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Assessing the impact of transport provision factors on the efficiency of a regional transportation system

Abstract

The level of transportation services is a relevant characteristic of the socio-economic development of regions. This level is expressed by the indices of transport availability which characterizes the degree of territory saturation with communication lines (infrastructure) of one or several kinds of transport. Transport provision of regions increases their spatial connectivity and the accessibility of territories, promoting the increase of volumes and speed of cargo transit and population mobility. This research presents a correlation regression analysis of the impact of transport provision characteristics on the efficiency of the regional transportation system of the Russian regions. The research showed that the scope of cargo turnover in million tons per kilometer produces the largest positive impact on the efficiency of the regional transportation system. Another significant positive factor is the volume of investment into capital assets of the relevant organizations. Apparently, the growth of capital investment into basic production assets allows increasing the cargo turnover of transportation companies, which is reflected on the scope of transportation services per capita. At the same time, the growth of passenger turnover (million passengers per kilometer) leads to a decrease in the resulting index. In our opinion, this can be due to competition within a sector. Specifically, a high level of roads loading, including with public transport, leads to an increase of unproductive loss of working time for business, delays and, consequently, reduced volume of goods turnover.

Keywords

Transport, transport system, transport provision, transport infrastructure, regions, cluster analysis, efficiency.

Introduction

Today, transport provision is one of the main factors of connectivity of the regional territory of Russia and a condition for its further socio-economic development. Transport provision characterizes the opportunities for the population to use transportation network to move anywhere in the country. [1] The growth of its level produces a direct impact on creating a common socio-economic space by providing steady links between the country regions and settlements. In turn, development of regional and interregional links, growth the cargo delivered creates conditions for forming optimal route-logistic patterns. [2] On the contrary, low degree of the transport infrastructure development reduces the efficiency of transportation of resources and finished products, thus increasing their bottom-line cost and, respectively, reducing the performance indicators of the regional economy complex.

Hence rather obvious is the establishment of the strategic goal of the Russian transportation system development up to 2030 and for the forecast period till 2035 in line with enhancing the spatial connectivity and transport accessibility of territories, increasing mobility of population and developing domestic tourism, increasing the volumes and speed of cargo transit and developing multimodal logistic technologies, as well as digital and low-carbon transformation of the sector with accelerated introduction of new technologies. [3]

Transport system facilitates organization of economic space, ensuring not only spatial division of labor and continuity of reproduction processes, but also the possibility to obtain a multiplicative effect due to a complex interconnection between various sectors of economy. [4] Transport infrastructure is a linchpin of the regional processes of production, distribution, exchange and consumption, organizing material flow and influencing a significant part of production and marketing costs, thus ensuring a sustainable growth of the regional economy. [5] This allows some researchers to rather categorically assert that the level of transport infrastructure development serves as a universal indicator, reflecting the current state of the entire economic complex of Russia. [6]

Materials and Methods

The research object is 12 indices characterizing the level of development of the transport system and transport provision in 85 subjects of the Russian Federation in 2020. At the first stage of analysis, descriptive statistics was obtained. Then we checked for normal distribution. To get rid of extreme values, we used quartile method and cluster analysis. Further analysis was carried out with the indices of 76 regions. Then we carried out correlation and regression

analysis, assessment and elimination of redundant variables which did not influence the resulting index. As a result, we obtained a model (Least squares) in the IBM SPSS Statistics software, assessed its quality and formulated conclusions.

Results

The resulting index characterizing the transport system efficiency is the volume of transport services per capita (in rubles). The positive dynamics of this index and its sharp fall in 2020 characterize the overall development of transport system and its role in the country's economic development (Fig. 1).

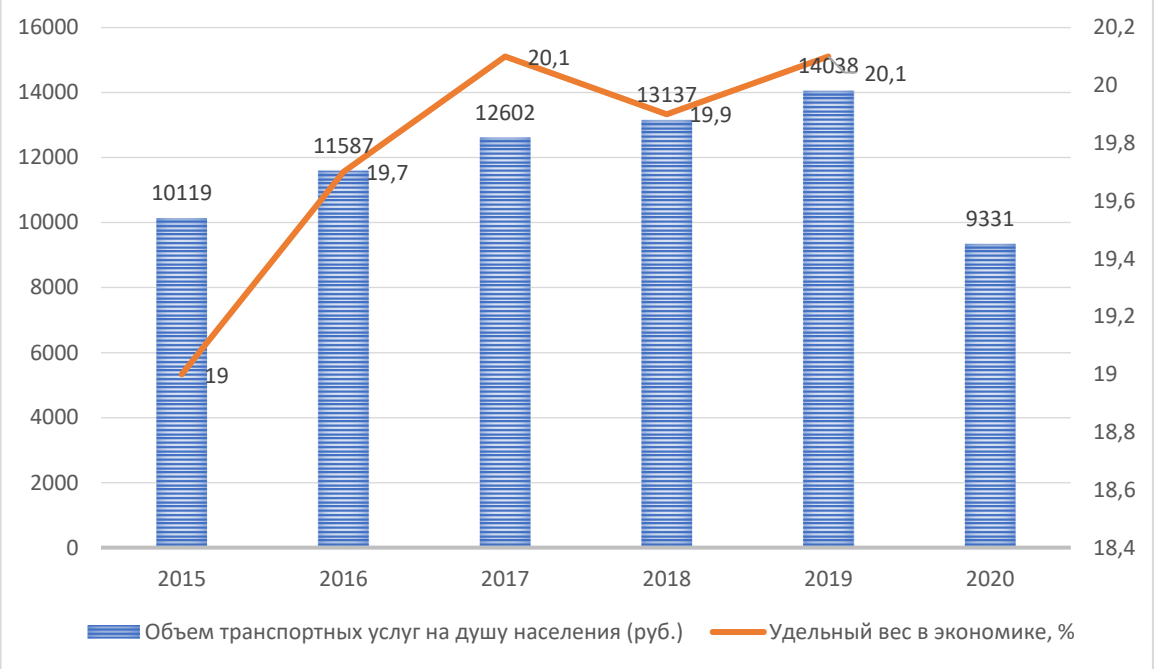

Fig. 1. Volume of transport services per capita and role of transport in economy [7]

The independent variables are 11 indices characterizing the state of the transport system in 85 Russian subjects according to 2020 data. (Table 1).

Table 1

Titles of variables and initial data of the model

Variable	Title
y	Volume of transport services per capita (rubles)
x1	Density of automobile roads of public use, hard-surfaced (by the end of the year; km of roads per 1,000 sq. km. of territory)
x2	Unit weight of hard-surfaced automobile roads of the total length
x3	Density of railroads by the end of the year; km of roads per 10,000 sq. km. of territory
x4	Number of goods-carrying vehicles – total
x5	Cargo turnover, mln tons/km
x6	Number of buses of public use per 100,000 of the population (by the end of the year; units)
x7	Availability of exploitation buses carrying out transportation along regular routes
x8	Passenger turnover, mln passengers/km
x9	Passenger transportation, mln people
x10	Investments into capital assets (without small businesses) – by the type of economic activity "Transportation and storing" (mln rubles)
x11	Turnover of organizations – by the type of economic activity "Transportation and storing" (bln rubles)

The initial data for the model were assembled in the MS Excel software. The research uses the method of multidimensional statistical analysis, including correlation and regression analysis using IBM SPSS Statistics package. At the first stage of analysis, descriptive statistics was obtained (Table 2).

Table 2

Descriptive statistics

	Average	Median	S.D.	Min	Max
y	7130	5186	6259	1092	34844
x1	230.9	203.0	210.6	1.000	891.0
x2	72.45	72.80	14.11	40.10	100.0
x3	151.5	139.0	107.1	0.000	490.0
x4	7350	6046	6627	215.0	31289
x5	142.9	8.000	258.0	1.000	989.0
x6	115.8	108.0	46.19	30.00	374.0
x7	1873	1296	1764	35.00	10560
x8	324.8	293.0	308.8	1.000	981.0
x9	90.53	52.20	116.4	0.5000	851.6
x10	16932	4489	26458	1.000	1.337e+005
x11	137.3	18.70	545.2	0.000	4822

Table 2 demonstrates a large diversity of indices of the transport and transport infrastructure development by region. This was rather predictable. For example, Moscow, being the main transport node of Russia, has hyper concentrated transportation functions (over 80% of all intra-Russia aviation flights are to Moscow). Besides, this region is one of the most densely populated.

The initial analysis of the variables showed outliers in all variables. Checking for normal distribution with Kolmogorov-Smirnov test showed that all variables have other than normal distribution. To get rid of extreme values, we used quartile method and cluster analysis. The carried out cluster analysis showed that all regions can be divided into three clusters. Table 3 shows distribution of the regions by clusters.

Table 3

Cluster distribution of regions

Cluster number	Regions	Number of regions
1	Moscow, Khanty-Mansi Autonomous Okrug - Yugra, Republic of Sakha (Yakutia), Magadan region, Sakhalin Region, Chukotka Autonomous Region	6
2	Belgorod region, Bryansk region, Vladimir region, Voronezh region Ivanovo region, Kaluga region, Kostroma region, Kursk region, Lipetsk region, Moscow region, Oryol region, Ryazan region, Smolensk region Tambov region, Tver region, Tula region. Yaroslavl region, Republic of Karelia Komi Republic, Arkhangelsk Region without Autonomous Okrug, Vologda Region, Kaliningrad Region, Leningrad Region Murmansk region, Novgorod region, Pskov region, St. Petersburg, Republic of Adygea, Republic of Kalmykia, Republic of Crimea Krasnodar Territory, Astrakhan Region, Volgograd Region, Rostov Region, Sevastopol, Republic of Dagestan, Republic of Ingushetia, Kabardino-Balkarian Republic Karachay-Cherkess Republic, Republic of North Ossetia-Alania, Chechen Republic Stavropol Territory, Republic of Bashkortostan, Republic of Mari El, Republic of Mordovia, Republic of Tatarstan, Udmurt Republic, Chuvash Republic, Perm Territory, Kirov Region, Nizhny Novgorod Region, Orenburg Region, Penza Region, Samara Region, Saratov Region, Ulyanovsk Region, Kurgan Region, Sverdlovsk Region region, Tyumen region without autonomous districts, Chelyabinsk region, Republic of Altai, Republic of Tyva, Republic of Khakassia, Altai Territory, Krasnoyarsk Territory, Irkutsk Region, Kemerovo Region,	76

	Novosibirsk Region. Omsk Region, Tomsk Region, Republic of Buryatia, Trans-Baikal Territory, Kamchatka Territory, Primorsky Territory, Khabarovsk Territory, Amur Region, Jewish Autonomous Region	
3	Nenets Autonomous Okrug, Yamalo-Nenets Autonomous Okrug	2

The initial and final centers of clusters are shown in Table 4.

Table 4

Clusters	Initial centers of clusters	Final centers of clusters
1	2404271.2	1871485.383
2	142199.7	457679.0948
3	5206287.1	5139385.35

The data of Table 4 show a large gap between the values of the 1st, 3rd and 2nd clusters. The analysis of outliers based on quartiles showed the presence of outliers in the aggregate, which coincided with the values of indices in the 1st and 3rd clusters. Thus, based on this analysis, we removed the data of the regions of the 1st and 3rd clusters (8 well-to-do regions). Further analysis was carried out with the indices of 76 regions.

Then we built the multiple regression model (Table 5).

Table 5

Regression analysis

Indicator-factor	Coefficient	Standard error	t-statistics	P-value	R^2	P	F
const	4871.67	609.249	7.996	1.55878E-11	0.552	1.4703E-12	29.534
x5	0.42	0.209	2.012	0.047947774			
x8	-1.23	0.494	-2.493	0.014971904			
x10	0.05	0.007	7.942	1.97093E-11			

The analysis of the model obtained shows the lack of autocorrelation and heteroskedasticity; the remainders are normally distributed.

The dependence of the volume of transport services per capita can be described with a linear equation having the following form:

$$Y = 4871.67 + 0.42 \cdot x_5 - 1.23 \cdot x_8 + 0.05 \cdot x_{10} \quad (1)$$

As can be seen from the equation, the largest positive impact on the transport system efficiency is made by the volume of cargo turnover in the region in million tons per kilometer. At the same time, a significant positive factor is the volume of investment into capital assets of the relevant organizations. Apparently, the growth of capital investment into basic production assets allows increasing the cargo turnover of transportation companies, which is reflected on the scope of transportation services per capita. At the same time, the growth of passenger turnover (million passengers per kilometer) leads to a reduction of the resulting index. Obviously, this is due to competition within the sector: a high level of roads loading, including with public transport, leads to an increase of unproductive loss of working time for business, delays and, consequently, reduced volume of goods turnover.

The obtained determination coefficient (0.552) testifies to the influence of other factors not included into the built model.

The carried out modeling proved that the transport system efficiency is influenced by the cargo turnover growth, investments into capital assets and passenger turnover.

Discussion

Transport provision of territories and regions was researched in numerous works by Russian and foreign scholars. [8,9,10,11,12,13] The key disputable question in them is the method of assessing the transport provision of territories.

One of the most popular methods of assessing the regional transport provision is calculations based on extensive statistics. Among them – the index of transportation network density per 1,000 sq. km.; density of communication lines per 10,000 of the population; transport mobility of the population, etc. Analysis of the general

indices is carried out mainly by calculating coefficients of transport infrastructure provision of individual territories, usually regions and cities. These are Engel's, Uspensky, Golts, Vasilevsky coefficients. [1,14,15,16] Having differentiated indices of the quality of transport system performance, researchers propose using an integral index of transport provision for a certain i-th territory. [17]

At the same time, scholars point out such drawbacks of this analysis as its narrow informativity in terms of the impact of transport development for solving the prospective tasks of socio-economic development. [18] Moreover, these coefficients do not account for geographical features of the territory, technological features of the transport infrastructure, aviation connectivity of the regions, etc. To minimize the said drawbacks, researchers propose using an integrated Uspensky coefficient (Engel–Youdzuru Kato index) taking into account the cargo turnover. [18]

Indeed, in the northern regions of the Russian Federation, seasonal communication lines, the so-called winter snow roads, are rather widely spread. As a rule, they are not accounted for in the studies of transport provision of territories. [19] That is why, the use of the seasonal communication lines index is substantiated by the lack of alternatives in the northern regions. In this regard, experts propose using an integral index method, allowing differentiation in the indices of average weighted temporal and monetary expenses for cargo transportation. The set of methodological tools elaborated by a collective of authors is based on classical methods of assessing a transport system of a region, making it possible to take into account the presence of seasonal types of transport communications in the northern regions of the country.

The integral method of assessing transport provision by several key indices underlies the ranking of regions by the most developed transport systems. [18]

In her works, M. P. Deruzhinskaya proposes using summarizing (modified Bennett coefficient) and integral types of indices of infrastructural provision of territories. [20] At that, she rightfully marks that their use in the original form is rather complicated for several reasons. For example, Engel's coefficient is restricted by the indices assessed, and Bennett's method – by incomplete array of information.

Some researchers propose using qualitative parameters of transport asymmetry when determining the level of transport provision of regions. [2, 21] At that, they mark that the transport asymmetry per se is not a problem if all regions show the indices, providing the transport system goals, not lower than the basic level. [21] Hence, the position determined by various rankings with a system of integral indices loses its significance. Solely important becomes the degree of the regional transport system lagging behind the "leader". [21] Besides, the current lagging behind can be rather rapidly overcome by investments into transport infrastructure.

A significant number of researchers analyze the relationship between transport security and economic growth of cities, provinces, regions and countries. [22,23,24,25] The results of studies, in general, demonstrate a stable effect of this relationship, however, it somewhat weakens or increases under the influence of socio-economic, geographical, climatic and other factors. Nevertheless, reducing inequality in the provision of transport infrastructure can solve the problem of regional economic growth in the long term. [26,27]

In our study, we will undertake an analysis of the impact of transport security factors on the effectiveness of the regional transport system. According to experts, transport provision in the Russian regions is very low. [21,28] The reasons for this are the following: insufficient level of financing of the transport industry, high wear and tear of the transport infrastructure, limited transport mobility in difficult weather conditions and seasons.

The Russian experts often assess transport provision in the regions as rather low, [28] explaining it mainly by insufficient funding of the transport sector, large deterioration of the transport infrastructure, limited transport mobility under hard weather conditions and seasons, etc.

Conclusions

The research results confirmed the locomotive role of transport system in ensuring the development of other economic sectors. Analysis of the state of transport system in the Russian Federation subjects showed a high heterogeneity of transport provision. In eight out of 85 regions, the outliers of indices are extremal. Econometric analysis showed that the transport system efficiency is determined by the intensity of its business use (volume of cargo turnover), amount of investment into capital assets of the transport companies, intra-sector competition for using roads among passenger-carrying companies. Other factors were not included into the model, but they can be used for assessing the factors and conditions of development of various kinds of transport (railroad, automobile, etc.) in other research projects.

The research can be further directed towards identifying the conditions of transport development in federal regions, where the proximity to neighbors and the presence of intra- and inter-sector economic links determines the formation of added value chains. As a consequence, the development of leader regions involves outsider regions into economic circuit and simulates their growth. Such methods and approaches as cluster, correlation-regression and spatial analysis are planned to be used. The results obtained will be useful for elaborating the directions of improving the transport system of economic development of the regions.

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