Russia's transport communication, influencing not only domestic traffic flows, but also international logistics chains, is JSC "Russian Railways".

Disruptions in the transportation process due to the realization of risks at the main infrastructure facilities of JSC "Russian Railways" predetermine the economic consequences both for consumers of services, operators, and infrastructure owners. Several studies in terms of justification of innovations, and project management in the field of safety and efficiency of railway traffic [2-19] do not fully take into account the specifics of the unique object under study. The existing methodologies need to be refined and continue to be tested.

However, to ensure the accuracy and reliability of the estimates, scientific approaches should be used that allow the building of cash flow models adequately to the real conditions of implementation. It is necessary to take into account the peculiarities of the objects of the main railway transport infrastructure with traffic safety, which determines the prerequisites of the relevance of the research.

Purpose of the study: building a map of the risks of disruption of the transportation process and economic losses on the mainline infrastructure of rail transport.

The object of the study: the enterprises of railway transport involved in all stages of the life cycle of the mainline infrastructure of railway transport.

The subject of the study: tools and procedures for identifying economic risks of violations of the safety of mainline infrastructure of railway transport.

2 Research Objectives

1. Formulation of the concept: economic risks of investment projects of construction of mainline infrastructure of railway transport.
4. Approbation of the methodology on the example of the ESSI.
5. Conclusions and recommendations for applying the methodology.

3 Research Methodology

In the study, it is accepted that the economic risk of investment projects of mainline railway transport infrastructure construction is a combination of individual and aggregate risks, expressed through the impact of uncertainty on the economic outcomes of the project under conditions of restrictions on the safety of transportation activities.

Individual project risk is an uncertain event/condition whose occurrence negatively affects one or more project objectives.

Cumulative project risk is the impact of uncertainty on the project as a whole, arising from any sources of uncertainty, including individual risks that represent the negative impact of the effects of variations in project outcomes on stakeholders.

Risk management includes the most important stage-risk identification. The effectiveness of risk assessment and mitigation measures largely depends on the risk identification phase.
Risk identification is the process of identifying individual project risks, as well as sources of aggregate project risk, and documenting their characteristics.

![Sequence of identification procedures](image)

**Fig. 1.** Sequence of identification procedures

Let's note that documentation of characteristics is the outcome of the conducted research, expressed in the form of the risk register. The probability and impact matrix is also the outcome of risk identification, but it is made at the stage of risk management planning.

For all types of mainline railway infrastructure facilities management projects, it is necessary to consider systems of economic risk identification.

Thus, the identification of economic risks in the conditions of safety on the main railway infrastructure includes risk analysis:
- Technical risk (technologies, technical processes);
- Construction risk (includes all elements of design and construction activities, including:
  - Geotechnical risk (topographic, engineering-geological, and hydrological conditions of the construction site area);
  - Operational risk (all facility operation processes, including monitoring, control, and troubleshooting of software automated control systems of the facility);
  - Management and executive risk (project management decisions and processes);
  - Social risk (the legitimacy of the project);
  - Contract risk (all processes related to the conclusion of the contract and the bidding process);
  - Commercial risk (suppliers and partnerships);
  - External risk (legislation, exchange rates, and rates, competition)

This stage allows you to move consistently to the identification of risks. It is recommended to use the framework hierarchical structures (as a template) with subsequent refinement. The list of categories or structures is based on the goals of the project.

To categorize the risks of the main railway transport infrastructure, let us formulate options for the project objectives by the example of the reconstruction of transport tunnels (Figure 2):
Obtaining a net profit from the increase in throughput capacity under conditions of safety constraints during construction and operation and facility (C1);
- Maintaining the profitability indicators of the operation of the object under conditions of security restrictions during the construction and operation phase and the object (C2);
- Exclusion of losses from the operation of the object in conditions of safety limitations during the construction and operation phase and the object (C3);

The hierarchical structure of RBS risks for the main railway transport infrastructure reflects the main sources and the feasibility of taking into account economic risks depending on the stated objectives of the project is noted.

The risk assessment process is a step-by-step process, with each step specifying which actions and methods are to be performed.

It is recommended that the risk analysis process begins by identifying the risk tolerance category for each facility, keeping in mind the following definitions:
- Negligible risk - the risk at which the possible value of losses, insignificantly affects the cost of erecting the object;
- Acceptable risk - the risk at which the investor, customer, or designer can accept the possible cost of loss;
- Conditionally acceptable risk - the risk at which the possible cost of losses the investor can allow to prevent an abnormal situation will cost more;
- Unacceptable risk - the risk, prevention of which is necessary regardless of the cost.

The ALARP method is often used to assess risk tolerance. This method implements the principle of "reasonably feasible", in which the condition of risk acceptability or tolerability is the extent to which the costs to reduce the risk are reasonable. In doing so, the ALARP method implies reducing the risk to the lowest possible level. This method is often used to manage railway risks. With the measures taken, the risk should be reduced to the acceptable values indicated in the yellow rectangles of the diagram:
Determine the economic risks should be based on the number of financial losses that the organization can afford. It is recommended to assign the level of risk tolerance no higher than the rate of profit, laid on the implementation of the object. On average, this figure can range from 6 to 15% of the estimated cost of the object. The level of risk neglect should be taken as 1% of the risk tolerance level.

The concept of economic risk is taken as the product of the severity of the consequence and the probability of its occurrence.

Thus, it includes direct financial losses for repair and restoration work, losses due to delays in commissioning the facility, and losses due to third-party compensation, which includes interruptions in train traffic.

The levels of risk tolerance about the rate of return and the relationship between the estimated profit standards of railway construction facilities and risk levels are shown in Figures 4 and 5.
Based on the proposed levels of risk, a risk matrix was developed. As reference points for the construction of the matrix of economic risks, the levels of risk tolerance and negligibility were taken.

So, the risk level of negligence of 1% of the value of the object corresponds to losses of 100% of the value of the object with a probability of consequences of 0.01. In this case, financial losses for the facility include losses for all consequences calculated in the cost of repair and restoration work on the facility, delays in the timing of commissioning the facility, losses of a third party (in this case JSC "Russian Railways") from damage to structures and infrastructure affected by work on the facility and disruptions in train traffic caused by delays.

The economic risk matrix (including direct costs of elimination and restoration of risk, delay of work, and compensation to third parties) is presented in Table 1.
Table 1. Economic Risk Matrix using the ESSI as an example.

<table>
<thead>
<tr>
<th>Likelihood of consequences</th>
<th>The severity of the consequences in % of the value of the object</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>300%</td>
</tr>
<tr>
<td></td>
<td>10000%</td>
</tr>
<tr>
<td>1*10^{-1}</td>
<td></td>
</tr>
<tr>
<td>6*10^{-2}</td>
<td></td>
</tr>
<tr>
<td>3*10^{-2}</td>
<td></td>
</tr>
<tr>
<td>1*10^{-2}</td>
<td></td>
</tr>
<tr>
<td>6*10^{-3}</td>
<td></td>
</tr>
<tr>
<td>3*10^{-3}</td>
<td></td>
</tr>
<tr>
<td>1*10^{-3}</td>
<td></td>
</tr>
</tbody>
</table>

Unacceptable level of risk
Risk tolerance level
The negligible level of risk

After assessing the numerical value of the degree of each risk should calculate the total risk $R$, possible in the specific conditions of construction and operation of the object, according to the formula:

$$R = \sum_{j=1}^{m} p_j \cdot \mathbb{Y}_j$$ (1)

Where $p_j$-probability of occurrence of possible risk events, $j = 1,2,...$ $m$–number of possible risk event options, $\mathbb{Y}_j$ is the mathematical expectation of the damage of the $j$-th risk event.

Management practice shows that the risk management system based on any of the methods of determining the total risk and used in the periods of design, construction, and operation of railway transport facilities can significantly reduce the possibility of abnormal and emergencies.

As a outcome of statistical processing of experts' opinions, the probabilities of occurrence/occurrence of risk elements (causes, events, consequences), the effectiveness of measures to reduce the probability of occurrence/occurrence of risk elements, as well as the amount of damage from the implementation of consequences, are formed. To each element of risk, the received values of its parameters are assigned. After the multiplication of the corresponding probabilities and the sums of consequences, it is necessary to receive the sizes of private risks, that is risks of realization of the consequences caused by a concrete cause and occurrence of a concrete event (table 2). After that it is necessary to make operations of addition of risks for identical elements of risk (events and consequences), and also the general risk of the Object is defined.

The main task of qualitative risk assessment is to obtain reliable information about the types of risk, their probability, and their cost. The risk assessment map (matrix) is mainly informational in nature.

First of all, measures are developed to reduce the risks. To reduce the probability of the event "damage to permanent and temporary tunnel structures and facilities as a outcome of an earthquake", it is necessary to provide for the installation of deformation and anti-seismic joints in critical places, as well as to consider the special design and technological solutions to increase the suppleness of the lining.

Also, provide for measures to reduce the undesirable effects on the EIS under consideration:
- perform long-term and short-term forecasts of seismic monitoring stations;
- provide equipment with compensating devices;
- ensure that emergency notification, shut down, and life support systems are equipped;
- provide for automated monitoring of geodynamic safety.
Often, the possibility of transferring risks through insurance is subsequently considered. Determine the optimal ratio of the cost of insurance (usually 1-2% of CIR) with the size of the risks based on financial models.

Table 2. Register of economic risks on the example of ESSI.

<table>
<thead>
<tr>
<th>№p</th>
<th>Reason</th>
<th>Probability of causes, d.e.</th>
<th>Adverse event (risk)</th>
<th>Probability of the event, d.e.</th>
<th>Damage /Consequences, e.g.</th>
<th>Probability of consequences, e.g.</th>
<th>Partial probability of consequences, e.g.</th>
<th>Economic risk, % of the value of the object</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Endogenous geodynamics of the massif seismicity 9 points) ПК65+ПК87</td>
<td>0,87</td>
<td>Earthquake damage to permanent and temporary tunnel structures and facilities</td>
<td>0,02</td>
<td>Local breakdown of the structure</td>
<td>0,15</td>
<td>0,0023</td>
<td>0,031</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Failure of engineering systems</td>
<td>0,28</td>
<td>0,0043</td>
<td>0,012</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Disruptions in train traffic</td>
<td>0,38</td>
<td>0,0059</td>
<td>0,009</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The collapse of the face with soil dumping</td>
<td>0,2</td>
<td>0,0031</td>
<td>0,008</td>
</tr>
<tr>
<td></td>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,01</td>
<td>0,0156</td>
<td>0,06</td>
</tr>
</tbody>
</table>

4 Conclusion

The methodology of economic risk identification on the main railway transport infrastructure has been proposed.

1. The concept of the economic risk of projects of construction of mainline infrastructure of railroad transport, reflecting the ratio of the severity of the consequences and the probability of its occurrence, is formulated.

2. The analysis of risk identification practices was carried out and methodological decisions for the construction of identification methods, including the stages of developing a
hierarchical structure of risks, determining the levels of probability and impact, building a matrix of probability and impact, and the formation of the risk register were taken.


4. Approbation of the method by the example of reconstruction of a railway transport tunnel. The main conclusions of the application of the methodology:

Thus, identification is an essential tool for risk analysis and management. For effective project management, current trends in risk management should be relied upon. Risk-based thinking will ensure accuracy at all stages of project implementation.

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