MODEL OF CONNECTIVITY OF TERRITORIES BY AIR TRANSPORT

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ABSTRACT

Ensuring the transport connectivity of territories plays a system-forming role in development of new areas, as well as in maintaining security and economic growth. From this point of view, finding ways for optimal and balanced development of a particular mode of transport to combine the interests of the regions already at the stage of preliminary consideration of project tasks is necessary. A model of expediency of the use of air transport in solving problems of connectivity of territories is proposed. The authors apply it to examples of connectivity between different regions and to different aircrafts. The model is also suitable for assessing the role of other modes of transport.

Keywords: accessibility of territories, transport network, air transport, model of connectivity of territories.

Background. *The problem of connectivity of territories for Russia is as acute as it is, because the area of our country is more than 17 million square kilometers. It is obvious that the development of territories of such scale, their transformation and life support require formation of a reliable and comprehensive transport infrastructure.*

Creating and ensuring the transport connectivity of the territories of the Russian Federation is undoubtedly a long and laborious process, it needs careful study of all available information, including the current state of the transport system in Russia, intercontinental communications, the most popular routes, prospects for growth and development of regions and economic sectors, economic, demographic and geographical position of the republics, territories and regions, trends in the global market and much more.

Abroad, in Europe in particular, work in this direction has been going on for more than a dozen years, which has resulted not only in strategic decisions [1], but also in practical implementation [2].

Aviation transport, although it is the most expensive for an end user, but fully complies with certain transport requirements: airplanes have the highest rates of speed and safety of the services provided. And also they do not require large infrastructure costs, except for construction of airfields, buildings and structures at the points of departure and arrival, air traffic control systems.

Objective. *The objective of the authors is to consider a model of connectivity of territories by air transport.*

Methods. *The authors use general scientific methods, comparative analysis, evaluation approach, graph construction method.*

Results.

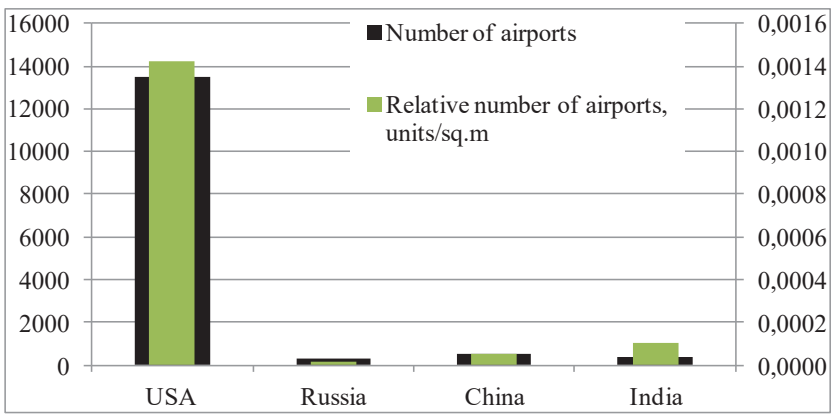
I.

Making a preliminary decision on the choice of a particular type of transport for communication between the regions of the Russian Federation depends on many factors.

According to The Global Competitiveness Report for 2013–2014 [1], in terms of the quality of transport infrastructure, Russia ranks 93 out of 142 countries included in this study. In the report for 2017–2018, Russia is already in 38 place. Including the quality of air transport infrastructure, it ranks 59th, while it used to be in 102 place. But despite good dynamics, the country continues to have transport infrastructure that does not correspond to its scale.

Comparison of the main infrastructure transport indicators [2, 3] of air transportation of the Russian Federation with the United States, China and India (Pic. 1) shows our strong backlog in both absolute and relative numbers of airports. Russia has even fewer airports than India, while having multiple dominance in territory. In the first place by the chosen criterion are the United States, in which the relative and absolute number of airports exceeds the Russian parameters by two orders of magnitude.

In China, the growth of incomes of population and corporations spurs demand for transportation, and civil aviation has become the fastest growing industry: since 2005, over ten years, the volume of transported goods has increased by 3,5 times, and the freight



Pic. 1. Number of airports in Russia, USA, China and India.

turnover has increased by 4 times. At the same time, the fleet from 2010 to 2015 increased from 2607 to 4511 aircrafts.

Compared to China and the United States, the turnover of goods in our country lags significantly behind. Since 2005, over ten years, it has increased by only 10% [4]. The nature of «stability» of freight turnover in the USA is basically the same, but only there the absolute values of the indicators are almost twice as high (7800–8300 billion t.km). In turn, the dynamics of China's cargo turnover are impressive. From 2005 to 2010, it almost doubled, and in 2005 it was equal to the US cargo turnover, and from 2010 to 2014 it grew by another 30%, exceeding the level of 2004 more than doubled.

It can be assumed that in China, geographic and climatic potential is used quite effectively, when different types of transport do not constitute tough competition, but harmoniously complement each other. Probably, the reasons for increase in freight turnover in the country are also associated with a giant leap in infrastructure transport processes. So, in 2009, the most advanced as of today high-speed railway lines Wuhan–Guangzhou and Zhengzhou–Xian were commissioned. The growth of the road network from 2004 to 2010 was 100%. By the end of 2006, the country had 12 seaports with a cargo turnover of 100 million tons, a year later there were 14 of them, and by the end of 2008, they were 16. In 2017, there were four more «hundred million» ports in China.

Taking into account the fact that in the sphere of transport connectivity of the territories, the Russian Federation is far from the leading positions in the world, the government has adopted the Transport Development Strategy for the country until 2030 [5]. The strategy is aimed at creating a unified transport space of Russia based on a balanced accelerated development of transport infrastructure, ensuring availability and quality of transport services for population in accordance with social standards, accessibility and quality of transport and logistics services in the field of freight traffic, realization of transit potential and improving transport safety systems [6].

Optimization of the transport network will be associated with creation of economically reasonable reserves of capacity of existing and under construction lines, speed and high-speed systems for transportation of passengers and goods, especially in areas of priority economic development, remote and inaccessible regions.

II.

The main systemic task of the transport strategy according to many leading experts is construction of the transport and economic balance of the regions of the Russian Federation, priorities of transport infrastructure development [7].

It is indisputable that each type of transport today has its own specific problems, as well as common, affecting all types at once. For example, for air transport, one of the specific problems is to reduce the number of airports and airfields by 2,5 times, which resulted in the closure of many airlines [8]. The common problems for all types of transport have become low compared with the western level of technical production base, weak infrastructure, inaccessibility of transport services in remote regions.

The most lagging infrastructural regions in our country are the northern and agrarian ones. This is due to the fact that only rail freight transportation remains the only stable in terms of frequency of communication throughout the year [9]. While, for example, road transportation significantly depends on climatic conditions, when poor road conditions lead to an increase in operating costs of equipment and tariffs, and in remote regions due to off-road during the autumn and spring periods, settlements can only be reached using air or water transport.

An example of such a situation is the Republic of Sakha. Every year, the so-called northern delivery is carried out here, however, due to shallowing of rivers, there have been several occasions when the dry-cargo ships were idle for several months in one place, waiting for the water level to rise. After shallowing and disruption of navigation in 2013, more than half of the volume of cargo began to be delivered by road. In winter, trucks drive along the channels of frozen rivers, and roads make their way through the snow between the villages. Their length can be from tens to one and a half thousand kilometers. But do not forget that the cars themselves are very vulnerable. In the 2016–2017 season, anomalous snowfalls and warm weather prevented the opening of the winter roads in the Kolyma group of uluses on time, and cargoes reached some villages only in April. In 2017, in Yakutia, land transportation accounted for about 60% of mandatory cargo deliveries, or more than 7 thousand tons. About a third (about 4 thousand tons) was delivered by river vessels and only 219–220 tons by cargo aircraft [9].

In the presence of infrastructural imbalances, assessment of the transport potential, especially from the point of view of sustainability and long-term socio-economic prospects of the territories of intensive industrial growth, is of particular importance.

Since the main task of the study is to determine the optimal and balanced development of a particular mode of transport for the sake of ensuring the connectivity of the territories, to achieve the goals it is proposed to form a rating method by which for each mode of transport, depending on its characteristics, throughput, costs creation and maintenance of infrastructure, type of territory, its length, etc. (the full set of criteria includes a significantly larger number of them), a certain indicator of the region's readiness (disposition) to solve the problem would be displayed.

III.

The model being created consists of three main elements: a variable (territorial) module, a permanent (functional) module, and a distance module. Each of them has a set of criteria by which an assessment is given to the modes of transport being analyzed. The model is based on expert assessment: a group of competent individuals conducts a rating procedure for incoming variables. To increase the accuracy of the results, an increase in the number of experts is recommended. The advantages of the model include its simplicity and undemanding to computing power.

The principle of the model is to form an aggregated connectivity rating (RC) of two elements, the role of which is performed by individual regions of the Russian Federation. In addition, it is advisable to form a rating of potential capabilities for these elements, indicating the necessary technologies that are available or to be developed. Type of dependence of connectivity rating for a specific type of transport:

$$RC = \Sigma RC_i + DM, \quad (1)$$

where i – set of regional elements in the transport chain, RC_i – connectivity rating of one region, DM – data obtained as a result of formation of the distance module.

The connectivity rating is a quantity dependent on many variables. To formalize the model, these

Pic. 2. Examples of inefficient directions of cargo transportation by air.

variables were grouped as territorial and functional modules. Each of them includes the corresponding variables.

The territorial module was not in vain given the status of a variable, since the proposed methodology is applied to the data set of the subjects of the Russian Federation, each of which has a unique set of characteristics. Characteristics include climatic and geographical indicators.

The final rating point of a functional module is a fixed value that does not depend on natural and geographical characteristics of the region, but can only change over time if the economic, political, scientific and other situations in the country and the world change.

Obviously, the influence of variables, even belonging to the same module, must be different. There are variables that have a significant impact, and there are those whose change should not affect the model. Based on this, it was decided to assign each criterion the degree of their significance (the weight of the criterion). The group of extremely important criteria includes such as time, reliability and speed of delivery of goods, as well as ensuring their safety, availability of a particular type of transport for the population, the cost of creating and operating its own fleet of vehicles (rental, rolling stock leasing). According to experts, consumers of services pay attention to the values of these indicators primarily when choosing one or another delivery method.

Since the listed criteria are only part of the general system of criteria, their significance in the general model is evaluated according to a single rule. It was decided to assign each of them a degree of significance on a five-point scale, where 1 point is «least important» and 5 is «extremely important». To expose points is the duty of experts. After the rating points for the territorial and functional module are formed, the total coefficient-rating of the region should be determined. It is intended to show the attractiveness of a particular subject of the Russian Federation for using each of the modes of transport in question.

The result of the calculation will be a multidimensional array of ratings to ensure the connectivity of two geographical points of the Russian Federation (regions) by criteria, for example, the volume of passenger or cargo transportation by various types of transport. The claimed method allows to choose an economically optimal approach to improve connectivity, and hence accessibility of territories. With availability of information on the prospects for development of transport connectivity, it is possible to more fully and accurately forecast the ways to ensure it, to invest in related programs, taking into account the expected social and economic effects.

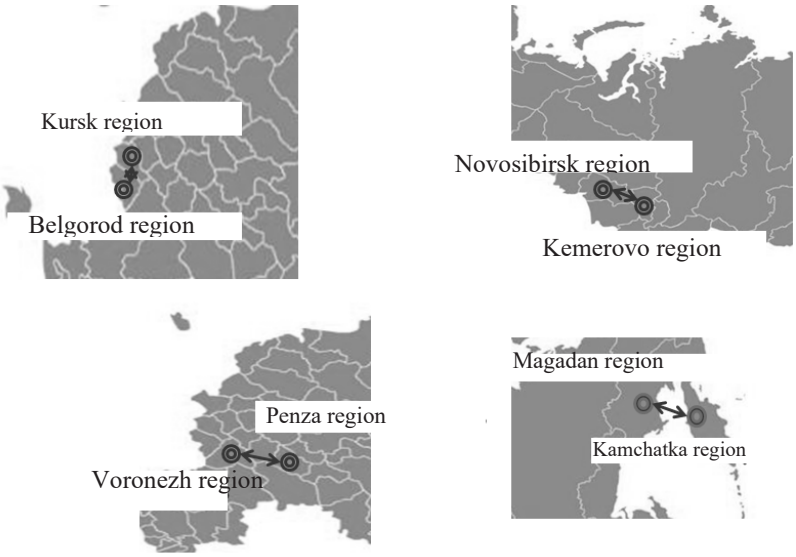
IV.

For transportation of goods the most preferred mode of transport is an airship. This is indicated by both territorial and functional modules. Leadership of such an obvious slow mover is primarily due to the fact that it, despite its greater dependence on weather conditions as compared to an aircraft, requires lower costs for creation and maintenance of the infrastructure necessary for its operation, while having similar characteristics on safety of cargo transportation, reliability, safety, etc.

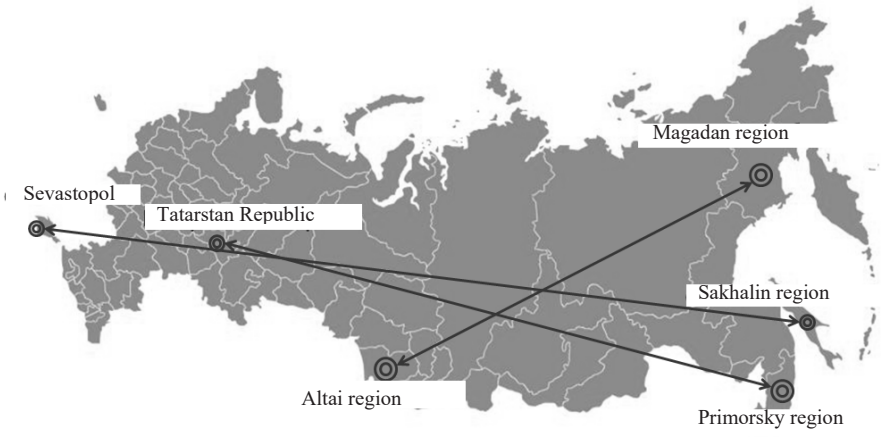
It is believed that an aircraft is effective as a means of transportation in cases where the distance between the point of departure and the point of arrival exceeds 500 km. Of course, there are regular flights to a smaller distance, but often this is due only to inability to use any other type of transport. Pic. 2 presents examples of such unattractive directions of transportation. We also note that although Voronezh and Penza regions are in different federal districts and therefore there are obvious objects of model calculations, the distance between them is too small for the reciprocal delivery of goods by air for them to become effective.

The exception to the judgments about inexpediency of using air transport as a means of transporting goods within one federal district is the Ural, Siberian and Far Eastern federal districts. This is explained by the fact that the distances between the subjects that are part of one federal district, as well as the distances between the bordering subjects of different districts, are quite large. Among other things, it is these federal districts that have such difficult climatic conditions that, while not being comfortable for air transport, make them completely ineffective for any other kind of freight transportation.

Pic. 3. Examples of effective directions of cargo transportation by air.



Pic. 4. The most effective routes for passenger transportation by helicopter.



Pic. 5. The most effective routes for passenger transport by air.

Pic. 3 shows examples of the most efficient directions of cargo transportation when using air transport.

As it was supposed, first of all the regions where the use of air transport is most beneficial are all northern regions of the Russian Federation located in the Arctic Circle and in permafrost conditions: the Sakha Republic, Magadan region, Chukotka and Yamalo-Nenets Autonomous Districts. Aviation is optimal in terms of ensuring connectivity with other territories of the country and for Kaliningrad region.

As for passenger transportation, the same regions as for aircraft transportation are also less attractive regions for helicopter transportation: Arkhangelsk region, Republic of Karelia, Kamchatka region. The main reason is the climatic features of the regions. Nevertheless, the developed model allows to choose a relatively optimal solution even in such conditions. The helicopter type of air transport is still rated for use in these regions better than that of the aircraft. The main advantage of helicopters is undemanding of the level of infrastructure of points of departure and arrival. However, it is more profitable to use this type of transport for short distances between neighboring subjects. Such transportation will be less costly for passengers and for airlines.

In the analysis of helicopter passenger transportation, several most attractive routes were identified. Among them (Pic. 4): Magadan region – Kamchatka region, Kursk region – Volgograd region, Novosibirsk region – Kemerovo region, Voronezh region – Penza region. The average distance of these routes is 600–800 km.

As for passenger aircraft routes, an aircraft is «designed» for longer distances, and with increasing flight length, its efficiency also increases. On average, the length of such routes is from 1000 to 7000 km. Among the most attractive lines for passenger transportation (Pic. 5): Sevastopol – Sakhalin region, the Republic of Tatarstan – Primorsky region, Altai region – Magadan region.

Conclusions. *Today, one of the main tasks set by the state is formation of a single transport space of our country and ensuring the connectivity of its regions, including with the help of air transport. The accelerated development of the aviation industry requires a large number of preparatory measures and calculations. Conducted research work represents the initial stage of creating a model of connectivity of territories. The feasibility of using a particular type of transport depends on many factors and each of them needs an objective and scientifically based assessment, qualified interpretation and system vision.*

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