The transport construction investment project effectiveness assessment by Monte Carlo Method

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Abstract. The study focuses on the effectiveness basis of the transport construction investment projects operating at three investment levels, taking into account risks using the Monte Carlo simulation method. The model on the example of a railway line has been developed. An assessment of the investments’ budgetary, social and commercial effectiveness based on the investment sources has been provided. A comprehensive criterion for substantiating the effectiveness of a project operating at three investment levels, taking risk into account, has been proposed. A risk profile has been built. The average value of the risk level using the Monte Carlo method has been estimated. An example of substantiating the effectiveness of an investment project taking into account the risk of building a railway line has been given.

Introduction
Transport infrastructure implementation of the development projects in Russia, on the one hand, is important for ensuring the economy industrialization, and on the other hand, the required investment volumes cause a high level of risk in terms of achieving the declared investment efficiency. Based on this, the sequence of measures for the infrastructure projects construction state programs’ implementation is not ensured. Capital redistribution and efforts concentration often goes against railroad construction projects. The lack of deep scientific and methodological studies at the stage of project justification, the poor adaptation of the substantiating effectiveness classical methods to the specific railway construction projects’ specifics, as well as the lack of confidence in the methods of accounting for uncertainty and risk, are the essential prerequisites for this problem situation’s development.

The modern scientific base makes attempts to improve the rationale for the investment projects’ effectiveness. However, the results obtained do not fully meet the investors’ expectations, because the results reliability level remains insufficient. The authors believe that existing models for calculating the investment and construction projects’ effects are more focused on calculating commercial effectiveness due to the complexity of accounting for socio-economic effects or budgetary effectiveness.

Methodological aspects of the investment efficiency assessment are developed by Losev K.V., Budagov A.S. [1], Kogan A.B. [2], Tarek M.T., Khvatova T.Yu. [3].
An important contribution to the study of problems associated with assessing the investments effectiveness in road and infrastructure projects was made by the works of the following scientists: Oparin S.G. [4], Kazaku E.V. [5], Semyannikova O.G., Nekrasova I.Yu. [6], Wiseman [7], A. Annsar, A. Buzzier, D. Lunn [8], Cantarelli [9], Randolph [10].

The necessity and justification of the railway network construction in Russia are considered in the works of Derbas N.V., Leontiev R.G. [11], Pak M.V. [12], Skurin L.V. [13].

The problems of the transport infrastructure formation, as one of the main factors of increasing the investment attractiveness of the territory, are considered in the works of Tsarionova Yu.V., Zausaev V.K., Bystritsky S.P. [14], [15].

The works of Oparina S.G., Kachalova R.M. [16], Stasishina-Olshevskaya A.E. [17] are devoted to the transport investment projects’ management and risk assessment problems.

Burakov P.V., Porval A.V. [18] proposed to apply the Monte Carlo method in the economic feasibility of projects. The investment risk analysis was performed by W. Hurley [19], R. Clark, A. Lowe [20].

At the same time, in these studies, the three-level system of relationships within the investment project, as well as the technology for uncertainty and risk generated by the system accounting, is not sufficiently disclosed.

The purpose of the research is the effectiveness substantiation of the project invested from the federal and regional budgets, as well as by the private investors taking into account risks using the Monte Carlo simulation method.

**Research Methodology**

To justify the investment projects effectiveness for the construction of railway lines, the cash flow model should reflect the economic nature of the investments formation and interact with the system of primary distribution and the national income redistribution. The study provides that for the investments from the federal and regional budgets, consisting of tax revenues at the federal and regional levels, budgetary efficiency is calculated. It also takes into account social efficiency (for regional investments) and commercial efficiency for enterprises - investors.

Thus, the investment project’s effectiveness is understood as the financial inflows relations totality in the form of tax deductions to the federal budget, to the regional budget, the effects of increasing regional employment of the population and net profit from the sale and transportation of goods to the volume of investments corresponding to the project participants’ level [5].

The state investments’ contribution from the federal budget has the largest share. The investments from the funds of the Investment Fund and other structures on the federal level should be compared with the tax deductions accompanying the project’s implementation. The tax on profits from the sale and transportation of goods deducted to the Federal budget from 2017 to 2024 is 3%. Value added tax is determined at a rate of 0% for the export of goods and 20% for domestic sales during the quarter. Individual income tax is determined at a rate of 13% of the payroll per year. The mineral extraction tax is determined for each type of mineral and is calculated from their value for a calendar month at the rates regulated by the Tax Code.

The following tax types should be attributed to the regional level:

- federal taxes redistributed to the constituent entities of the Russian Federation (income tax (10%, 17%, 18%), personal income tax, 13% (30% is paid to the constituent entities budget of the Russian Federation);
- regional taxes (corporate property tax).

Income tax is paid 17% from 2017 to 2024 and 18% in other periods. The property tax of the organizations is determined based on the residual value of the property. The tax rates determined by the constituent entities’ laws of the Russian Federation with respect to railways cannot exceed 1 percent in 2017, 1.3 percent in 2018, 1.3 percent in 2019, and 1.6 percent in 2020.

Land tax for the Russian Railways infrastructure is not paid, because land is a federal property and can be leased.
To take into account the uncertainty and estimate the average level of risk in this study, the Monte Carlo method is used in comparison with the risk adjustment method. The Monte Carlo method’s essence is to generate the pseudo-random values of the project parameters, calculate the effective performance indicators and evaluate their average value and standard deviation. With the digital environment development, sufficient volumes of statistical data have become available, on the basis of which it is possible to formulate the variable parameters distribution laws or apply the normal distribution law.

In conditions of increased risk and uncertainty accompanying the capital-intensive projects’ implementation, it is advisable to supplement the total payback criterion by taking into account the uncertainty of the project’s main parameters. To identify risks, a risk map is constructed (Table 1.1). The authors investigated the risk factors for changes in the goods transportation volume and the cost of their implementation (pre-design factor, market).

**Table 1.1. Risk Map of Investment Project for Railway Construction.**

| Risk factors          | Sources of Risk Factor                                                                 | Degree of influence                                                                 | Risk Assessment Model Parameters                                                                 |
|-----------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Contracted            | Features of the contract system in the Russian Federation, probability of fulfilling a contract with an unscrupulous supplier, the possibility of contract appreciation | - Subject and conditions of the contract at all stages of the project life cycle;  
- The reliability of determining the initial (maximum) price of the contract;  
- Supplier’s reliability;  
- Delay in financial settlements and terms of contract work |                                                                                  |
| Predesign            | Uncertainty of exploration; engineering uncertainty                                       | - The reliability of determining the total volume of explored minerals of the i<sup>th</sup> type;  
- Reliability of the geodetic, geological and environmental surveys’ results; |                                                                                  |
| Design and technical | Uncertainty of the design decisions results and approval of design documentation       | - Quality of project documentation;  
- Qualification of specialists;  
- Quality and cost of technologies, solutions and designs adopted in the project;  
- Delay in passing the state examination of design documentation; |                                                                                  |
| Political and legal  | Changes in the tax system at the federal and regional levels                          | - Change in preferential tax conditions;  
- Change the list of taxes;  
- Change in tax rates;  
- Errors in determining the tax base; |                                                                                  |
| Production and technical | Violations of technology and timing of work                               | - Inconsistency of work with design solutions;  
- Non-compliance of work with applicable law;  
- Quality of work;  
- Failure to meet deadlines; |                                                                                  |
### Operational Uncertainty

- Uncertainty of the adoption process on the balance of infrastructure;
- The quality of the locomotive fleet and wagon fleet;
- Streamlined transport management process;
- Integrity of transport companies;
- The level of qualification of railway operation specialists;
- The presence of the required number of specialists of relevant qualifications;
- Level of track facilities, wagon and locomotive fleet;

### Opportunistic Uncertainty

- Decrease in cost of sales of goods;
- Reduced market demand for certain types of resources.

In this model, minerals are taken into account as cargo, the extraction and transportation of which has become possible as a result of railway construction.

The aggregate criterion for substantiating the effectiveness of an investment project in railway construction, taking into account uncertainty, should be considered not to exceed the obtained values of the average value (mathematical expectation) of the standard values payback period at each level [5].

Using the pseudo-random number generator, using the specified uncertainty characteristics of random factors, the cargo transportation volumes are sequentially generated at the cost of their sale in step i, by the repeatedly modeling random factors, the payback period of the investment \( M_{fa} \) is determined as a grade average. Standard deviation \( y_f \) reflects the probabilistic nature of the indicator.

### Example

The construction of the “Polunochnaya – Obskaya” railway line is envisaged by the Strategy for the Development of Railway Transport in the Russian Federation until 2030. The project implementation will ensure the financial inflows to the Federal level, socio-economic inflows for the constituent entities of the Russian Federation and commercial effects for the enterprises and organizations participating in the investment and construction project. The length of the railway is 790 km. The calculated period 44 years, including 6 years of construction. The costs are divided into three levels: 70% - the federal level, 12% - the regional level and 18% - the level of enterprises.

Among the main cargoes, copper is highlighted (the highest selling price). Probabilistic characteristics of the copper cost (2016): the mathematical expectation of the cost is 0.228876 million rubles; the standard deviation is 0.033197 million rubles.

The amount of risk adjustment is 8%. The discount rate, as amended, is 17.66%.

Monte Carlo simulation has been performed for 100 thousand times. The obtained evaluation results (Table 1.2) are correlated with the cumulative efficiency criterion. It should be noted that the average score is more accurate and to some extent, the indicators are higher than the deterministic ones. The authors also note that taking Monte Carlo uncertainty into account is based on the use of the statistical data, which increases the confidence level in the estimation results. Whereas the risk adjustment method uses the assigned values of risk adjustments depending on the subjective representations of the uncertainty degree.

**Table 1.2.** The results of determining the payback using Monte Carlo method, months.
| Name                      | FB  | RB  | Russian Railways | EF  |
|---------------------------|-----|-----|------------------|-----|
| Expected value            | 128.4 | 85.9 | 81.7             | 82.7 |
| Standard deviation        | 12.72 | 0.99 | 2.19             | 2.40 |
| Maximum                   | 205  | 89  | 102              | 105  |
| Maximum                   | 99   | 82  | 77               | 77   |
| Payback without uncertainty| 128  | 86  | 81               | 82   |
| Risk-adjusted payback period | 129  | 87  | 81               | 82   |
| Required Payback Level    | 130  | 90  | 90               | 90   |

Using the Monte Carlo add-in, the selected parameters’ probabilistic characteristics are introduced into the model and the probabilistic characteristics of the resulting indicator are calculated - the payback period for each of the investment levels. The calculations showed that the project’s effectiveness is achieved at all the investment levels for each of the participants. The federal level reflects the relationship of the capital inflows and tax deductions’ largest volume to the federal budget generated by the investment project. The regional level demonstrates the ratio of the constituent entities investments in the Russian Federation and tax deductions to the regional budget, as well as an increase in regional employment due to the new workers’ inclusion in the operation of the railway and due to an increase in the average wage. The enterprise level takes into account the interests of private investors and reflects the efficiency for the Russian Railways and mining companies.

Summary
Thus, a model for evaluating budgetary effectiveness for investments from the federal and regional budgets has been built in the study, taking into account the social effect of increasing regional employment, as well as commercial efficiency for the enterprises’ investments share - investors, future mining companies.

Based on the model, it is possible to identify the most acceptable investment volumes in order to achieve the optimal return on investment. So, for Russian Railways, the required investment is 5-8%, which ensures that the return on investment is reached within 10 years.

The model for substantiating the investment projects’ effectiveness for the railway lines construction, taking into account uncertainty, reflects the specifics of the investment project and takes into account the probabilistic factors of uncertainty, which provides more reliable results than the results of a deterministic assessment.

The Monte Carlo method has proved itself to be a more accurate mathematical apparatus for estimation. The results obtained should be characterized as more reliable than the results of a point assessment by the risk adjustment method.

The results of the study showed that the greatest importance on performance indicators is provided by the volume and cost of goods at the time of commissioning.

An insignificant effect is exerted by the factor of the population migration influx in the construction area.

Due to the high investment return rate, the indicator of investment efficiency is more sensitive to the selected factors in the early stages of assessment (up to 10-15 years). The payback period for the regional level, as well as the enterprise level, is more sensitive than the payback period at the federal level.

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