Formation the Parametric Model of an Operational Status Transport Interchanges System

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Abstract. The article is devoted to the analysis of possible solutions to traffic congestion, which have become an integral part of the modern space of the cities and regions population vital activity, especially near houses and shopping complexes. It is impossible to characterize the modern transport system without mentioning errors when planning the organization of traffic, as well as in the design and construction of transport hubs. Attempts to solve the problem of traffic congestion have been made repeatedly in various countries of the world, but all of them were of a differentiated nature and national specificity. Many researchers believe that in order to level transport problems, it is necessary to build new road junctions and separate traffic flows. However, according to the authors, the most suitable, in particular, for our country, can be a comprehensive approach to solving these problems. This approach involves the creation of a parametric model of forming an indicators system for assessing the operational state of road interchanges in the living environment formation conditions. This system allows taking into account the integral impact of technological, economic, environmental and social factors that affect the efficiency of transport interchanges.

1. Introduction

The key system-wide problems of the Russian Federation transport industry development are: “The forecast of the Russian Federation socio-economic development for 2016 and for the planning period of 2017 and 2018” (developed by the Ministry of Economic Development):

- Presence of territorial and structural imbalances in transport infrastructure development;
- Inadequate availability of transport services for the population, labor mobility;
- Insufficient transport services quality;
- Insufficient transport security;
- Strengthening the negative transport impact on the environment.

Plus, the global economic crisis has significantly affected the development of the Russian transport system, in particular, the volume of freight turnover, which dropped sharply (January-February 2016 relative to 2015 was at least 20%), while there were significant limitations of economic growth, caused by insufficient the transport system development. RF Government Decree of 15.04.2014 N 319 "On approval of the Russian Federation, the state program "The transport system development". RF Government Decree of 05.12.2001 N 848 (amended on 29.07.2016). "On the Federal Target Program "The transport system of Russia development (2010 - 2020)" [1,2].

Due to the significant shortage of financial resources in Russia, a significant reduction in allocation of state support, transport companies need significant adjustments to the long-term transport strategy,
which defines the main directions and targets for the Russian Federation transport system development for the period up to 2030. Based on the above, it can be stated that for the effective Russian Federation transport system development in conditions that combine the availability of modern rolling stock, transport infrastructure, communication systems, have sufficient financial capabilities, research and analytical centers and, importantly, actively and profitably use enormous geopolitical opportunities.

2. Materials and Methods

However, the problems identified have a very wide range of affects and its solution requires a differentiated approach in respect of each of its direction. The authors of the article focused on the transport system modernization process, as one of the people’s modern living environment main element.

The determinant of further research was a set of state strategic documents:

1) Transport strategy of the Russian Federation for the period up to 2030 (This document laid in 2018 a triple increase in the rate of construction and reconstruction of the Russian Federation transport arteries. The document says that the length of federal highways that meet the standards should grow from 40.9 thousand kilometers last year to 45.9 thousand kilometers in 2021. The government is ready to allocate up to 48.9 billion rubles for targeted projects in the regions from 2017 to 2020) [3];

2) The state program of the Russian Federation "Development of the transport system" (2010 - 2020) [4];

3) The program of activities of the State Company "Russian Highways" for the long term (2010 - 2020) [5];

4) The strategy of creating a network of highways and high-speed roads in the Russian Federation until 2030 [6];

5) Development strategy of the state company «Avtodor» until 2030 [7];

6) Regional transport development program [1].

![Figure 1. The scheme of linking transport strategies and programs of the Russian Federation for the period up to 2030 [compiled by the authors].](image)

All the documents indicated in Figure 1 allow, with varying degrees of elaboration, to evaluate the necessary directions of the existing Russian Federation transport system modification. But there is a global problem: the lack of connection between the general transport strategy of the Russian
Federation and the regional Transport strategy. This problem can be solved through the formation of a “Regional Program for the Transport Development”, which will allow to:

1) coordinate investment priorities;
2) create a concerted development plans;
3) develop an integrated system of strategic documents for transport planning at the federal and regional levels;
4) determine the conditions of the transport system balance.

As a result, the strategic goal of the Russian Federation transport system development will be to meet the needs of an innovative, socially oriented development of the economy and society in competitive, high-quality transport services.

Traditional models of the transport systems development had a lot of flaws (Table 1).

**Table 1.** Characteristics of the traditional models transport system development in relation to the parametric system [14].

| Model view       | Principles of operation                  | Main tasks                                                                 | The range and mechanism of action                                                                 | Parametric system characterizing the model | Disadvantages                                                                 |
|------------------|------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------|-------------------------------------------------------------------------------|
| Local            | Spontaneous development                  | transportatio n organization; reduction of transportatio n distance.       | The coverage area of a large city, the municipal organization of the vehicle, ensuring optimal traffic flows. | Resonant parametric systems              | Does not solve the problem of traffic congestion - poor logistics            |
| Regional         | Optimal concentration and logistics of transportation, taking into account regional factors. | ensuring timely delivery of goods and passengers; implementati on of the main regional transportatio n. | Within the boundaries of the region, the economic region, provides the management of the elements of the transport system. | Non-resonant parametric systems | All elements of the transport system are managed only within the limits of a separate agglomeration and do not allow building a common system for organizing and controlling transport operations. |
| Country (national) | Optimization of transport support for the entire economy. | creation of interdistrict transport balance; implementati on of interstate transportatio n. | Formation within the borders of the state of an accessible and sustainable transport system as a basis for transport integrity. | Non-resonant parametric systems | Despite the presence of the basis of transport integrity, this system is not flexible under the changing needs of the regions. |

The analysis of the table allows us to state that the expansion of the people living environment and urban agglomerations growth pose problems in creating intersections of courtyard travel routes with
adjacent highways. As a rule, in the case of two regional significance streets intersection, the construction of an adjustable intersection is carried out, this satisfies the traffic intensity level and its capacity. However, in case of intersection with the main street of urban significance, or at the intersection of two such streets, it is necessary to build road interchanges at several levels, or roundabouts. However, this is problematic in dense residential development of cities.

In addition, the intensive flow of vehicles creates a high level of noise, which without special protective equipment will adversely affect the health of the population living at a distance less than the established sanitary rules [8].

When it is impossible to organize a comfortable environment with a green zone and natural noise protection, which are trees and shrubs, it is proposed to install acoustic screens on the plots, which allow to reduce the noise level to the norm.

To exclude further similar situations, the authors of the article propose to study the built-up area in more detail. When designing, take into account the dimensions of the territories allocated for the natural sound-proofing layer, or, in case of impossibility of its creation, use suitable types of road junctions, or install acoustic screens. In exceptional cases, it is possible to demolish buildings that fall into the sought-for land areas, with the preliminary these houses residents’ resettlement. During the construction of road junctions, it is necessary to consider projects more carefully, taking into account not only the requirements of the road inspection, but also the priority of ensuring comfort for residents of nearby houses.

Summing up the preliminary results of the author's research, it should be noted that in order to implement the Russian Federation transport development program of the until 2030, it is necessary to achieve much higher quality results, than the comparative statistics of the Russian transport system current state shows. Given the fact that the criterion for assessing the impact of changes introduced into the transport system is the social effect, the authors identified and critically analyzed the main methods that are used in practice to evaluate it. The analysis showed that the methods of assessing the social effect do not allow to take into account all the criteria and parameters of the Russian Federation transport system functioning in various regions, which requires the additional tools development [9].

The generalization and systematization of all the considered documents and models of the transport system development allowed the authors to develop a parametric model of forming an indicators system based on factors affecting the road junctions’ operational efficiency (Fig. 2).

3. Results

The author's parametric model of an operational status transport interchanges system consists of five logically interconnected blocks, characterizing the main processes used to create a pilot project road junction with high use efficiency.

Each block represents a separate scope of the proposed author's model:

Block 1 "Object". It consists of a control object [Ob], which is represented by a traffic intersection, and a real control object [D], which is represented by the traffic interchange users [10, 11, 12, 13].

In the case under study, the following were chosen as users of the interchange: Q — the number of transport units; f is the frequency of the junction use or its possibility; P - cost of the junction operation for users; Ob - transport interchange as a control object.

Block 2 "Parametric". This block allows you to identify and determine the value of the adjustable parameters that affect the quality of the junction. All parameters are divided into two groups: technical and economic, and represent the means of isolating and changing the composition of the controlled parameters. Technical parameters include automated and mechanized measurements:

1.1. Intensity of movement.
1.2. The composition of the movement.
1.3. Car distribution of lanes.
1.4. Traffic density
1.5. Load factor road movement.

The economic parameters include the results of marketing research consumer solvency:
2.1. Field (primary).

2.2. Cabinet (secondary).

Block 3 "Expert". Within this block, an expert assessment process is presented, consisting of four subprocesses of the quality of the functioning of the traffic interchange. This process consists of four subprocesses:

Subprocess A - Targeted formation of knowledge about the parameters of the functional environment of the junction and the quality of its functioning.

Subprocess B consists of intermediate goals formation and the forecast of final states based on the adjustable parameters selected in Block 2.

Subprocess C - Conducting a horizontal analysis to clarify the consistency of the objectives and the actual operation of the traffic interchange.

Subprocess D - drawing up an expert opinion and forming a strategy for changing projects, means for automatic and interactive formation of projects and design strategies, means for correcting imitation and design structures, means for isolating and changing the composition of control and adjustable parameters.

Block 4 - “Legal”. Within the framework of this block an implicit contract is formed which controls the institutional framework of the projects being created for traffic interchange.

Block 5. "Managerial". This block allows you to create a strategy and tactics for the formation of road junction projects based on the selection of macronutrients of a high-quality functioning transport system.

The main purpose of the creation of Block 5 “The parametric model of an operational status transport interchanges system” is modified in the formulation of the effectively functioning system isolating macronutrients task, which is replaced by a complex system of the specific transport interchange efficiency functioning indicators, specified in the Russian Federation Transport System Development Program.

The Program contains provisions that have no specificity [15]:

1) evaluation of the effectiveness of the Program is carried out by quantitative and qualitative indicators of social, commercial and budgetary efficiency;

2) as the quantitative indicators used integral discounted effect and quality - performance payback of the Program, taking into account the discount. Quantitative indicator of the effectiveness of the Program is the integral effect, or net present value, calculated as the difference between revenues from the implementation of investment projects and the cost of capital investments on them with discounting;

3) qualitative indicator of the effectiveness of the program is the payback period, taking into account the discount, which characterizes the minimum time period after which the accumulated discounted effect becomes and remains non-negative. The payback period is designed for social, commercial and budgetary efficiency. In assessing the effectiveness of the Program priority is given to indicators of social efficiency, since they allow for a more complete assessment of the economic consequences of its implementation.

Thus, the main expected results of these programs implementation in terms of improving existing and newly created road junctions’ operational status should be reflected in four areas of the Russian Federation citizens’ life: the environmental sphere, the economic sphere, the government, and the social sphere.

To parameterize the outcomes expected, the authors of the article propose to evaluate the effectiveness of the road junctions’ operational status through the final effects specified in the Transport Development Program: social, commercial and budgetary. For this, the authors propose to consider each effect in the framework of the corresponding efficiency system, which has its own parametric data and the qualitative results expected [16, 17, 18, 19]:

1) Economic efficiency: assesses the integral effect or net present value (NPV), calculated as the difference between the income from the implementation of investment projects and the cost of capital
investments on them, taking into account discounting. Accordingly, the maximum effect is achieved while maximizing the economic and social effects;

**Figure 2.** The parametric model of an operational status transport interchanges system [compiled by the authors].

2) Social efficiency is the sum of the “social priority” estimated using quantitative and value indicators. At the same time, the “social priority” in the implementation of capital investments in the improvement and development of transport infrastructure in the regions of the Russian Federation depends on the following parameters: population density in the territory in question (in person / sq. km), the volume of retail turnover per 1000 inhabitants of the territory under consideration (in million rubles), the number of students at secondary specialized institutions and primary vocational education per 1000 inhabitants (in people), the cost of fixed assets of the territory economy in question per 1000 hectares of territories (million rubles). Therefore, the maximum effect is achieved by maximizing the environmental and social effects;

3) Budget efficiency: assessed in terms of reducing the number of public sector acts participation in solving transport problems. Such an assessment can be made only by introducing into the practice of interaction a “smart contract”, which takes into account the needs and capabilities of all the actors involved in the operation of the transport interchange. That is, fiscal efficiency reaches its highest level while maximizing the effect of public administration.

Such systems are called non-resonant parametric systems, which can be described using dynamic mathematical models. To solve them, a scenario approach is used to assess the possible development strategy of each system by playing different scenarios based on the chosen mathematical dynamic model using different sets of parameters and analyzing the corresponding decisions obtained.
Most of the dynamic systems [20], including the country junction system, after some transformations can be represented by the following non-linear ordinary differential equations systems (1):

\[
\frac{dx}{dt} = f(x, u, \lambda), x(t_0) = x_0, \tag{1}
\]

where \( x = (x^1, x^2, \ldots, x^n) \in X \subset \mathbb{R}^n \) is the state vector of the transport system; 
\( u = (u^1, u^2, \ldots, u^l) \in W \subset \mathbb{R}^l \) - vector of controlled (adjustable) parameters of the transport system \( W \); 
\( \lambda = (\lambda^1, \lambda^2, \ldots, \lambda^m) \in \Lambda \subset \mathbb{R}^m \) is the vector of uncontrolled parameters; \( \Lambda \) is an open connected set of parameters of the mapping \( f(x, u, \lambda): X \times W \times \Lambda \to \mathbb{R}^n \) \( \frac{dx}{dt}, \frac{dx}{du}, \frac{dx}{d\lambda} \) are continuous in \( X \times W \times \Lambda \); 
\([(t_0), (t_0) + T] \) is a fixed period of time.

As is known, the solution of the considered system of ordinary differential equations depends both on the vector of initial values \( x_0 \in \text{Int}(X) \), as well as on the values of the vectors of controlled \( (u) \) and uncontrolled \( (\lambda) \) parameters. Therefore, the result of the development (change) of a nonlinear dynamic system for a given vector of initial values \( x_0 \) is determined by the values of the vectors of both controlled and uncontrolled parameters.

It is also known that in order to judge by the decisions of the system about the object described by it, this system must have the property of immutability of the qualitative picture of trajectories with small perturbations of the right side of system (1) in some sense. In other words, system (1) must have the property of coarseness, or structural stability.

As part of the problem to be solved evaluating the performance of the transport interchange offers a system of equations (1) represented as follows (2):

\[
\begin{align*}
\frac{d(TR)}{dt} &= f(Cos + Ecol + Econ + Gef) \to Econ \to \text{max} \\
\frac{d(TR)}{du} &= f(Cos + Ecol + Econ + Gef) \to Cos \to \text{max} \\
\frac{d(TR)}{d(\lambda)} &= f(Cos + Ecol + Econ + Gef) \to Ecol \to \text{min} Cd \\
\frac{d(TR)}{d(\lambda)} &= f(Cos + Ecol + Econ + Gef) \to Gef \to \text{min Pg}
\end{align*}
\]

Where \( \overline{TR} = f(Cos + Ecol + Econ + Gef) \) is the state vector of the transport system; \( Pg \) - the number of acts of state participation; \( Cd \) - the cost of the damage; \( Econ \) - economic effect; \( Cos \) - social effect; \( Ecol \) - environmental impact; \( Gef \) - the effect of public administration.

Thus, due to the lack of scientific provisions in the Russian Federation Transport Development Program of the traffic interchanges parametric regulation, the offers can be a tool applied to solve this problem and will provide quantitative targets for improving the performance of existing transport hubs and only planned projects.

4. Discussion

The model proposed allows a sufficiently detailed description of the procedure for assessing the parameters of the road junctions’ operational status within the framework of the program for the transport system development, as it focuses on all the factors affecting the functionality of the proposed interchanges.

For comparison, the process of modeling the transport system development as a whole is subject to general geographical and economic laws, and, according to experts, is divided into three stages:

1) Creating an object model.
2) Study of the socio-economic characteristics of the facility with the help of special operations.
3) Transferring the results to the real interchange project prototype.
According to the authors of the article, in the modeling of traffic intersections it is advisable to use models of general partial systems, which, according to Professor D. Harvey, make it possible to obtain the results of the processes manifestations (in this case, transport) without a complete understanding of the internal system functioning itself [21, 22, 24]. Based on this, the basis for the construction of transport interchanges functioning models should set a number of parameters, namely: the basic principle of action, the basic tasks to be solved, the choice of the area and mechanism of the system elements action, which is consolidated in the proposed author's model.

Thus, the model proposed eliminates the shortcomings of its predecessors and allows for a more systematic look at the transport interchanges operation problem.

5. Conclusion
The basic principles of an integrated approach to transport policy at the official level were outlined in the “Transport Strategy of the Russian Federation for the period up to 2020” adopted in 2004. However, we have to admit that it is almost impossible to implement the chosen directions using only methodical recommendations and conceptual models of the process organization. Requires detailed applied development in terms of individual elements and the functioning of the model as a whole, which will take into account the modern needs of the living environment and in conjunction with the developed management tools, focused on the efficiency and quality of the proposed model, will create an urban space for the normal life of the urban population.

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