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Implementation of strategic infrastructure projects: Modeling of effects and results

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Abstract

The article describes the modelling of strategic infrastructure project effects and results using methods of analysing direct and indirect effects and helping to determine the feasibility of railway infrastructure project implementation. Neglecting this fact significantly reduces the overall efficiency of infrastructure projects, and in some cases leads to the wrong decisions that reject project implementation.

Investigations made by authors allow to identify, classify and quantitatively estimate the direct and indirect effects from the implementation of infrastructure projects, including integrated assessment of budgetary efficiency and an assessment of economic effects for the development of territories.

Among indirect effects the special attention was paid to the multimodal effects resulting from the redistribution of passenger and cargo flows and more rational capacity of the transportation system. The attention was paid to the multiplier effects caused in related sectors of the economy, agglomeration effects leading to increased connectivity of urban and suburban areas and the corresponding growth in employment, investment and productivity, the effects of optimising subsidies, etc.

Scenario forecasting procedures were used within the presented investigations. Macroeconomic effects, bottlenecks in the railway system impact on the level of undertransportation of goods as well as price arbitrage were determined for various scenarios.

Keywords: strategic management, infrastructural projects, railway system development, direct and indirect effects.

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战略性基础设施项目的实施：效应和结果的建模

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摘要

该文章提出使用估计直接和间接影响的方法对战略性基础设施项目的实施效应和结果的建模。这些方法在确定铁路基础设施发展项目的可行性方面发挥了关键作用。如果不考虑这些效应和结果，基础设施项目的实际整体效率将被大大低估，在某些情况下会导致不实施这些项目的错误决定。

作者所做的计算已经确定并结构战略性基础设施项目的实施直接和间接的效应，对已其进行量化，包括对财政效率的全面评估和对领土发展的经济影响的评估。

在众多的间接效应中，特别注意的是由于客流和货运的重新分配以及更合理地使用运输网络而产生的多种形态效应；在相关经济部门引起的乘数效应；导致城市和郊区的连通性增加并相应增加就业、投资和生产力的集聚效应；补贴优化的效应等。

计算中使用了情景预测程序。对不同情景，确定了宏观经济效应并评估了铁路网络瓶颈对投资货物部门的货运短缺和价格套利的影响。

关键词：战略管理，基础设施项目，铁路发展，直接和间接效应。

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Введение

The key tool for economic growth and overcoming restrictions is the implementation of strategic infrastructure projects in the field of railway transport. At the same time, such projects are very capital-intensive and often cannot be implemented in full due to limited funding. This factor plays a particularly significant role in the current conditions of sanctions pressure.

Making a decision on the implementation of large infrastructure projects requires a thorough analysis of the socio-economic effects that accompany the implementation of such projects, as well as the development of the most effective tools to increase the socio-economic level of the development of territories through the implementation of infrastructure projects for the development of railway transport hubs [Jesionkiewicz, 2017; Cengiz et al., 2022].

The results of modeling various options for underfunding the development of railway transport and the formation of unsatisfied demand for transportation showed a significant slowdown in the pace of economic development in the presence of infrastructural constraints [Gorelik et al., 2022].

It is important that the calculations performed showed the importance of developing not only freight, but also passenger high-speed, rapid and suburban transportation, the level of which is directly related to transport opportunities and incomes of the population.

1. Effects from the implementation of strategic infrastructure projects

According to the Strategy for the Development of Railway Transport in the Russian Federation until 2030 railways will allow the Russian state, economy and society to achieve the following results:[1]

- acceleration of economic growth in Russia and multiplier effect on GDP growth;
- reduction of transport costs of economic entities and release of funds for the development of other areas of the domestic economy;
- formation of territorial industrial and scientific clusters and minimisation of disproportions in interregional development;
- Ensuring broad trade links between economic centers;
- increasing the overall competitiveness of the Russian economy and the country's attractiveness for business development and investment inflows;
- development of transport engineering and other interrelated sectors of the economy.

All generated effects can be classified into direct and indirect ones [Blanquart, Koning, 2017; Yan, Lee, 2021; Du et al., 2022].

Direct effects are measured through gross value added (GVA) [Buzulutskov et al., 2020], which is the difference between the cost of an industry's products and the cost of the resources needed to produce it, and is calculated as the difference between the output of goods and services and their intermediate consumption[2]. The following elements are distinguished in the composition of gross value added:

- payroll fund for employees (including social insurance);
- net profit;
- net mixed income;
- taxes on production;
- production subsidies (–);
- consumption of fixed capital;
- indirectly measured financial intermediation services (–).

The effects can be assessed both at the level of the country as a whole and for individual regions. In the first case, the input-output balance for the country is used, in the second - the processes of production and distribution of products of the corresponding region. At the same time, the regional intersectoral balance, as a rule, differs significantly from the intersectoral balance of the national economy. This is due to differences in the structures of outputs and final demand, as well as in the value of specific material costs. The latter is explained by the fact that in the same sectors of the national economy, different regions have industries

[1] https://annrep.rzd.ru/reports/public/ru?STRUCTURE_ID=4498.
[2] https://rosstat.gov.ru/bgd/free/b99_10/isswww.exe/stg/d010/i010810r.htm.

with different characteristics of the output structure and technologies used [Pyataev, 2016; Hanke, 2017].

Indirect effects take into account the demand that is formed in sectors that produce resources for the railway industry and supply it [Zhou et al., 2021]. Thus, in the course of the development of railway transport hubs, there is a corresponding increase in the costs of intermediate products (fuel, electricity, materials, etc.), which leads to an increase in production in related industries [Yu et al., 2019; Petri et al., 2021]. Further, through the costs of related industries, there is growth in almost the entire economy. An increase in gross output is accompanied by a corresponding increase in income: taxes, wages, profits, which are redistributed and transformed into an increase in the final demand of the state, business, and the population [Wu et al., 2021].

In the context of the generated effects, it is important to note the impact of transport projects on the real estate market, which is multidirectional: the construction of new infrastructure can lead to both a drop in real estate prices (due to an increase in noise levels, changes in view parameters, environmental pollution) and their growth (improvement transport accessibility and saving time) [Lapidus, 2013; Zhou et al., 2021].

In addition, when assessing the economic effects generated by the projects for the development of railway transport hubs, it is necessary to take into account the so-called external effects that arise in a situation where the social or economic activity of one structure has an impact on another structure (group of persons) and this impact is not taken into account or not compensated [Trachuk, Sayapin, 2014; Jhangiryan, 2021; Jiang et al., 2022]. Such effects can be both positive and negative.

In terms of railway transport, the former can be classified [Kumar, 2021]:

– saving time on the way for passengers and cargo;
– increase of safety of transportations of passengers and cargoes;
– reduction of emissions of harmful substances and noise level (when choosing alternative options);
– beneficial effects of public transport due to increased physical activity;
– social integration and barrier-free environment;
– subjective wellbeing – perception of the surrounding world or the level of happiness.

Negative effects are formed by the following components [Blanquart, Koning, 2017; Chen et al., 2021]:

– environmental pollution, climate change, increase in noise level;
– negative impact on nature and landscape.

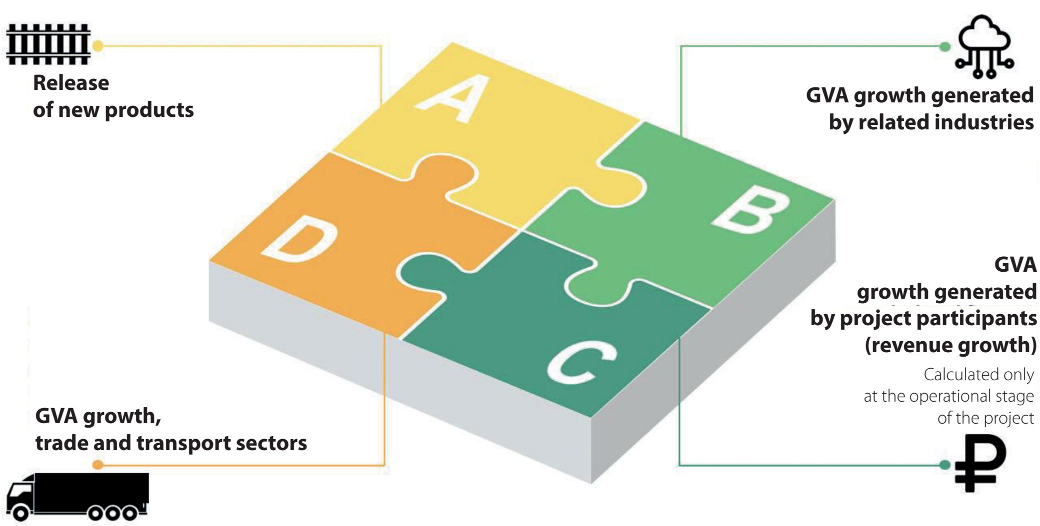
The final effect of the project implementation can be obtained by comparing the potential benefits and costs, including through a comparison of various alternatives.

Thus, the performance indicators for the implementation of infrastructure projects for the development of railway transport hubs can be classified into two groups: economic effects and social effects.

Within the first group, potential effects are achieved through an increase in gross value added in four areas (Fig. 1). The second group forms six potential effects, which are presented in Fig. 2.

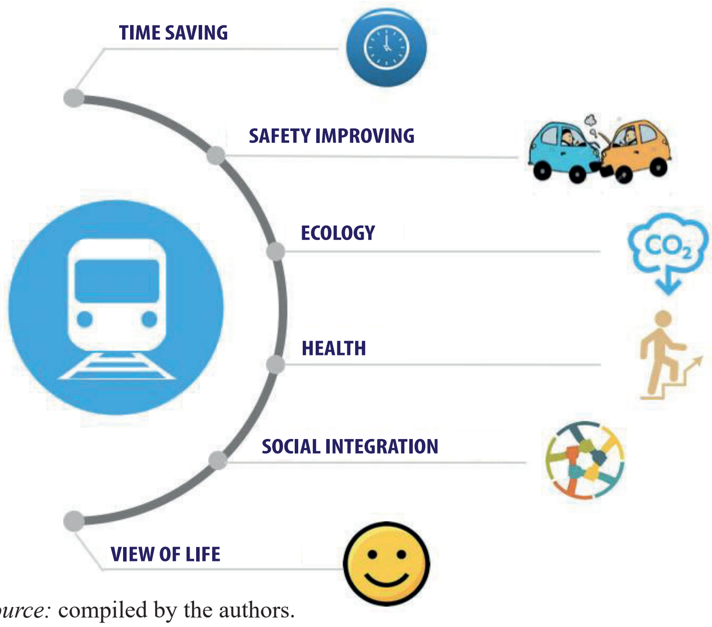
The quantitative measurement of the considered effects is possible on the basis of econometric modeling, which is characterised by a high degree of individuality for each individual railway project.

Fig. 1. GVA growth generated by implementation of investment and operational stages of infrastructure project



Source: compiled by the authors on the basis of the Methodology approved by the Decree of the Government of the Russian Federation of November 26, 2019 No. 1512.

Fig. 2. Positive effects generated by infrastructure projects in railway transport



Source: compiled by the authors.

2. Model of dependence of investments in the development of railway infrastructure projects and positive socio-economic effects

Most infrastructure projects are characterised by insufficient funding from both private investors and the state. In this regard, there is a need for a better justification of financing the implementation of infrastructure projects by building a model that allows for scenario forecasts to identify the most effective and efficient approaches to their implementation.

Such a model should reflect the principles of quality infrastructure investments, such as:

– compliance with the goals of sustainable development and ensuring the growth of the national economy;
– economic efficiency throughout the life cycle of the infrastructure project;
– minimal negative impact on the climate and the environment;
– resistance to natural and emergency events;
– compliance with socially oriented goals;
– managerial efficiency and transparency in making investment decisions [Kuzmin, 2020; Linder, Litvin, 2020].

In our opinion, to deeply analyse the relationship between investments in infrastructure projects for the development of railway transport hubs and the achievement of positive socio-economic effects, as well as an increase in the level of development of territories, a structured model of econometric equations based on the CDM model is most appropriate [Trachuk, Linder, 2016 ; 2020].

The structural model developed by us consists of three main parts.

1. The first part is an analysis of investments in infrastructure projects for the development of railway transport hubs.

The first group of equations of the model is designed to estimate the probability that the state, region or private investor will make a decision to invest in infrastructure projects for the development of railway transport hubs. In the case of a decision to invest it estimates the relative amount of investment (intensity) defined as the amount of investment related to the population of the region.

To specify the first part of the model it was decided to use Heckman's censored regression equations. A feature of this model is the ability not only to assess the probability of making a decision on investments in development projects, but also to calculate the relative value of these investments. The model consists of two relations. The first equation is a binary choice model that evaluates the binary decision "invest / not invest" depending on a number of factors that will be defined later in the text. The second ratio is a linear model that determines the relative amount of investment in infrastructure projects for the development of railway transport hubs. It should be noted that the advantage of the Heckman model is the ability to take into account not only the regions that are already investing in railway infrastructure development projects, but also those where it is only planned to invest.

Thus, the specification of the first part of this mathematical model has the form expressed by equations (1) and (2).

The first equation has a latent (unobservable) variable that describes a region's decision to invest in rail infrastructure:

$$D_i = \begin{cases} 1, \text{если } D_i^* = d_i x + \varepsilon_i > \vartheta \\ 0, \text{если } D_i^* = d_i x + \varepsilon_i \leq \vartheta \end{cases}, \quad (1)$$

where D_i is an explicit variable that takes the value 1 if the region has decided to invest in the development of the railway transport infrastructure, and 0 if not; D_i^* is a latent variable that describes the probability of a region investing in railway infrastructure and is a conventional regression model that depends on a number of factors – independent variables; d_i are independent variables that are factors influencing a region's decision to invest in railway infrastructure; x – column vector of model parameters; ε_i – is a column vector of residual terms (random errors).

Heckman's censored regression uses the assumption that random errors are described by a normal distribution.

Regions are inclined to invest in infrastructure projects for the development of railway transport hubs if the explicit variable D_i is above a certain threshold value ϑ, which can be characterised as a selection criterion, for example, the projected amount of socio-economic effect from investing in railway infrastructure.

To determine the factors d_i that influence the region's decision to invest in railway infrastructure, an analysis of the Moscow and St. Petersburg railway transport hubs was carried out. Based on this analysis, a list of factors was compiled:

- d_1 – economic/financial factors due to the need to attract a significant amount of financing to the infrastructure project;
- d_2 – management factors due to insufficient support from the leadership of the region or the development strategy;
- d_3 – competence factors due to the lack of qualified personnel capable of developing and subsequently supervising the implementation of an infrastructure project;
- d_4 – regulatory factors caused by the pressure of regulatory bodies and other authorities;
- d_5 – technological factors due to the infrastructure readiness of the region, the deterioration of the existing railway networks and nodes.

The second relation in Heckman's censored regression describes the relative amount of investment when deciding whether to make investments in the first equation of the model, which is expressed as the amount of investment in the development of railway infrastructure, calculated per inhabitant of the region:

$$Inv_i = \begin{cases} Inv_i^* = i_i y + e_i, \text{если } D_i = 1 \\ 0, \text{если } D_i = 0 \end{cases}, \qquad (2)$$

where Inv_i is an explicit variable that takes the value of the amount of investment in the development of railway infrastructure, if the region decides to invest, and 0 if not; Inv_i^* is hidden variable describing the amount of investment in the development of railway infrastructure; i_i are independent variables that are factors describing the relative amount of investment in railway infrastructure; y – column vector of model parameters; e_i is a column vector of residual terms (random errors).

2. The second part of the model describes the dependence of investments in various elements of the railway infrastructure on the intensity of investments in infrastructure projects.

According to the study [Kuzmin, 2020], the following areas of investment in railway infrastructure elements can be distinguished:

Modernisation of railway infrastructure in order to increase the speed of rolling stock. One of the most important indicators of the effective functioning of the railway infrastructure is the ability of rolling stock to reach its set speed on track sections. At the same time, general figures for the average speed weighted along the length of sections are often given, but the actual average section speed is ignored, which often turns out to be significantly lower due to the need for trains to accelerate or brake for a long time in front of sections with appropriate speed limits[3].

For example, according to the "Speed in Priority" study[4], the weighted average speed over the length of route sections is more than 70 km/h, while the average section speed is 40.9 km/h, which negatively affects the overall efficiency of the railway infrastructure.

Also, the speed of rolling stock is significantly slowed down due to the non-uniform electrification of railway tracks. When a train moves from tracks electrified with direct current to tracks using alternating current technologies, it is necessary to change the locomotive, inspect the train, etc., which significantly increases the total travel time.

Development of multimodal terminal and logistics centers. The development of such promising elements of the infrastructure of railway networks as multimodal terminal and logistics centers is capable of increasing freight and passenger traffic.

The lack of multimodal terminal and logistics centers leads to significant time losses in the accumulation of goods, their redistribution and also increases the range of rail transport, thereby reducing its attractiveness relative to road or sea.

The main areas of investment can be: the construction of new or improvement of existing container terminals, the provision of large hub terminals with smaller satellite terminals. It is also important to build new warehouses and revise approaches to the provision of warehouse services in order to increase the share of goods requiring special transportation conditions and, in general, to increase the comfort of using the railway infrastructure for shippers and consignees.

Development of transport interchange nodes. The development of transport hubs and other elements of passenger infrastructure can have significant agglomeration effects, expressed primarily in the growth of wages and, as a result, tax deductions in large agglomerations, as well as in a number of other indirect effects, such as improving the quality of life due to noise reduction, safety improvement, carbon emission reduction, real estate development, etc.

Modernisation of border crossing infrastructure. Train traffic often slows down when crossing border points. This

[3] Overview of the cargo transportation industry in Russia (2018). EY. https://assets.ey.com/content/dam/ey-sites/ey-com/ru_ru/topics/automotive-and-transportation/ey-overview-ofthe-cargo-industry-in-russia.pdf.

[4] Tsypleva N. (2017). Speed is the priority. Gudok, 155(26294), 6 Sept. http://www.gudok.ru/newspaper/?ID=1385773&archive=2017.09.06.

is due to many factors. For example, the need to change the gauge of the rolling stock from the railway gauge of 1520 mm to the gauge of 1435 mm greatly slows down the passage of the border crossing. As a result, it is necessary to spend time reloading containers on the rolling stock of the appropriate gauge or to change the bogies of the wagons, which as a result leads to costs on the side of consignors and consignees.

In addition, slowdowns may be due to the low processing capacity of the border crossing in general, as well as the lack of automation of customs processes and customs document flow.

Implementation of digital platform solutions. As noted above, the digitalisation of railway transport hubs will not only increase the efficiency of the transport system, the throughput of nodes, but will also have a beneficial effect on all market participants.

The introduction of digital platforms is designed to improve the ease of use of urban and intercity transport infrastructure for passengers, increase the efficiency of integrating rail transport into the urban transport system, improve the reliability and quality of services provided for consignors and consignees, the speed of customs checkpoints and border crossings, as well as increase the speed of the MTLC.

Thus, the specification of the second part is mathematically expressed by the relations:

$$SpeedInv_i = \overline{Inv_i}z + k_i\alpha + \epsilon_i, \tag{3}$$

where $SpeedInv_i$ is the region's investment in the modernisation of the railway infrastructure in order to increase the speed of rolling stock; $\overline{Inv_i}$ is the average volume of investments in the development of railway infrastructure, calculated per inhabitant of the region; k_i are independent variables that are factors describing investments in railway infrastructure elements; α is the column vector of model parameters; ϵ_i – column vector of residual terms (random errors);

$$MTLCInv_i = \overline{Inv_i}z + k_i\alpha + \epsilon_i, \tag{4}$$

where $MTLCInv_i$ is the region's investment in the development of multimodal terminal and logistics centers;

$$TRUInv_i = \overline{Inv_i}z + k_i\alpha + \epsilon_i\ , \tag{5}$$

where $TPUInv_i$ is the region's investment in the development of transport hubs;

$$PogranInv_i = \overline{Inv_i}z + k_i\alpha + \epsilon_i, \tag{6}$$

where $PogranInv_i$ is the region's investment in the modernisation of border crossing infrastructure;

$$DigiInv_i = \overline{Inv_i}z + k_i\alpha + \epsilon_i, \tag{7}$$

where $DigiInv_i$ is the region's investment in the implementation of digital platform solutions.

3. The third part of the model analyses the relationship between the relative amount of investment in infrastructure projects for the development of railway transport hubs and the achievement of positive socio-economic effects.

As noted by researchers earlier, the economic effects from the introduction of infrastructure projects for the development of railway transport hubs are complex and relate to many aspects of the functioning of the regional economy: the labor market, the productivity of industrial enterprises and small firms, and are also expressed in stimulating a direct expansion of sales opportunities, opportunities entering new markets or the emergence of new firms and, as a result, an increase in the number of jobs.

The combination of these factors leads to an increase in the activity of development companies in the region, which also increases the standard of living of citizens. The development of residential and commercial construction increases demand in the markets of labour and building materials, thus having indirect effects on other sectors.

In turn, an increase in supply in the real estate markets makes it possible to reduce the population density, which, coupled with the improvement of the transport connectivity of the districts, increases the standard of living of residents.

In addition, the current study identified a number of direct and indirect effects:

Direct Effects:

- increase in gross value added during the implementation of a non-structural project;
- increase in tax and other mandatory payments arising in related sectors of the economy.

Positive indirect effects:

- agglomeration effects expressed as wage growth;
- reducing costs and lost taxes by improving the safety of passenger and cargo transportation;
- reducing emissions of harmful substances and noise level;
- subjective wellbeing benefits.

Negative indirect effects:

- environmental pollution, climate change, increased noise levels;
- negative impact on nature and landscape.

Thus, the socio-economic effect from the implementation of infrastructure projects for the development of railway transport hubs can be described by the relation (8):

$$\begin{aligned} SocEff_i = VDS + Nal + Agl + Safe + Clean + \\ + Well - Waste - Distr \end{aligned}, \tag{8}$$

where VDS is the increase in gross value added during the implementation of a non-structural project; Nal – increase in tax and other mandatory payments arising in related sectors of the economy; Agl – magnitude of agglomeration effects; *Safe* – the magnitude of the effects of reducing costs and lost taxes by increasing the safety of passenger and cargo transportation; *Clean* – the magnitude of the effects of reducing emissions of harmful substances and noise levels; *Well* – the value of subjective welfare benefits; *Waste* – the amount of damage from environmental pollution, climate change, increased noise levels; *Distr* – the amount of damage from the negative impact on nature and landscape.

In turn, the relationship between the relative value of investments in infrastructure projects for the development of railway transport hubs and the achievement of positive socio-economic effects is described by equation (9):

$$SocEff_i = \overline{Inv_i} z + SpeedInv_i \beta + MTLCInv_i \beta + TRUInv_i \beta + \\ + ProgranInv_i \beta + DigiInv_i \beta + \sigma_i , \quad (9)$$

where $SocEff_i$ – socio-economic effect from the implementation of infrastructure projects for the development of railway transport hubs; α and β are the corresponding column vectors of model parameters; σ_i is a column vector of residual terms (random errors).

For a deeper analysis of the relationship between investments in infrastructure projects for the development of railway transport hubs and the achievement of positive socio-economic effects, as well as an increase in the level of development of territories, it was decided to consider two calculation scenarios in the analysis.

Scenario 1: Investments are made in the infrastructure of railway networks, nodes and necessary related facilities, while the level of digitalisation is minimal.

Scenario 2: Investments are made in the infrastructure of railway networks, nodes and necessary related facilities, as well as in the development of digital platform solutions.

2. Research Methodology

A preliminary telephone survey was conducted to verify the key provisions of the model, as well as to prepare questionnaires for subsequent data collection. A preliminary discussion was held with 15 representatives of companies implementing infrastructure solutions in the field of railway tracks and junctions, regional authorities, as well as consulting agencies.

In this case, the experts meet one of the following criteria:

1) the expert occupies a managerial position in a subdivision of an organisation engaged in the implementation of infrastructure projects for the development of railway transport hubs;
2) the expert is a competent consultant specialising in railway infrastructure projects;
3) the expert is a representative of the regional authorities responsible for the implementation of railway infrastructure projects.

After verification of the model and the questionnaire, questionnaires were sent to 204 experts selected according to similar criteria, of which 112 responded, the response was 55%. The characteristics of the sample is presented in Table. 1.

Table 1

Sample characteristics

Characteristics of expert companies	Number of respondents	Share of respondents (%)
Company implementing infrastructure projects:		
less than 5 years	23	21
from 5 years to 10 years	35	31
over 10 years	25	22
Consulting companies	17	15
Regional authorities in the field of transport	12	11

Source: compiled by the authors.

3. Research results

The results of the analysis using the two-stage censored Heckman regression (the first group of equations) are presented in Table. 2. The decision of the regions to invest in railway infrastructure projects was assessed using a probit model, where the independent variables were: economic/financial factors (*d*1), management factors (*d*2), competence factors (*d*3), regulatory factors (*d*4), technological factors (*d*5).

In addition, for the correctness of the calculations, control variables were included, such as the number of inhabitants of the region, the indicator of relations with other regions (binary variable: 1 – donor region, 0 – recipient region) and the regional budget.

The relative value of investments is defined as the volume of investments in the development of railway infrastructure, calculated per inhabitant of the region.

The results demonstrate the significant influence of financial and economic factors due to the high resource intensity of infrastructure railway projects. The decision to invest is significantly influenced by managerial factors.

In these scenarios, both the decision-making and the intensity of investments are significantly influenced by technological factors due to the state of the infrastructure, which is explained by the increased demand for investments in the event of deterioration of existing networks. Regulatory factors show a relatively smaller degree of influence for both scenarios.

The results of the investment analysis in the development of railway transport hubs with a breakdown

Table 2
Forces influencing the regions' decision making on investment in railway infrastructure projects

Exogenous variables	Scenario 1		Scenario 2	
	Decision on investment in railway infrastructure	Relative value of investments in railway infrastructure development	Decision on investment in railway infrastructure	Relative value of investments in railway infrastructure development
Method of analysis	The first component of the model is Heckman's censored regression			
	The first equation	The second equation	The first equation	The second equation
Economic/financial factors (d_1)	0.506 (0.101)	0.621 (0.132)	0.555 (0.106)	0.671 (0.125)
Management factors (d_2)	0.350 (0.092)	0.227 (0.062)	0.406 (0.096)	0.256 (0.088)
Competency factors (d_3)	0.331 (0.071)	0.161 (0.052)	0.321 (0.069)	0.154 (0.069)
Regulatory factors (d_4)	0.198 (0.056)	0.121 (0.048)	0.215 (0.060)	0.138 (0.056)
Technological factors (d_5)	0.244 (0.051)	0.321 (0.069)	0.380 (0.056)	0.357 (0.074)
Region size (log of number of inhabitants)	0.321 (0.069)	—	0.321 (0.069)	—
Relationship indicator (binary variable: 1 – donor region, 0 – recipient region)	0.125 (0.048)	0.129 (0.043)	0.135 (0.050)	0.142 (0.049)
Regional budget (billion rubles)	0.421 (0.087)	0.398 (0.079)	0.450 (0.089)	0.427 (0.075)
Number of observations	112		112	
Model quality assessment – Heckman's lambda	0.225 (0.110)		0.193 (0.102)	
Wald test for Ho, rho = 0	5.64		21.18	
Log-likelihood function	1453.24		3201.37	

Notes: 1. Numbers shown are marginal effect values. 2. Statistical significance of the coefficients: $p \leq 0.01$. 3. Robust standard errors are given in brackets.
Source: compiled by the authors.

by investment areas (the second part of the model) are presented in Table. 3.

The estimated value of the relative value of investments in the development of railway infrastructure has a moderate impact, with the largest values being achieved in the case of investments in the development of multimodal terminal and logistics centers and transport hubs in both scenarios, and in investments in the introduction of digital platforms in Scenario 2.

The implementation of public-private partnership programs has the strongest impact on investment across the board in both scenarios. This feature can be explained by the fact that the model of interaction between private investors and the state has established itself as one of the most effective mechanisms for investing in large infrastructure projects and allows the development of railway junctions as efficiently as possible: the competence of private investors in combination with state subsidies and benefits (in terms of providing access to land or infrastructure on favorable terms, project financing, etc.) allow you to achieve maximum results.

Interaction with representatives of consulting companies most strongly affects investments in multimodal terminal and logistics centers and transport hubs in Scenario 1, as well as investments in digital platform solutions in Scenario 2. This may be due to the fact that consulting companies have a greater understanding of the functioning of railway junctions as parts of urban and agglomeration infrastructure,

Table 3
Results of the railway hubs development investment analysis split in accordance with the areas of investment

Exogenous variables	Scenario 1					Scenario 2				
	SpeedInv (I)	MTLCInv (II)	TPUInv (III)	PogranInv (IV)	DigiInv (V)	SpeedInv (I)	MTLCInv (II)	TPUInv (III)	PogranInv (IV)	DigiInv (V)
1	2	3	4	5	6	7	8	9	10	11
Estimated value of the relative value of investments in the development of railway infrastructure	0.271 (0.062)	0.387 (0.085)	0.392 (0.100)	0.189 (0.058)	0.056 (0.024)	0.264 (0.067)	0.335 (0.079)	0.378 (0.096)	0.192 (0.054)	0.307 (0.084)
Implementation of public-private partnership programmes (1 – yes, 0 – no)	0.396 (0.097)	0.657 (0.142)	0.721 (0.154)	0.385 (0.094)	0.074 (0.021)	0.385 (0.100)	0.664 (0.138)	0.717 (0.162)	0.407 (0.091)	0.651 (0.123)
Interaction with representatives of consulting companies (1 – yes, 0 – no)	0.112 (0.051)	0.345 (0.078)	0.480 (0.102)	0.129 (0.035)	0.154 (0.048)	0.124 (0.060)	0.368 (0.090)	0.475 (0.119)	0.136 (0.039)	0.562 (0.145)
Interaction with specialised flagship universities (1 – yes, 0 – no)	0.208 (0.054)	0.125 (0.048)	0.214 (0.042)	0.201 (0.037)	0.167 (0.023)	0.199 (0.055)	0.146 (0.041)	0.224 (0.045)	0.197 (0.035)	0.343 (0.077)
Region size (log of number of inhabitants)	0.222 (0.067)	0.298 (0.061)	0.303 (0.075)	0.112 (0.053)	0.068 (0.012)	0.217 (0.051)	0.308 (0.069)	0.321 (0.069)	0.139 (0.042)	0.098 (0.034)
Relationship indicator (binary variable: 1 – donor region, 0 – recipient region)	0.117 (0.049)	0.135 (0.047)	0.154 (0.041)	0.122 (0.029)	0.057 (0.015)	0.110 (0.029)	0.123 (0.035)	0.168 (0.031)	0.134 (0.039)	0.112 (0.027)
Regional budget (billion rubles)	0.321 (0.084)	0.374 (0.093)	0.406 (0.121)	0.424 (0.107)	0.117 (0.028)	0.338 (0.082)	0.363 (0.077)	0.416 (0.089)	0.441 (0.094)	0.214 (0.063)
Number of observations	112	112								
McFadden Rsquared	48.31%	54.12%								
LR-statistic	71.23	66.14								
Prob (LR-statistic)	0	0								

Notes: 1. SpeedInv (I) – investments in the modernisation of the railway infrastructure in order to increase the speed of rolling stock; MTLInv (II) – investments in the development of multimodal terminal and logistics centers; TPUInv (III) – investments in the development of transport hubs; PogranInv (IV) – investments in the modernisation of the infrastructure of border crossings; Digi (V) – investment in the implementation of digital platform solutions. 2. Numbers shown have marginal effect values. 3. Statistical significance of the coefficients: $p \leq 0.01$. 4. Robust standard errors are given in brackets.
Source: compiled by the authors.

which allows them to provide effective assistance in the design of infrastructure solutions and lead to greater satisfaction of residents of the territories where these projects are implemented. Also, some consulting companies have extensive expertise in the deployment of industry 4.0 digital technologies, including platform solutions, the integration of which improves the accessibility and usability of the railway transport infrastructure for both the public and commercial users.

Interaction with specialised flagship universities plays the most significant role in the deployment of digital platforms in Scenario 2, since such educational institutions are also centers for the accumulation of competencies in this area and, in particular, serve as platforms for conducting research.

Thus, the results of the analysis show that the most sensitive to the nature of implementation and participants in the implementation of infrastructure projects are

Table 4

Ratio of investments in infrastructure projects aimed at railway transport hubs development and positive socio-economic effects

Exogenous variables	**Equation of socio-economic effects (dependent variable – socio-economic effect from the implementation of infrastructure projects for the development of railway transport hubs)**	
Analysis method – LSM (least squares method)	**Scenario 1**	**Scenario 2**
Estimated value of the relative value of investments in the development of railway infrastructure	0.089 (0.021)	0.096 (0.014)
The intensity of investments in the modernisation of railway infrastructure in order to increase the speed of rolling stock	0.172 (0.063)	0.186 (0.056)
Intensity of investments in the development of multimodal terminal and logistics centers	0.388 (0.102)	0.401 (0.127)
Intensity of investments in the development of transport interchange nodes	0.284 (0.079)	0.322 (0.082)
Intensity of investments in the modernisation of border crossing infrastructure	0.243 (0.058)	0.264 (0.067)
Intensity of investments in the implementation of digital platform solutions	0.112 (0.048)	0.357 (0.099)
Region size (log of number of inhabitants)	0.087 (0.012)	0.093 (0.027)
Relationship indicator (binary variable: 1 – donor region, 0 – recipient region)	0.135 (0.058)	0.144 (0.047)
Regional budget (billion rubles)	0.178 (0.083)	0.199 (0.075)
Number of observations	112	112
McFadden R-squared	48.31%	54.12%
LR-statistic	71.23	66.14
Prob (LR-statistic)	0	0

Notes: 1. The numbers shown have marginal effect values. 2. Statistical significance of the coefficients: $p \leq 0.01$. 3. Robust standard errors are indicated in brackets.

Source: compiled by the authors.

projects for the construction of multimodal terminal and logistics centers, transport interchange hubs and projects for the introduction of digital technologies in the railway infrastructure, since such projects require a wide range of competencies and taking into account the interests of various end users to achieve the maximum socio-economic effect.

The results of calculating the third part of the model - the impact of the relative value of investments in infrastructure projects for the development of railway transport hubs on achieving positive socio-economic effects are presented in Table. 4.

According to the results obtained for both scenarios, the volume of investments in railway infrastructure development projects is positively associated with the positive socio-economic effects achieved, which is consistent with the theory.

At the same time, the strongest positive relationship is observed for investments in the development of multimodal terminal and logistics centers (elasticity is 0.388 in scenario 1 and 0.401 in scenario 2) and transport hubs (elasticity is 0.284 in scenario 1 and 0.322 in scenario 2), and to digital platform solutions in Scenario 2 (elasticity is 0.357).

It should also be noted that the introduction of digital platform solutions in the railway infrastructure increases the efficiency of investing in its other elements, which can be explained by an increase in the connectivity and speed of the entire railway network due to digitalisation, as well as an increase in the level of convenience for both passengers and consignors and consignees.

4. Conclusions and further research

The article considers the main economic effects arising depending on the performance indicators of the implementation of infrastructure projects for the development of railway transport hubs. It was proposed to consider two groups of effects arising depending on the performance indicators of the implementation of infrastructure projects for the development of railway transport hubs: economic and social.

Economic effects include: release of new products; GVA growth generated by trade and transport sectors; GVA growth generated by the project participant (revenue growth); GVA growth generated by related industries. Social effects include: saving time; improving security; ecology; health; social integration; perception of the world.

The constructed econometric model for two scenarios showed that the volume of investments in railway infrastructure development projects is positively related to the positive socio-economic effects achieved, which is consistent with the theory.

At the same time, the strongest positive relationship is observed for investments in the development of multimodal terminal and logistics centers and transport hubs, as well as in digital platform solutions.

Thus, when implementing projects for the development of railway transport hubs, not only economic effects arise, but also social ones, which take into account the most important aspects for the state and society, such as increasing the level of security, improving the environment and public health.

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