Modern Risk Analysis in the Planning and Implementation of Modernization Projects in Railway Infrastructure

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Abstract—**The implementation of modernization projects in railway infrastructure is accompanied by a number of risks that affect their successful implementation within the planned budget and time. In general, risks are considered as technical, financial, environmental and social. The identification and management of these risks is essential for the successful implementation of the project within the set scope, and this has an impact on the provision of modern and safe rail transport. Modern approaches to detailed planning and risk assessment, as well as the implementation of new monitoring technologies contribute to successful transport projects. The modern approach to risk management devotes a special role to public participation. The goal is to minimize social tension and achieve a better understanding of projects on the part of the population. This study analyzes and improves risk management methods for planning and implementing railway infrastructure modernization projects.**

Keywords — risk management, railway projects, risk assessment, probability of occurrence.

I. INTRODUCTION

Most railway projects have a long planning and implementation period, involving many subcontractors, different interests, a large budget, which makes them vulnerable to a large number of risks. Different sources can lead to this large-scale group of risks. It can be financial reasons, design changes, safety problems, environmental factors, political instability. The larger the projects, the more important risk management becomes for the success of the project. Emerging problems in railway projects usually affect the state.

By definition, projects are a unique activity limited within a certain budget and time, which explains the accompanying risks. There are no risk-free projects. For the successful implementation of the project, early identification of possible risks and their management by minimizing or eliminating them is necessary. Risk avoidance would lead to stagnation, to lagging behind others. "If a project does not involve any risk... Don't do it. Risk and reward go hand in hand," write American project management experts Tom de Marco and Timothy Lister. Risk is a consequence of one or more causes, as a result of which one or more events occur and inevitably accompanies any project. Risk management as a process always starts with identifying and managing potential risks. A missed risk can jeopardize the project, which requires risk management to be applied throughout the entire life cycle [1].

II. MATERIALS AND METHODS

Risk accompanies future events that may affect the scope, schedule and budget of the project. Risk refers to problems that have not arisen that have a negative impact and can also happen to positive opportunities that do not lead to danger.

In general, risks are classified into two large groups: general risks and specific risks. The general risks relate to political, social, economic and legal processes over which the parties to the project cannot exert influence. These factors influence the choice of the project to be implemented and the amount of funding. The types of risk in the management of transport projects are presented in Table 1. [2][3].

TABLE 1 TYPES OF RISK

	Types of risk	These include:
General risks	Political risks	Government policy Tax regime; Foreign Economic Policy; Concession; Etc.
	Trading risks	Currency regime; Inflation; Interest rate.
	Legal risks	Change in laws and legal acts.
Specific risks	Development risks	Licenses and permits; Tenders; Delay in project planning; Problems with contracts.
	Construction risks	Construction delays; Problems with construction and installation works; Overspending; Debt risk,
	Operating costs	Technical risks; Demand; Delivery; Management; Fire; Flood; Zemetrenie; Damage to facilities; Financing of the project' Etc.

Financial and regulatory risks are leading factors for the success of a construction project. Financial uncertainty in most cases is the result of fluctuations in the prices of materials and labor. Dynamic price changes lead to inaccurate project budget forecasts. Regulatory risks are related to frequently changing laws and regulations [4].

A particularly relevant risk factor that affects all areas of the economy is the shortage of qualified labor. The shortage of labor can be at all levels – workers, technicians, managers [5].

The occurrence of an unforeseen risk leads to a negative, demotivating impact on the project team. To reduce risk, regular employee and manager training, automation, collaborative work platforms, breaking the project into small pieces, and using agile management methodologies are recommended [6].

The success of railway projects depends on the project team. Unskilled team members are usually the cause of overscheduling, reduced productivity, and more [7].

The risk associated with the protection of the confidentiality of information assets related to the project should not be overlooked [8].

A. Risk management

Risk management is a management policy including procedures and practices for risk analysis and control [9][10].

The project risk management model based on statistical data has been developed in two steps. The first stage includes the collection of data from surveys, project documentation and their preliminary processing (cleaning). In the second stage, the data is analyzed with multiple regression analysis. Regression analysis examines the linear correlation between multiple dependent and independent variables, which makes it extremely suitable for risk assessment in the project [11].

Risk management in railway infrastructure projects is a process involving specific management activities. The goal is to anticipate the possible obstacles and the projects to continue their implementation while remaining within the planned budget and duration. For the successful implementation of the project, it is necessary to implement a risk management process throughout the entire life cycle.

The following methods shall be used to assess the likelihood of risk:

a) probabilistic methods – using Gaussian distribution;

b) scenario methods – the implementation of the project is described through various scenarios;

c) statistical methods – using statistical data, the main statistical parameters are calculated, including average, variance and probable distribution;

d) expert methods – by filling in questionnaires, the probability of occurrence of the risk event in the project is assessed;

e) Insurance risks – If the project is unable to ensure its implementation in the event of a risk event, it is necessary to apply insurance measures for risk management;

f) inventory planning – by setting aside funds for unforeseen expenses;

g) Sustainable methods – use estimates that are not always optimal, but retain their reliability when deviating from the expected distribution patterns. These assessments are called stable in theory [12].

Every project should have a risk management plan. The use of appropriate software to create a risk management plan facilitates the monitoring of the processes for the implementation of identification, assessment, mitigation and monitoring activities. It must also include a contingency plan.

The risk management plan describes the activities in four steps:

a) Risk identification – using data from similar projects, potential risks that may affect the implementation are assessed;

b) Risk assessment methodology – ranking risks based on their probability and level of impact. A risk assessment matrix may be used.

c) Designation of risk management officers – for each project risk, there must be a responsible person who monitors and responds if necessary [13].

d) Risk register – contains information about all identified risks, their description and impact measures.

e) Risk mitigation – creating a plan to mitigate risk and mitigate its impact.

To identify hazards in railway projects, it is recommended to use the HAZOR (Hazard and Operability Analysis) method. It is used during the design period and in the process of operation. Considers risk events as a deviation from the norms for design, construction and operation [14].

Not all risk quantification studies go through the sequence of steps, often limited to the identification of hazards, especially when reliable data are lacking [15].

B.   Risk assessment methodology

In the ISO/IEC 31010 standard "Risk management" – Methods for risk assessment, 31 methods of risk assessment are considered. A combination of several methods suitable for different stages is recommended [16].

The following methods are applied for risk assessment: mathematical statistics, numerical methods, probability theory, graph theory, machine learning and artificial intelligence, decision tree, critical point, environmental risk analysis, cost-benefit analysis [17].

The risk assessment includes two variables. One variable is a quantitative assessment of the probability of the occurrence of the risk, and the other represents its consequences. A five-point scale is used to assess the likelihood of risk occurrence. Table 2 provides the scale for assessing the likelihood of occurrence of risk.

TABLE 2 PROBABILITY OF RISK OCCURRENCE

P – Probability of occurrence of risk	Scale
Almost unbelievable	1
Unlikely	2
Probable occurrence	3
Highly likely occurrence	4
Common	5

This scale is used in combination with a risk impact assessment to build a risk analysis matrix. By multiplying the probability of occurrence and the severity of the impact, an overall risk rating is obtained, which supports the decision-making process for risk mitigation or management. The scale can be adapted depending on the specifics of the project by expanding the categories.

Estimates of possible risk effects are presented in Table 3.

TABLE 3 POSSIBLE CONSEQUENCES OF RISK

Consequence C	Importance of the possible consequences of risk
2	No significant effect

4	Small effect
6	Medium effect
8	Critical effect
10	A catastrophic effect. Project failure.

The general formula for calculating risk that is applied in engineering systems and project management is [18].

$$R = P * C, \qquad (1)$$

Where:

R – risk

P – probability

C – consequence.

Table 4 presents the calculated risk values according to Formula 1 and a scale for the level of significance for the project.

TABLE 4 RISK VALUE

Designation	Risk level	Risk level
R1	Very low risk	$R \leq 10$
R2	Low risk	$11 \leq R \leq 20$
R3	Moderate risk	$21 \leq R \leq 30$
R4	High risk	$31 \leq R \leq 40$
R5	Veri high risk	$31 \leq R \leq 40$

The considered risk assessment method is the most used in European transport projects. After categorizing the risks, management managers are appointed.

For quantitative risk assessment, three-step and five-step matrices are often used, using formula (1) for calculation. An important point in risk assessment is the determination of an acceptable risk. It refers to risks with minimal impact on the implementation of the project [19].

III. RESULTS AND DISCUSSION

Risk management in railway projects is a task of strategic and operational planning aimed at identifying, analyzing, controlling and minimizing threats that could adversely affect the technical, time, financial or safety implementation of the project. Due to the high degree of complexity, the long life cycle and the important role of the railway infrastructure, it is necessary to apply a systematic approach to risk management.

A methodology for risk assessment should be short and clearly spelled out. There should be no opportunity to interpret what to do and how to do it.
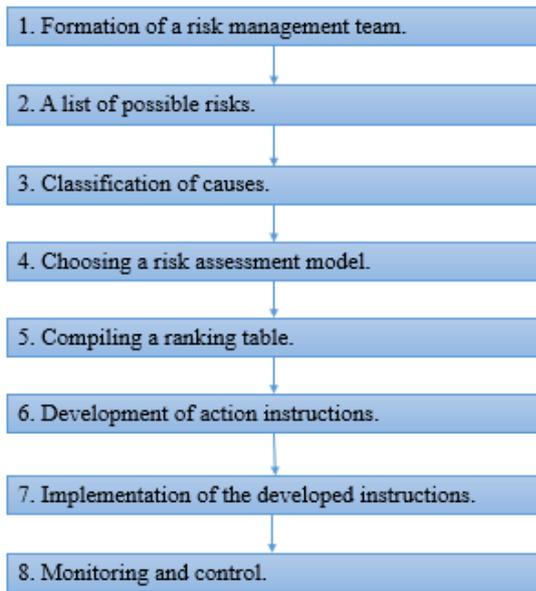
1. Formation of a risk management team.

2. A list of possible risks.

3. Classification of causes.

4. Choosing a risk assessment model.

5. Compiling a ranking table.

6. Development of action instructions.

7. Implementation of the developed instructions.

8. Monitoring and control.

Fig. 1. Risk management methodology

Based on the methodology, project risks are simulated in terms of delay, cost and quality.

Figure 1 presents a methodology for risk management for railway projects. It identifies, analyzes, assesses risks and provides an action plan to achieve the project objectives.

In conclusion, the presented methodology provides a robust framework for effective risk management in railway projects. Through a combination of theoretical principles and practical tools, it contributes to higher safety and efficiency in the implementation of railway infrastructure projects.

IV. CONCLUSIONS

This study examines articles and standards published in the last five years. The conclusion is that the topic of risk management in the design and implementation of railway projects was poorly considered during the period.

The future of risk management in rail projects lies in the use of artificial intelligence (AI) in the risk identification process and impact assessment procedures. By analyzing historical data from multiple similar projects, AI can predict potential risks and minimize human error.

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