Models of functioning and resources allocation of road and transport infrastructure

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Abstract. Specific features of functioning of a modern road and transport infrastructure on the example of Kemerovo region are determined. As a tool for justifying management decisions and the formation of projects for short-term periods, a set of indicators of functioning and resources allocation of the road and transport infrastructure was proposed. Taking into account the situation in Kemerovo region, three types of scenarios for the development of projects in the road and transport infrastructure are considered, depending on the investment potential: optimistic, mild and pessimistic. To eliminate uncertainties in the planning of functioning and resources allocation of road and transport infrastructure at the strategic level, the model for the problem of functioning and resources allocation in the road and transport infrastructure within the fuzzy-set theory was formulated. The modeling of scenarios based on the developed fuzzy model of functioning and resources allocation in the road and transport infrastructure at a qualitative level was performed. The proposed models for the functioning and resources allocation in the road and transport infrastructure made it possible to obtain quantitative and qualitative assessments of the system condition for assessing the effectiveness of functioning in operational and strategic planning in the conditions of uncertainty.

1. Introduction

The existing condition of the road and transport infrastructure does not fully meet the modern requirements of both the economy of Kemerovo region and the economy of the entire Russian Federation [1], the socio-economic development is largely constrained by the condition and level of highways development. At present, with an excess of the normative load, almost 27% of the road network is operated, while the local road network is not developed enough [2]. In Kemerovo region 26.73% of public roads do not meet the regulatory requirements for transport performance indicators, including 66.36% of regional or inter-municipal roads and 11.32% of local roads. The accelerated increase in the country automobile fleet has not yet led to a corresponding increase in the volume of construction, reconstruction and repair of the road network, and repair of roads in recent years has even somewhat decreased. For example, with the increase in the length of public roads by 15% over the past 10 years, the fleet of vehicles has increased by more than 1.7 times. The axle load of 11.5 tonnes was observed on sections of federal roads with a total length of 2613 km (5.2% of the total length of the network) with a demand in 22000 km, a 10-tonne load – on 11900 km (23.8% of the total network length) with a demand in 26 thousand km, respectively [2].

2. Tools for justifying the management decisions and the formation of projects for short-term periods

One of the reasons for the existing situation in the road and transport infrastructure is that the system of resources allocation functions in the conditions of uncertainty [3, 4].

As a tool for justifying management decisions and project formation for short-term periods, the following set of indicators for the functioning and resources allocation in the road and transport infrastructure is proposed [5]:

- infrastructure indicator Ind_1, characterizing the length of the sections of transportation lines, on which there are limitations of traffic and carrying capacity due to non-compliance with regulatory requirements;
- indicator of transport work Ind_2, characterizes the volume of transport using the reserve routes due to the non-compliance of highways, in which the main routes are laid, with the regulatory requirements and transport performance indicators;
- operational indicator Ind_3, characterizing the value of consignments delivered by motor transport within the time limits exceeding the standard (contractual) period;
- social indicator Ind_4, characterizes the value of additional time spent by the population on the road due to the non-compliance of roads to regulatory requirements;
- economic indicator Ind_5, characterizes the efficiency of investments directed to the road and transport infrastructure, it is proposed to use the net present value as an indicator (NPV).

To develop projects in the road and transport infrastructure, a scenario approach is used, which is determined by the level of possible financing. In this connection, three types of scenarios (optimistic, mild and pessimistic) are considered for the conditions of Kemerovo region depending on the investment potential. The length of sections of transportation lines with restrictions on traffic and carrying capacity due to non-compliance with regulatory requirements for the beginning of scenarios is 5070 km [6].

The optimistic scenario presupposes a high level of investment, compliance of the speed of construction works and current maintenance of road facilities, with the level of motorization and planned volumes of transportation, the violation of delivery deadlines depends only on the extent of the reserve routes, which will be used only during the construction works. In the mild scenario, the level of investment is 50% of the required level, the speed of construction works and current maintenance of road facilities are comparable or slightly ahead of their wear rate, the violation of delivery deadlines is due not only to the length of reserve routes, which are supposed to be used during the construction works, but also the presence of sections on the transportation lines, on which there are limitations for traffic and carrying capacity because of the non-compliance with regulatory requirements.

According to the pessimistic scenario, the level of investment is 25% of the required level, the speed of construction works and current maintenance of the road facilities are comparable or slightly lower than the rate of their deterioration, the duration of delivery delays is due not only to the length of reserve routes, which will be used during the construction works, but also to the presence of sections on the transportation lines with limitations on traffic and carrying capacity because of the non-compliance with regulatory requirements.

The simulation results are presented in figure 1, the period is 12 years (from 2019 to 2030) in accordance with the Transport Strategy of the Russian Federation until 2030 [2].

3. Problem model of functioning and resources allocation of road and transport infrastructure within the fuzzy-set theory

To eliminate uncertainties in the planning of functioning and resources allocation of road and transport infrastructure at the strategic level, it is proposed to use the fuzzy-sets method [7] to develop appropriate mathematical models.

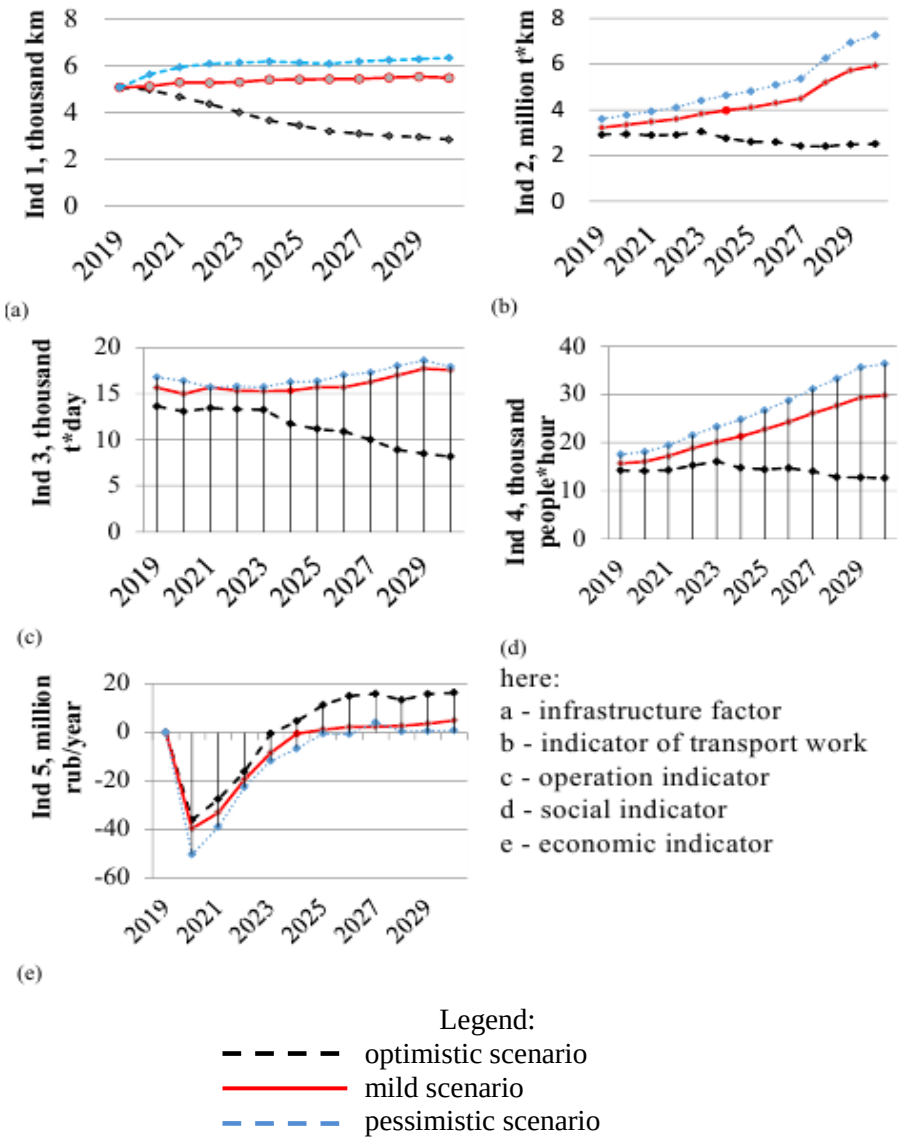

Figure 1. Forecast estimates of indicators of road and transport infrastructure functioning and resources allocation in it – Ind_1, Ind_2, Ind_3, Ind_4, Ind_5 (at the quantitative level).

Thus, the application of fuzzy models of road and transport infrastructure functioning and resources allocation in it will help to solve the following tasks:

1. Definition of a set of criteria, constraints, factors that detail the assessment of the system condition.
2. Formation of judgments about the interrelations and interdependencies of factors and constraints.
3. Selection of environmental factors (combinations of factors) that are of greatest importance for modeling the planning system of road and transport infrastructure functioning and resources allocation in it.

Let us formulate the problem model of functioning and resources allocation of road and transport infrastructure within the fuzzy-set theory:

$$\mathrm{SCRA} =< T, R|M, \mathrm{A}, P, E, I, O, F(x), B, X_{\mathrm{d}}, \mathrm{X_c}, \mathrm{K} > \qquad (1)$$

where SCRA is the system condition of resources allocation in the road and transport infrastructure;

T – the period of time for which the assessment of the system condition of resources allocation in the road and transport infrastructure is performed;

R – the resources necessary for functioning of the system of road and transport infrastructure;

$M = \{M_1, M_2, \dots, M_i\}$ – the set of formalized descriptions of material resources, which are an important factor for functioning of the system of road and transport infrastructure;

$A = \{A_1, A_2, \dots, A_i\}$ – the set of conditions (desired, planned, required) of the planning system of the road and transport infrastructure functioning and resources allocation in it;

$P = \{P_1, P_2, \dots, P_k\}$ – the set of formalized descriptions of human resources that are an important factor for functioning of the road and transport infrastructure;

$E = \{E_1, E_2, \dots, E_j\}$ – the set of formalized descriptions of economic resources that are an important factor for the functioning of road and transport infrastructure;

$I = \{I_1, I_2, \dots, I_n\}$ – the set of formalized descriptions of infrastructure resources, which are an important factor for the functioning of road and transport infrastructure;

$O = \{O_1, O_2, \dots, O_R\}$ – the set of formalized descriptions of organizational and managerial resources, which are an important factor for the functioning of the system of the road and transport infrastructure;

$F(x)$ – the function that characterizes the importance of a combination of resources for achievement of the planned condition of resources allocation in the road and transport infrastructure;

$B = \{B_1, B_2, \dots, B_x\}$ – the set of constraints that must be taken into account when developing alternative trajectories for the achievement of the planned condition of resources allocation in the road and transport infrastructure;

$XC = \{X_{C1}, X_{C2}, \dots, X_{Cd}\}$ – the set of actual estimates of the significance of analyzed factors (their impact on the functioning of the road and transport infrastructure);

$Xd = \{X_{d1}, X_{d2}, \dots, X_{dc}\}$ – the set of importance estimates of environmental factors combinations in terms of the importance and appropriateness of taking into account their influence on the possibility of achieving the planned condition of the system of resources allocation in the road and transport infrastructure;

K – the criterion for choosing a set of preferred factors and their combinations for taking into account the development of alternative trajectories of achieving the planned condition of the system for resources allocation in the road and transport infrastructure;

The results of modeling the scenarios proposed above on the basis of the developed fuzzy model of the road and transport infrastructure functioning and resources allocation it are presented in figure 2.

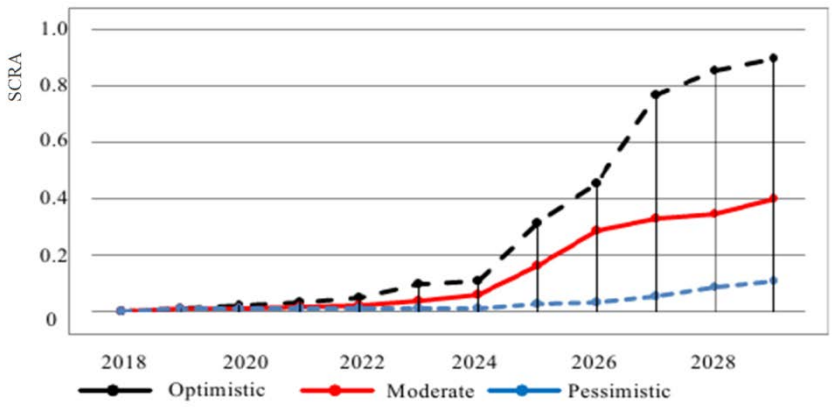

Figure 2. Forecast estimates of the system condition of resources allocation in road and transport infrastructure (at a qualitative level).

Forecast estimates allow to correct the development strategy of the road and transport infrastructure taking into account the formalized presentation of qualitative estimates of its indicators.

4. Conclusion

The proposed models of the road and transport infrastructure functioning and resources allocation make it possible to obtain quantitative and qualitative estimates of the system condition for assessing the functioning efficiency in operational and strategic planning in the conditions of uncertainty.

References

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