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Algorithm for the selection of public-private partnership projects for planning the resources allocation in road and transport infrastructure

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Abstract. Features of functioning of the modern road and transport infrastructure in terms of attracting private investments in infrastructure projects through the mechanisms of public-private partnership are identified. An additional set of indicators is proposed for evaluating the public-private partnership projects in the road and transport infrastructure. An algorithm was developed for selection of the projects implemented in the road and transport infrastructure using public-private partnership mechanisms. The problem of the preferred choice of projects for the construction of roads from a variety of alternatives was solved. The proposed algorithm for selecting public-private partnership projects in planning the resources allocation in the road and transport infrastructure, which contains additional tools in the form of a set of indicators of the functioning and resource allocation of the road and transport infrastructure, can be used to solve the problem of choosing a project that satisfies maximally all the requirements stated by the customer taking into account the level of investment opportunities.

1. Introduction

One of the tools to increase financing is to attract private investment in infrastructure projects through public-private partnership mechanisms. Currently, in the legal documents there are several definitions of the term public-private partnership, which to various extents reflect the essence and content of the object under consideration [1, 2, 3].

The term public-private partnership (PPP) is understood as an investment agreement concluded in accordance with the legal regulations of the Federal Law-224 and Federal Law-115 between private partners, on the one hand, and a public partner, on the other hand, for a period established by the agreement on public-private partnership in order to allocate resources and risks, to stimulate an increase in private investments in the economy, to reduce the share of the state in projects that are more effectively implemented by business.

The practice of implementing infrastructure projects involving PPP mechanisms in the Russian Federation is borrowed from world experience, which has seven basic forms of agreements [5].

In the Russian Federation in the field of construction and reconstruction of roads, three PPP models are legally regulated [2, 3]:

- owner-operator contract, in which a private partner on the basis of a lease agreement operates a road;
- a concession agreement, a private partner builds and operates a road facility owned by a public partner for remuneration;



- a life cycle contract, a private partner finances the work on the design, construction, maintenance and repair of a road facility at the expense of own or borrowed funds.

The most widespread in PPP projects, implemented by “Avtodor” Group of Companies in the period from 2010 to 2019, turned out to be a concession with a direct collection of fees and a concession with the fee of the concedent [4]. For the future periods, within the “Roadmap” used for implementation of the “Strategy on the development of road transport for the period up to 2030” it is planned to increase the financing of infrastructure projects through PPP mechanisms, for example, construction in 2019-2022 of a network of transport and logistics terminals on the main trucking directions, etc. [1].

2. Development of an algorithm for the selection of roads construction projects using PPP mechanisms on a quantitative and qualitative level

In the period from 2010 to 2018 financing of the road and transport infrastructure in the Russian Federation was carried out inconsistently and to a greater extent at the expense of budget funds (figure 1), which led to underfunding or disruption of the schedule of roads reconstruction. As a result, by January 2019, the share of roads complying with regulatory requirements was 80% [4].

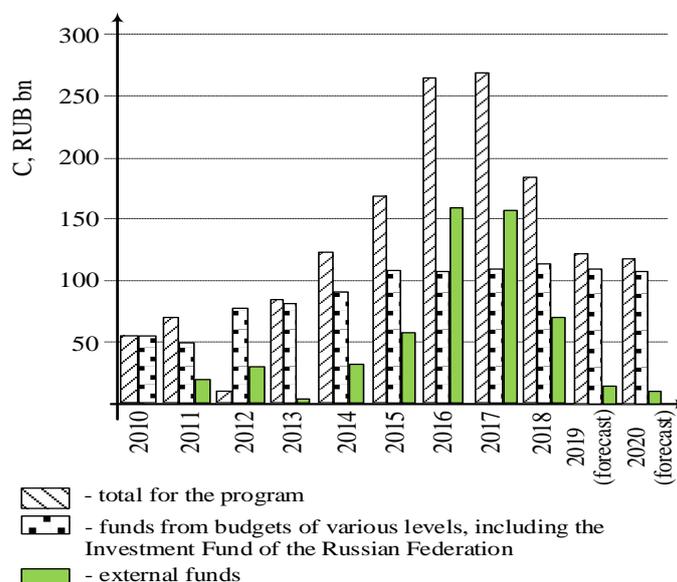


Figure 1. The volume and sources of financing the organization of roads construction and reconstruction in the Russian Federation for the period 2010-2020 [1].

In connection with the increase of the share of attracted funds in the financing of infrastructure projects due to PPP mechanisms, the issues of improving the algorithm for selecting PPP projects when planning the resources allocation in the road and transport infrastructure has become very important.

The existing international and developed in Russia approaches to the method of selecting PPP projects when planning the resources allocation in the road and transport infrastructure allow the process to be divided into two stages:

- primary selection of PPP projects;
- integrated assessment.

During the initial selection of PPP projects it is advisable to use the indicators approved by the order of the Ministry of Economic Development of the Russian Federation No. 894 dated November 30, 2015 (“Methods for evaluating the effectiveness of a public-private partnership project, a municipal-private partnership project and determining their comparative advantage”) as selection criteria [6]:

- the volume of the public partner participation in the implemented infrastructure projects using PPP mechanisms, (PRV), rub.;
- the volume of net discounted expenses of the budget system of the Russian Federation in the implementation of infrastructure projects using PPP mechanisms, (PBV), rub.

The projects that score the highest number of points determined by the method of expert assessments will receive greater priority at the stage of initial selection of projects using the PPP mechanism.

At the stage of integrated assessment it is recommended to carry out the procedure for selecting projects after calculating the following indicators [7, 8, 9]:

- net present value of the project (NPV_{pp});
- Debt service coverage ratio (DSCR);
- internal project rate of return (IRR);
- profitability index (PI).

At this stage, priority is given to projects implemented with the involvement of PPP mechanisms, in which the above indicators have higher values.

In this paper, the following set of indicators for the functioning and distribution of resources of the road and transport infrastructure is proposed as an additional toolkit for justifying the choice of public-private partnership projects [10]:

- infrastructure indicator Ind_1 , which characterizes the length of the sections of transport communications with limitations on carrying capacity due to the non-compliance with regulatory requirements;
- the indicator of transport work Ind_2 characterizes the volume of traffic using the reserve routes due non-compliance of roads with regulatory requirements, which are used for the main routes, and with transport performance indicators;
- operational indicator Ind_3 – characterizing the value of shipments delivered by road transport in terms exceeding the standard (contractual) term;
- social indicator Ind_4 , characterizes the value of the additional time of the population being on the way due to the non-compliance of highways with regulatory requirements;
- economic indicator Ind_5 – characterizes the efficiency of investments directed to the system of road and transport infrastructure, it is proposed to use the net discounted income as an indicator.

The above set of indicators has a scope in cases where the procedure of the projects formation is based on quantitative data. Ranking projects with the use of the PPP mechanism, depending on the significance of the indicators, is carried out by the method of expert assessments.

The choice of a project implemented with the involvement of PPP mechanisms implies the following conditions:

$$Ind_1(t + 1) \leq Ind_1(t), t \in [0, T] \quad (1)$$

$$Ind_2(t + 1) \leq Ind_2(t), t \in [0, T] \quad (2)$$

$$Ind_3(t + 1) \leq Ind_3(t), t \in [0, T] \quad (3)$$

$$Ind_4(t + 1) \leq Ind_4(t), t \in [0, T] \quad (4)$$

$$Ind_5(t + 1) \geq Ind_5(t), t \in [0, T] \quad (5)$$

where t – the calculated period, years;

T – the duration of the project, years.

For projects in which the formation procedure is based on a fuzzy presentation of primary and intermediate data, the following condition is proposed as a tool for assessing the state of the resource allocation system and justifying the choice (at a qualitative level) [11]:

$$SSRR(t + 1) \geq SSRR(t), t \in [0, T] \quad (6)$$

where SSRR is the assessment of the state of the resource distribution system of the road and transport infrastructure.

The algorithm for the selection of road construction projects using PPP mechanisms at the quantitative and qualitative level is shown in figure 2.

The final stage is the ranking of projects by analyzing hierarchies. Projects that have passed the assessment and selection procedure described above are included in the portfolio and prepared for implementation.

3. Results and discussion

The task of the choice of the most preferable project from a set of possible options can be formulated as follows:

Let A_j be a set of alternative options for road construction projects. It is necessary to choose the most preferable road construction option according to the highest priority of efficiency V_{A_j} , which ensures maximum customer satisfaction, by maximizing the local criteria $Ind_1, Ind_2, Ind_3, Ind_4, Ind_5$, which are indicators of the functioning and resources allocation of the road and transport infrastructure.

It is required to determine one of the many projects for implementation that has the highest priority of efficiency among the alternatives of the taken decision:

$$V_{A_j} = \max \{v_{A_j}\} \cdot j = \overline{1, n} \quad (7)$$

where V_{A_j} is the highest priority of efficiency; v_{A_j} – the weight coefficient of each alternative project; A_j – alternative options of project.

The weight coefficient of each alternative is calculated by the following formula:

$$v_{A_j} = \sum_{i=1}^m v_{Ind_i} \times v_{Ind(A_j)} \quad (8)$$

where v_{Ind_i} – the priority vector of particular criteria; $v_{ind(A_j)}$ – the priority vector of the considered alternative projects; Ind_i – local criteria characterizing the requirements for the considered alternative projects.

$$Ind_i = \{Ind_1, Ind_2, Ind_3, Ind_4, Ind_5\} \quad (9)$$

where $\{Ind_1, Ind_2, Ind_3, Ind_4, Ind_5\}$ is a set of indicators of the functioning and resources allocation of road and transport infrastructure.

The task of selecting alternative road construction projects implemented using the PPP mechanisms that have passed the primary and comprehensive selection is proposed to be solved by the hierarchy method [13] using the following example. There are three alternative road construction projects:

- alternative project 1 (A_1): the road is laid on the land owned by the municipality. The road has two traffic lanes with width of 3.5 m. The radii of the curves are 600-2000 m. The ratio of the curved sections of the route to the straight ones is 65%;
- alternative project 2 (A_2): the road is laid on the land owned by the municipality and coal mining enterprise in the ratio of 60x40. The road has two traffic lanes with width of 3.5 m. The radii of the curves are 2000-3000 m. The ratio of the curved sections of the route to the straight is 40%;
- alternative project 3 (A_3): the road is laid on the land owned by a coal-mining enterprise. The road has two traffic lanes with width of 3.0 m. The radii of the curves are 5000-2000 m. The ratio of the curved sections of the route to the straight is 15%.

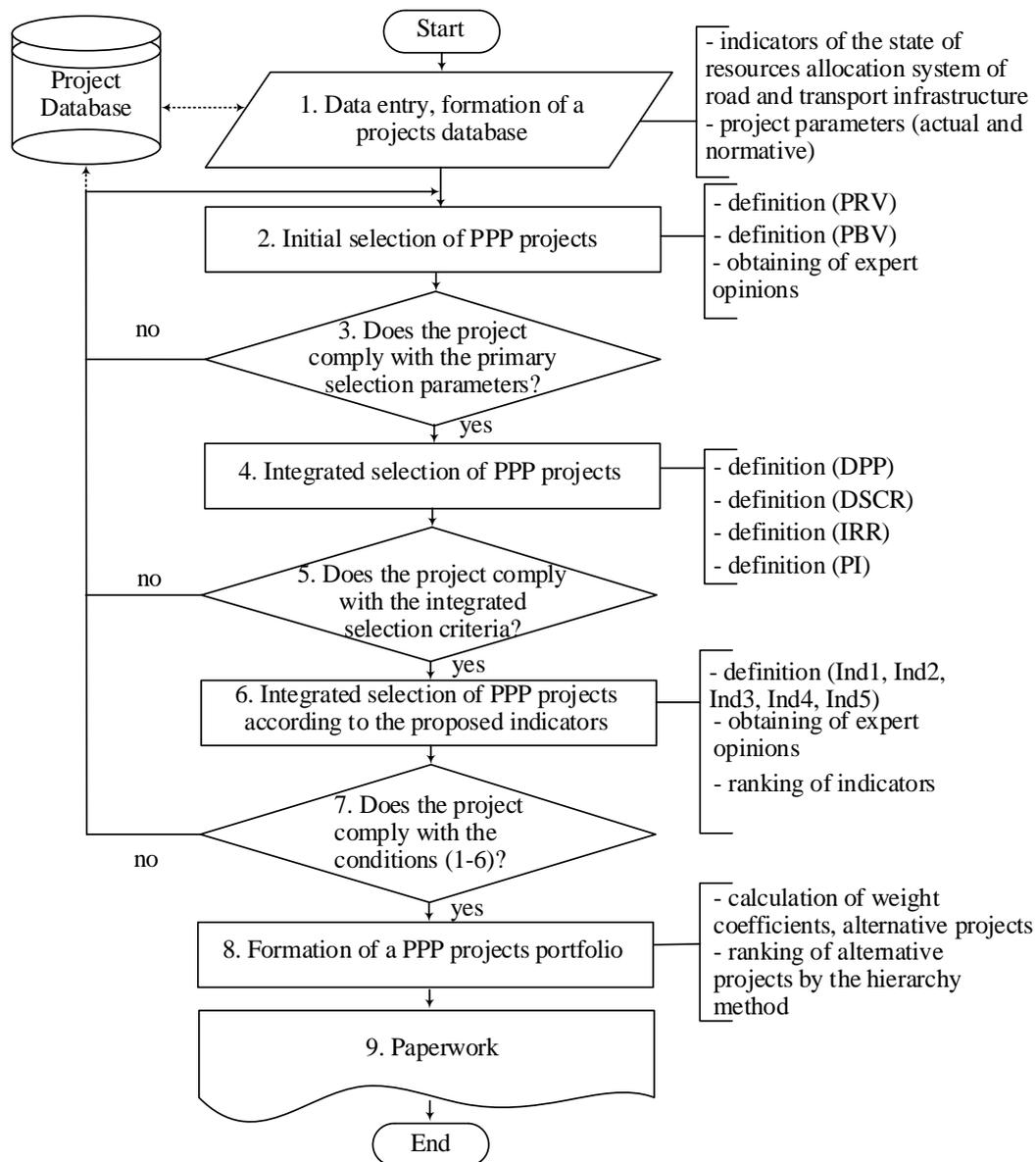


Figure 2. Algorithm for the selection of road construction projects using PPP mechanisms on a quantitative and qualitative level.

To identify the project with the highest priority of efficiency, the following sequence of steps is required:

Step 1. An assessment of the relative importance of indicators in relation to the higher level of the hierarchy is performed, while significance is interpreted as a contribution to the achievement of a common goal. The assessment is carried out by comparing pairs of alternatives of a certain level with other elements of the same level. For carrying out pair comparisons, as a rule, the scale of relative preference is used.

Step 2. Construction of the hierarchical structure of the task on choosing a road construction project. In this example, the hierarchy structure will be three-level, as shown in figure 3.

Step 3. Creating a pairwise comparison matrix. Based on the assessment scale (table 1), we convert the opinions of experts on the comparability of various factors into quantitative indicators (table 2) and draw up a matrix of pairwise comparisons (table 3).

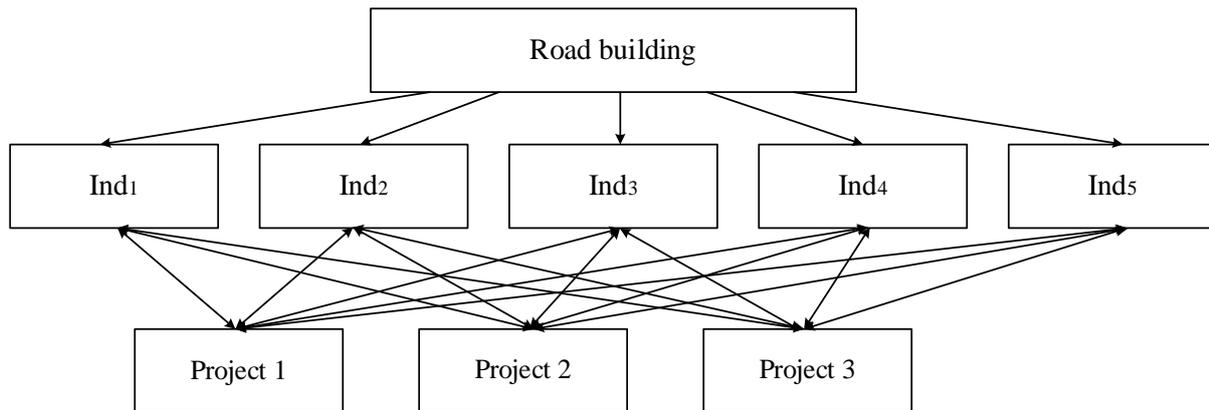


Figure 3. The hierarchical structure of indicators and projects.

Table 1. The scale of relative significance [13].

Value of a rating scale	Interpretation of the significance of the hierarchical structure element
1	equal
2	compromise between importance 1 and 3
3(1/3)	slightly better (worse) – 3 (1/3)
4	compromise between importance 3 and 5
5 (1/5)	better (worse)
6	compromise between importance 5 and 7
7	much better (worse)
8	compromise between importance 7 and 9
9	very strong superiority (lagging behind) – 9 (1/9)

Table 2. Initial matrix of pairwise comparisons of alternative projects by indicators.

Indicators	<i>Ind₁</i>	<i>Ind₂</i>	<i>Ind₃</i>	<i>Ind₄</i>	<i>Ind₅</i>
<i>Ind₁</i>	1	3	1	0.5	5
<i>Ind₂</i>	0.333333	1	2	5	2
<i>Ind₃</i>	1	0.5	1	8	6
<i>Ind₄</i>	2	0.2	0.125	1	8
<i>Ind₅</i>	0.2	0.5	0.166667	0.125	1
Σ	4.533333	5.2	4.291667	14.625	22

Table 3. Matrix for calculating the priority vectors of alternative indicator projects.

Indicators	<i>Ind₁</i>	<i>Ind₂</i>	<i>Ind₃</i>	<i>Ind₄</i>	<i>Ind₅</i>	priorities vector
<i>Ind₁</i>	0.220588	0.576923	0.23301	0.034188	0.227273	0.258396
<i>Ind₂</i>	0.073529	0.192308	0.466019	0.34188	0.090909	0.232929
<i>Ind₃</i>	0.220588	0.096154	0.23301	0.547009	0.272727	0.273898
<i>Ind₄</i>	0.441176	0.038462	0.029126	0.068376	0.363636	0.188155
<i>Ind₅</i>	0.044118	0.096154	0.038835	0.008547	0.045455	0.046622

From the point of view of achieving the goal, the most preferable choice of road construction option is the most significant is the operational indicator *Ind₃* (27.4%), followed by the infrastructure indicator *Ind₁* (25.8%), the next indicator of transport work *Ind₂* (23.3%). The social indicator *Ind₄* and the economic indicator *Ind₅* have the smallest weight coefficients (18.8% and 4.7%, respectively).

Step 4. Creation of matrices of pairwise comparisons for each indicator (tables 5, 7, 9, 11, 13).

Table 4. The initial matrix of elements pairwise comparisons of the infrastructure indicator Ind_1 .

Ind_1	project 1	project 2	project 3
project 1	1	4	0.5
project 2	0.25	1	0.2
project 3	2	5	1
Σ	3.25	10	1.7

Table 5. Matrix of elements pairwise comparisons of the infrastructure indicator Ind_1 .

Infrastructure Indicator Ind_1	project 1	project 2	project 3	priorities vector
project 1	0.307692	0.4	0.294118	0.333937
project 2	0.076923	0.1	0.117647	0.09819
project 3	0.615385	0.5	0.588235	0.567873

Table 6. The initial matrix of elements pairwise comparisons the infrastructure indicator Ind_2 .

Ind_2	project 1	project2	project 3
project 1	1	0.5	3
project 2	2	1	4
project 3	0.333333	0.25	1
Σ	3.333333	1.75	8

Table 7. Matrix of elements pairwise comparisons of the indicator of transport work Ind_2 .

Indicator of transport work Ind_2	project 1	project 2	project 3	priorities vector
project 1	0.3	0.285714	0.375	0.320238
project 2	0.6	0.571429	0.5	0.557143
project 3	0.1	0.142857	0.125	0.122619

Table 8. The initial matrix of elements pairwise comparisons of the infrastructure indicator Ind_3 .

Ind_3	project 1	project 2	project 3
project 1	1	1	2
project 2	1	1	3
project 3	0.5	0.333333	1
Σ	2.5	2.333333	6

Table 9. The matrix of elements pairwise comparisons of the operational indicator Ind_3 .

Operational indicator Ind_3	project 1	project 2	project 3	priorities vector
project 1	0.4	0.428571	0.333333	0.387302
project 2	0.4	0.428571	0.5	0.442857
project 3	0.2	0.142857	0.166667	0.169841

Table 10. The initial matrix of elements pairwise comparisons of the infrastructure indicator Ind_4 .

Ind_4	project 1	project 2	project 3
project 1	1	0.333333	4
project 2	3	1	5
project 3	0.25	0.2	1
Σ	4.25	1.533333	10

Table 11. Matrix of elements pairwise comparisons of the social indicator Ind_4 .

Social indicator Ind_4	project 1	project 2	project 3	priorities vector
project 1	0.235294	0.217391	0.4	0.284228
project 2	0.705882	0.652174	0.5	0.619352
project 3	0.058824	0.130435	0.1	0.096419

Table 12. The initial matrix of elements pairwise comparisons of the economic indicator Ind_5 .

Ind 5	project 1	project 2	project 3
project 1	1	0.333333	4
project 2	3	1	5
project 3	0.25	0.2	1
Σ	4.25	1.533333	10

Table 13. Matrix of elements pairwise comparisons of the economic indicator Ind_5 .

Eeconomic indicator Ind_5	project 1	project 2	project 3	priorities vector
project 1	0.153846	0.222222	0.146341	0.174137
project 2	0.076923	0.111111	0.121951	0.103328
project 3	0.769231	0.666667	0.731707	0.722535

Step 5. Determination of the highest priority for the effectiveness of alternative projects (formula 7). The highest priority of efficiency will be the maximum value of the weight coefficients obtained as a result of the product of the matrix of particular criteria priorities (columns 5 of tables 5, 7, 9, 11, 13) and the matrix of priority vectors of the considered alternative projects (column 7 of table 3).

$$\begin{pmatrix} 0.333937 & 0.320238 & 0.387302 & 0.284228 & 0.174137 \\ 0.098190 & 0.557143 & 0.442857 & 0.619352 & 0.103328 \\ 0.567873 & 0.122619 & 0.169841 & 0.096419 & 0.722535 \end{pmatrix} \times \begin{pmatrix} 0.258396 \\ 0.232929 \\ 0.273898 \\ 0.188155 \\ 0.046622 \end{pmatrix} = \begin{pmatrix} 0.328559 \\ 0.397796 \\ 0.273645 \end{pmatrix}$$

As a result of the calculations, we obtain the highest priority of the effectiveness of road construction projects (table 14).

Table 14. The highest priority of project effectiveness.

Projects names	The highest priority for efficiency in shares	Highest priority for efficiency in %
project 1	0.328559	32.86
project 2	0.397796	39.79
project 3	0.273645	27.36

According to the data of table 7, the most attractive for achieving the set goal (road construction) is project 2, the least attractive is project 3, and the compromise is project 1.

4. Conclusion

The proposed algorithm for selecting public-private partnership projects in the process of planning the allocation of resources in the road and transport infrastructure, which contains additional tools in the form of a set of indicators of the functioning and resource allocation of the road and transport infrastructure, allows it to be used for solving the problem of choosing a project option that meets all the requirements stated by the customer taking into account the level of investment opportunities. Also, the

proposed algorithm can be specified when programming social projects that provide attraction and efficient utilization of stakeholders' resources, when adjusting and implementing the existing development strategies and programs [14].

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