

EFFICIENCY OF PPP MECHANISMS FOR DEVELOPMENT OF TRANSPORT INFRASTRUCTURE

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ABSTRACT

The spheres of application of public-private partnership continue to expand. Concession agreements are regularly used in transport, especially in road construction. However, any such option requires comprehensive calculations, an integrated approach, reducing the risk to partners to a minimum, because only a spectacular project can be attractive and profitable when it comes to

long-term investment. The authors of the article reveal step by step the mechanisms of interaction between the parties in implementation of infrastructure projects, consider in detail the mathematical apparatus that assesses the budgetary effectiveness of investment programs, distribution of burden between the state and private partners throughout all stages of the life cycle of projects within the framework of PPP.

Keywords: public-private partnership, concession, economy, transport, infrastructure, life cycle of the project, efficiency, investment load.

Background. According to the law, PPP is a legal cooperation between a public partner, on the one hand, and a private partner, on the other hand, legally based on a combination of resources, risk sharing, which is carried out on the basis of a PPP agreement concluded in accordance with federal law for the purposes of attracting private investments into the economy, providing state authorities and local governments with access to goods, works, services and improving their quality [1].
Mechanisms of public-private partnerships are used very widely abroad [2]. They are reflected in many spheres of human activity: social (kindergartens, schools, medical institutions, etc.), transport (roads and railways, water and air transport, pipeline transport), housing and communal [3], energy, agrarian, even construction and operation of prisons [4].

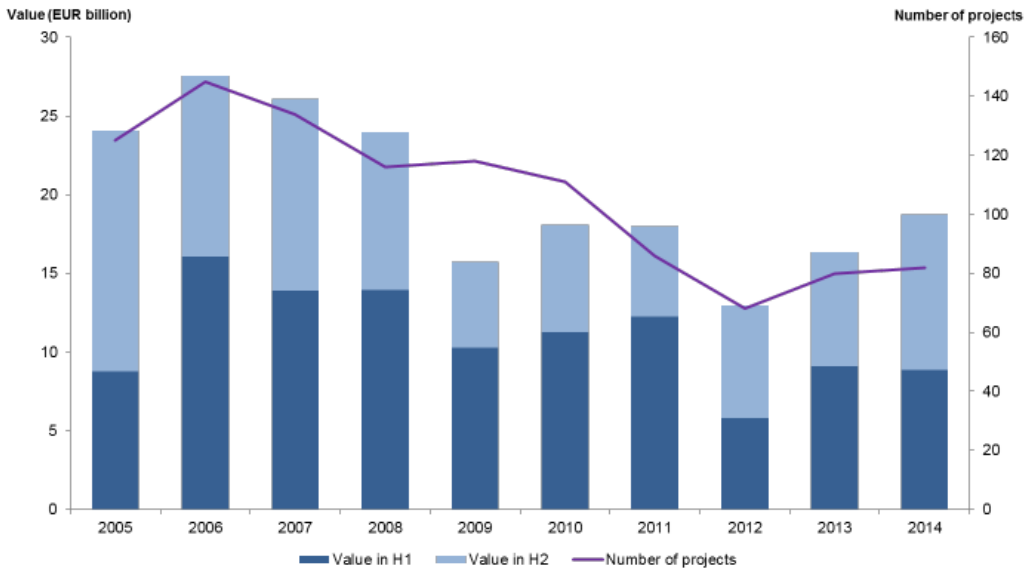
The spheres of application of public-private partnership continue to expand. PPP models are used in the military-industrial complex, space exploration. Until recently, these spheres have been considered as an exclusive prerogative of the state. For example, in the US, Germany and the UK, PPP schemes are being implemented that combine the benefits of public planning and private interest in implementation

Table 1

Stages of development of PPP in Russia

| № | Period | Brief description of the period |
|---|-----------|---|
| 1 | 1717–1836 | The emergence of a partnership between the state and private business in Russia. The construction of mills on the banks of the rivers Una and Shlyna on a concession basis. |
| 2 | 1836–1917 | The emergence and development of a network of railways. Construction of plants. The emergence of telephone networks. Elaboration and development of the legislative framework. |
| 3 | 1917–1937 | Revolution. In 1920, the Council of People’s Commissars adopted a decree on concessions of the RSFSR. On August 21, 1923 by decision of the Council of People’s Commissars of the USSR the Main Concession Committee (Glavkonses) was established. Over 2000 concessions have been created. |
| 4 | 1938–1991 | Liquidation of Glavkonses and the PPP institute. The USSR acted as a concessionaire in foreign projects for development of transport infrastructure. |
| 5 | 1992–2005 | After the breakup of the USSR, the search for forms of interaction between the state and private business begins in the conditions of market relations. The development of PPP laws and mechanisms begins. Privatization. Adoption of Federal Law No. 225 «On Production Sharing Agreements» |
| 6 | 2005–2012 | The adoption on July 21, 2005 of the Federal Law No. 115 «On concession agreements». Mechanisms such as the Investment Fund, model concession agreements, tenders for major transport projects have been developed. For this stage, 23 projects were implemented based on PPP, of which two major transport: – construction and operation of a multi-profile transshipment complex «Yug-2»; – construction of a bridge across the floodplain of the Yuribey River (Obskaya–Bovanenkovo route). By the end of 2012, there were 83 projects in Russia under implementation. |
| 7 | 2012–2015 | More than 9 federal documents regulating state-private partnership have been adopted. Growth in the number of PPP projects. By mid-2015, 595 projects were under implementation, with a total of 871 billion rubles. |
| 8 | 2015–2016 | In early July 2015, the State Duma and the Federation Council adopted the Federal Law «On the Basics of Public-Private Partnership, Municipal-Private Partnership in the Russian Federation and Amendments to Certain Legislative Acts of the Russian Federation» with the entry into force on January 1, 2016 At the beginning of 2016 in Russia there were 1285 PPP projects (a total of over 1 trillion rubles), 95 in the transport sector. |





Pic. 1 shows the volume of PPP projects implemented in the EU in 2005–2014. Volumes are presented in monetary (for the first and second half-year) and quantitative expression [7].

of national projects in the field of space exploration. The National Geospatial Intelligence Agency of the United States (NGA) has signed two NextView contracts with DigitalGlobe (September 2003) and GeoEye (September 2004), respectively, for \$530 and \$500 million to improve the resolution of incoming images from space. In 2006–2007 years these companies developed and launched dual-purpose satellites WorldView and OrbView-5 with equipment for surveying the Earth with a spatial resolution of 0,45 m [5].

Objective. The objective of the authors is to consider efficiency of PPP mechanisms for transport infrastructure.

Methods. The authors use general scientific methods, economic evaluation, comparative analysis, scientific description, mathematical apparatus, graph construction.

Results. In the field of railways, the mechanism of public-private partnership has also found its application. This is confirmed not only by Russian historical experience, but also by the modern world. So, on concession terms, Siemens implemented a 150 km railway project in Mexico, which connects eight cities. The term of the agreement was 30 years, and the total amount of investments – \$1,1 billion.

An example of such a project is the high-speed HSL Zuid line in the Netherlands. The volume of investments amounted to 1,2 billion euros and was

contributed by private investors (of which 90 % by private banks, 10 % by industrial companies, including Siemens) [6].

For Russia, PPP is also not something new. A brief description of the stages of PPP development in Russia is presented in Table 1.

Investment projects for development of transport infrastructure on the basis of public-private partnership should be evaluated on the basis of a comprehensive analysis of economic, social, environmental indicators covering the entire life cycle of the project, from the pre-project stage to the service life of the facility. Criteria for assessing the participation of partners should take into account the interests of both public and private levels.

The sequence of assessing the economic benefits of participants in implementation of investment projects based on public-private partnerships is as follows:

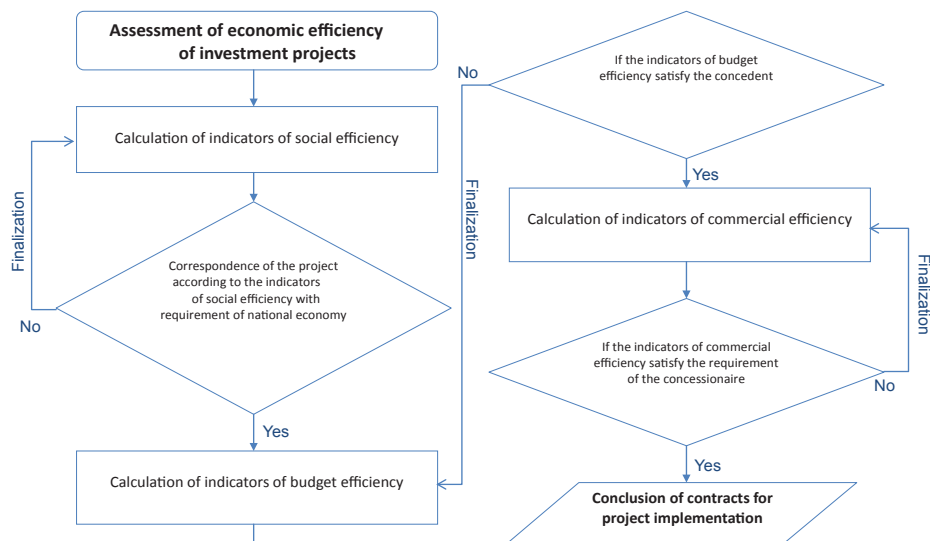
1) The social efficiency of the investment project as a whole is assessed. If it satisfies the national economic requirements by the indicators of social efficiency, then proceed to point 2. Otherwise, the analyzed project is either rejected or recommended for revision.

2) The indicators of the budget efficiency of the investment project are determined. If they satisfy the concessor, then go to step 3. Otherwise, the limit of

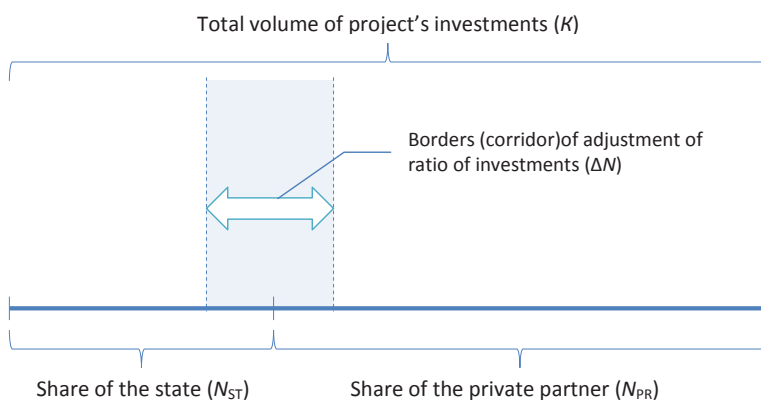
Table 2

Stages of the project's life cycle

| № | Characteristics of stages | Description of stages | Main participants |
|---|---|-----------------------|--|
| 1 | Pre-project stage | T_{pp} | Investors, customers, design organizations |
| 2 | Design stage | T_d | Customers, design organizations |
| 3 | Construction-installation works | T_{ciw} | Customers, contractors, design organizations, enterprises of construction industry |
| 4 | Operation of the facility under the concession agreement | T_c | Concessionaire, accompanying enterprises |
| 5 | Period of operation of the facility when it is transferred to the state | T_o | Concessor, accompanying enterprises |



Pic. 2. Algorithm for selection of projects for development of transport infrastructure, implemented on the basis of PPP.



Pic. 3. Ratio of shares of the state and the private partner in transport construction projects.

investments of the concessor is set, at which budgetary efficiency will satisfy him.

3) The indicators of commercial efficiency for concessionaires are calculated. If they satisfy them, they proceed to conclude contracts for implementation of the project. Otherwise, the importance of this commercial efficiency is increased by reducing private investment, or extending the duration of the concession, or both until an acceptable commercial efficiency is obtained for the concessionaire. After this, proceed to step 2. In case when the concessionaire does not economically benefit from investing in the project, it is considered expedient to implement the project with fully public funds.

With concessions, five stages of the life cycle of the project should be identified. Table 2 lists the main participants in implementation of investment projects for the life cycle stages.

Estimation of budgetary efficiency of investment projects at $T_p \geq T_c$ can be carried out according to the following indicators.

$$NPV_b = -\sum_{t=1}^{T_c} C_t^b \cdot \eta_t + \sum_{t=1}^{T_s} B_t \cdot \eta_t + \sum_{t=T_s}^{T_e} E_t \cdot \eta_t; \quad \eta_t = \frac{1}{(1+E)^t}, \quad (1)$$

$$PI = \frac{\sum_{t=1}^{T_s} B_t \cdot \eta_t + \sum_{t=T_s}^{T_e} E_t \cdot \eta_t}{\sum_{t=1}^{T_c} C_t^b \cdot \eta_t}. \quad (2)$$

The internal rate of return (E_p) is determined from the equation:

$$\sum_{t=1}^{T_s} \frac{B_t}{(1+E_p)^t} + \sum_{t=T_s}^{T_e} \frac{E_t}{(1+E_p)^t} = \sum_{t=1}^{T_c} \frac{C_t^b}{(1+E_p)^t}. \quad (3)$$

The payback period (T_o) of investments by the concedent is found from the equation:

$$\sum_{t=1}^{T_o} B_t \cdot \eta_t + \sum_{t=T_o}^{T_e} E_t \cdot \eta_t = \sum_{t=1}^{T_c} C_t^b \cdot \eta_t, \quad (4)$$

where NPV_b – budgetary net present value;

PI – profitability index;

E_p – internal rate of return (IRR);

T_o^p – payback period of investments;

C_t^b – investment costs of the concessor in the t -th year;

B_t – increase in the budget in the t -th year, due to the implementation of investment project;

E_t – economic effect of the concessor in the t -th year;

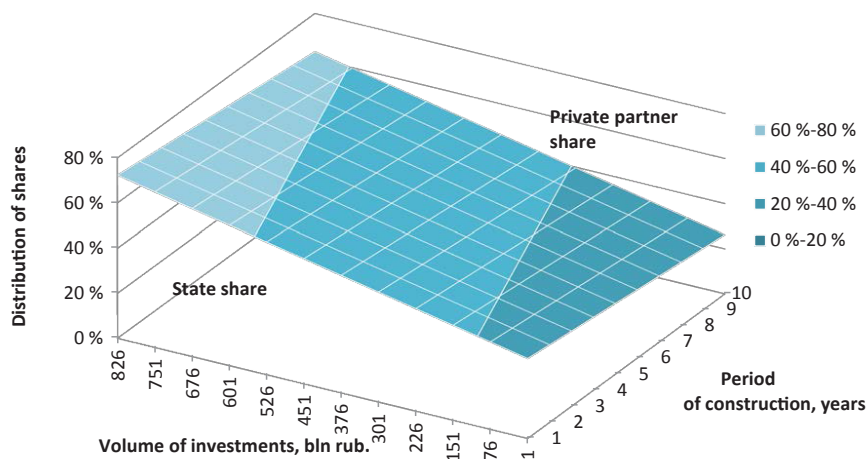
η_t – reduction coefficient of cash flows of future periods (discount coefficient);

E – rate of discount;

T_s – year of starting operation of the facility;

T_e – year of the end of the concession contract;





Pic. 4. Distribution of investment burden between the state and the private partner in projects for development of transport infrastructure.

T_h – calculation horizon.

t – period (calculation stage).

In determining the commercial effectiveness of the concessionaire:

$$NPV_c = -\sum_{t=1}^{T_c} \frac{C_t^{con}}{(1+E)^t} + \sum_{t=1}^{T_c} \frac{E_t^{con}}{(1+E)^t} - \frac{C_c}{(1+E)^{T_c}}, \quad (5)$$

$$PI = \frac{\sum_{t=1}^{T_c} \frac{E_t^{con}}{C_t^{con}} \cdot \eta_t}{\sum_{t=1}^{T_c} \frac{C_t^{con}}{C_c} \cdot \eta_t + \frac{C_c}{(1+E)^{T_c}}}. \quad (6)$$

The internal rate of return (E_p) of the concessionaire is found from the equality:

$$\sum_{t=1}^{T_c} \frac{E_t^{con}}{(1+E_p)^t} = \sum_{t=1}^{T_c} \frac{C_t^{con}}{(1+E_p)^t} + \frac{C_c}{(1+E_p)^{T_c}}. \quad (7)$$

The payback period (T_o) of the concessionaire is determined from the equations:

$$\text{when } T_o < T_c: \sum_{t=1}^{T_o} \frac{E_t^{con}}{(1+E_c)^t} = \sum_{t=1}^{T_o} \frac{C_t^{con}}{(1+E_c)^t}, \quad (8)$$

when $T_o = T_c$

$$\sum_{t=1}^{T_c} \frac{E_t^{con}}{(1+E_c)^t} = \sum_{t=1}^{T_c} \frac{C_t^{con}}{(1+E_c)^t} + \frac{C_c}{(1+E_p)^{T_c}}, \quad (9)$$

where NPV_c – commercial net present value;

C_t^{con} – investments of the concessionaire in the t -th year;

E_t^{con} – economic effect of the concessionaire in the t -th year;

C_c – expenses at delivery of object by the concessionaire to the state in T_c -th year.

Selection of investment projects implemented on the principles of PPP, is recommended to be carried out in accordance with the following sequence:

1. At the first stage, projects that do not have the required values of public performance indicators are discarded: $NPV_s \leq 0$, $IRR_s < En$, $T_o^s > T_o^{norm}$.

2. Projects for indicator NPV_b are analyzed, projects in which $NPV_b \leq 0$ are discarded.

3. Projects for indicator IRR_b are analyzed, projects in which $IRR_b \leq En$ are discarded.

4. The projects for T_o^b are analyzed, projects with indicators exceeding the established norm, are discarded.

5. The remaining projects are ranked in ascending order T_o^b .

6. With equal payback period, projects that have the maximum value of NPV_b , minimum investment costs and other best social and environmental indicators are selected.

7. Projects that fit within the limit of state resources are accepted for implementation.

All selected projects should ensure the real commercial effectiveness of the private partner. This requires an analysis of the calculation of the effectiveness of private investment.

Schematically, the algorithm for selecting projects for development of transport infrastructure implemented on the basis of PPPs is shown in Pic. 2.

The completion of the projects indicated in the block diagram is carried out by improving the indicators of the economic efficiency of investments: first of all, by changing the distribution of the investment load and changing the concession term.

Distribution of investments between the state and the private partner is presented in a schematic form in Pic. 3.

Projects with payback periods of up to 5–7 years, in some cases – 10 years are attractive for a private partner. At the same time, for the state the payback period for projects of high social significance can be more than 30 years.

To determine the optimal ratio of investments in PPPs, a sample of the projects presented on the portal of the public-private partnership development center was used [8].

Further, a correlation-regression analysis was performed to reveal the dependence, in which the function is the ratio of the investment shares of the state and private business, and the arguments – the planned implementation period and the volume of investments [9, 10].

The ratio of the shares of the state and private business in PPP projects for the development of transport infrastructure will look like:

$$\frac{N_{ST}}{N_{PR}} = \frac{0,3649 + 0,4462 \cdot 10^{-12} \cdot K - 0,0103 \cdot T_{CON}}{0,6351 - 0,4462 \cdot 10^{-12} \cdot K + 0,0103 \cdot T_{CON}}, \quad (10)$$

where N_{ST} – share of investments of the state;

Table 3

Distribution of investment burden between the state and the private partner in transport infrastructure development projects (state share is indicated)

| Investments, bln rub. | Construction period, years | | | | | | | | | |
|-----------------------|----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 35,5 % | 34,5 % | 33,4 % | 32,4 % | 31,4 % | 30,4 % | 29,3 % | 28,3 % | 27,3 % | 26,2 % |
| 76 | 38,9 % | 37,8 % | 36,8 % | 35,8 % | 34,7 % | 33,7 % | 32,7 % | 31,6 % | 30,6 % | 29,6 % |
| 151 | 42,2 % | 41,2 % | 40,1 % | 39,1 % | 38,1 % | 37,1 % | 36,0 % | 35,0 % | 34,0 % | 32,9 % |
| 226 | 45,5 % | 44,5 % | 43,5 % | 42,5 % | 41,4 % | 40,4 % | 39,4 % | 38,3 % | 37,3 % | 36,3 % |
| 301 | 48,9 % | 47,9 % | 46,8 % | 45,8 % | 44,8 % | 43,7 % | 42,7 % | 41,7 % | 40,7 % | 39,6 % |
| 376 | 52,2 % | 51,2 % | 50,2 % | 49,2 % | 48,1 % | 47,1 % | 46,1 % | 45,0 % | 44,0 % | 43,0 % |
| 451 | 55,6 % | 54,6 % | 53,5 % | 52,5 % | 51,5 % | 50,4 % | 49,4 % | 48,4 % | 47,3 % | 46,3 % |
| 526 | 58,9 % | 57,9 % | 56,9 % | 55,8 % | 54,8 % | 53,8 % | 52,8 % | 51,7 % | 50,7 % | 49,7 % |
| 601 | 62,3 % | 61,3 % | 60,2 % | 59,2 % | 58,2 % | 57,1 % | 56,1 % | 55,1 % | 54,0 % | 53,0 % |
| 676 | 65,6 % | 64,6 % | 63,6 % | 62,5 % | 61,5 % | 60,5 % | 59,4 % | 58,4 % | 57,4 % | 56,4 % |
| 751 | 69,0 % | 67,9 % | 66,9 % | 65,9 % | 64,9 % | 63,8 % | 62,8 % | 61,8 % | 60,7 % | 59,7 % |
| 826 | 72,3 % | 71,3 % | 70,3 % | 69,2 % | 68,2 % | 67,2 % | 66,1 % | 65,1 % | 64,1 % | 63,1 % |

N_{PR} – share of investments of the private partner;
 K – volume of investments, rub.;

T_{CON} – period of construction of the object, years.

As it follows from the dependence 10, the investment load on the state (N_{ST}) increases with the cost of the project (K) and decreases with the increase in duration of the facility construction (T_{CON}). At the same time, the investment burden on private business (N_{PR}) is growing with the increase in the duration of the facility construction (T_{CON}) and decreases with the increase in cost of the project (K).

In this there is logic: the higher is the cost of the project, the greater is the burden the state must take on; the sooner the project is implemented, the less investment burden is borne by the private partner. The distribution of shares is clearly shown in Pic. 4. Everything below the plane is the share of the state, everything, which is above the plane than the share of the private partner.

In Table 3 data are presented in a tabular form.

The risks of investments on transport can be classified according to Table 4. The risk assessment matrix can be constructed for investment projects in accordance with and with allocation of critical, large, medium, small and minor risks (Table 5).

Risks that arise at different stages of the life cycle of projects implemented on the basis of public-private partnership can be either for the state or for private investors. Table 6 describes those risks, the emergence of which is possible at the pre-project stage, the stage of development of project documentation, in the performance of construction and installation works, and the operation of the facilities commissioned.

The manifestation of risks and uncertainties in information causes a certain character of stochastic evaluation of the effectiveness of investments.

To improve the quality of the decision, it is expedient to check stability of its effectiveness with different values of initial information within the borders of its possible range of fluctuations and the most likely unfavorable situations of project implementation.

If the solution is the most economical in the range of possible values of the initial data and unfavorable

Table 4

Types of risks of investment projects and projects on transport

| Feature | Type |
|--|--|
| 1. Place of occurrence of risk | 1.1. External 1.2. Internal |
| 2. The sphere of manifestation | 2.1. Technological 2.2. Economic 2.3. Ecological 2.4. Social |
| 3. Nature of origin | 3.1. Natural 3.2. Risks related to human factor 3.3. Political 3.4. Legal 3.5. Technical |
| 4. Nature of distribution of the risk burden | 4.1. Unilateral 4.2. Bilateral 4.3. Multilateral |
| 5. Level of manifestation | 5.1. Industry risk 5.2. Risk of the enterprise (organization) |
| 6. Extent of prevalence | 6.1. Mass 6.2. Unique |
| 7. Frequency of damage | 7.1. Frequent 7.2. Risks of medium frequency 7.3. Rare |
| 8. Nature of possible financial implications | 8.1. Risks that cause direct damage 8.2. Risks with indirect damage |

situations of its implementation, then it can be recommended for adoption. This should be expected only for small ranges of changes in initial values. But the smaller is the range of data, the more likely that it will not include the actual values of this data, and this can lead to a significant deviation of the decision from the optimal one.

Insignificant ranges of fluctuations in the initial information can be taken only in the years close to the



Risk assessment matrix of investment projects

| Degree of risk exposure to the project | Probability of risk realization (p) | | |
|--|-------------------------------------|---------------------|--------------|
| | High, p = 1,0–0,7 | Medium, p = 0,6–0,4 | Low, p < 0,4 |
| Strong | Critical risk | Major risk | Average risk |
| Medium | Major risk | Average risk | Small risk |
| Weak | Average risk | Small risk | Minor risk |

Table 6

Main risks at the stages of the life cycle of investment projects

| Stages of the life cycle | Characteristics of risks | Party, bearing risk | Risk assessment |
|-------------------------------------|--|----------------------------|-----------------|
| Pre-project stage and design stage | 1. Risks due to the quality of pre-project documentation | State | Major risk |
| | 2. Risks of development of project documentation | State | Critical risk |
| | 3. Risks of land purchase and preparation of the territory of construction | State | Critical risk |
| | 4. Risks that arise when the necessary approvals are issued | State | Average risk |
| Construction and installation works | 1. Risk of increase in construction price | State and private investor | Critical risk |
| | 2. Risks of financial opportunities | State and private investor | Major risk |
| | 3. Risks of equipment supply | State | Small risk |
| | 4. Risks caused by extreme circumstances | State and private investor | Average risk |
| Operation of the object | 1. Risk of decrease in revenues | State | Small risk |
| | 2. Risk of increase in operating costs | Private investor | Major risk |
| | 3. Risk of detection of hidden defects after commissioning of the project | Private investor | Average risk |
| | 4. Emergency circumstances | State and private investor | Average risk |

reporting period. In the longer term, the range should be increased, but this leads to a decrease in the stability of the effectiveness of the decision.

When assigning input data in a probabilistically determined form, the evaluation of economic efficiency can be carried out using the mathematical expectation of the efficiency index.

If it is possible to specify the numerical values of the probabilities of possible values of the initial data, then for evaluation of effectiveness, for example, the mathematical expectation of the net discounted income is suitable:

$$NPV_{exp} = \sum_{i=1}^{n_p} P_i \cdot NPV_i, \quad (11)$$

where NPV_{exp} – mathematical expectation of net present value;

NPV_i – net present value at i -th condition of realization of the project;

P_i – probability of occurrence of i -th condition

$$\left(\sum_{i=1}^{n_p} P_i = 1 \right);$$

n_p – number of options of possible values of initial information.

In this case, the most economically effective option is the one that has the maximum value of NPV_{exp} .

In conditions of uncertainty, the initial data are characterized either by a segment (for a single

indicator) or by a region (for a set of indicators) of possible values. Then there are three cases:

1) numerical values of probabilities of various indicators cannot be established, but the probability of coincidence of actual initial data with one of the forecast boundaries is significant;

2) it is possible to indicate the degree of preference for changes in initial information on the boundary of the maximum (minimum) possible values;

3) evaluation of the economic efficiency of investments is carried out with the maximum uncertainty of the initial information, when one cannot give preference to a single value over the others in the entire range of possible fluctuations in the initial data.

In the first case, when the probability of coincidence of the initial data with the boundary values is significant, evaluation of economic efficiency of the solution can be made, for example, using the formula:

$$\max_j \min_i NPV_{ij} \left(i = \overline{1, N_n^{(j)}}; j = \overline{1, N_v} \right), \quad (12)$$

where NPV_{ij} – i -th value of net present value for j -th option of investment project;

$N_n^{(j)}$ – number of possible values of NDI for j -th option;

N_v – number of project variants being compared.

If it is possible to indicate the degree of preference for changes in the initial information along the boundary of the maximum possible values of the initial

data in comparison with the minimum possible (the second case), then the most efficient option is based on the generalized maximum of the net discounted income:

$$\max_j \left[\alpha_0 \max_i \text{NPV}_{ij} + (1 - \alpha_0) \min_i \text{NPV}_{ij} \right], \quad (13)$$

where α_0 – indicator of optimism reflecting the probability of such a change in the initial information of the j -th variant, which corresponds to the maximum value of NPV. The indicator is in the range (0; 1).

In the case where it is difficult to establish the degree of preference for coincidence of actual values of the indicators with one of the limits of the range of their possible fluctuation, the coefficient α_0 can approximately be equal to 0,3–0,4.

With the maximum uncertainty of the initial information, when no value of the indicator can be given preference over the others in the entire range of possible fluctuations in the initial data (the third case), the choice can be made in accordance with the maximum excess of NPV, and thereby, minimizing the risk, to get a big loss. The minimum excess for j -th version of the investment project is expressed by the dependence:

$$\tau_j = \min \begin{cases} \min_i \text{NPV}_{ij} - \max_j \min_i \text{NPV}_{ij} \\ \max_i \text{NPV}_{ij} - \max_j \max_i \text{NPV}_{ij} \\ (i = \overline{1, N_n^{(j)}}, j = \overline{1, N_v}). \end{cases} \quad (14)$$

That option, which has the maximum value of τ_j is accepted as economically most effective.

Conclusions. In general, the use of public-private partnership mechanisms will attract additional investments in transport construction, help solve the problem of transport infrastructure development. After all, without sufficient transport links between regions, it is impossible to implement effective management, pursue a policy that stimulates economic development. In times of crisis, in the sanctions war, transport construction can become a driver of the country's economic growth. According to experts, the development of transport infrastructure, thanks to the multiplicative effect, makes it possible to stimulate other related sectors of the national economy.

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