CHOICE OF METHODS FOR FORECASTING REGIONAL PASSENGER FLOWS

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ABSTRACT

In the system of railway traffic organization, the forecast of passenger flows is an information and analytical basis for development of train schedule and calculation of train schemes. For making sound management decisions, high accuracy of the forecast and a methodological base that meets modern conditions are necessary. The article is devoted to the study of the methods of calculation of passenger traffic, taking into account the specifics of their formation in the federal entities of the Russian Federation. A classification of regions according to the characteristics and trends in development of demand is proposed. The choice of an approach to forecasting the volumes of intraregional demand was carried out on the basis of the algorithm developed by the authors. The results of calculations are presented and the areas of application of forecast methods are determined depending on the local features identified.

Keywords: railway, regional passenger flow, traffic forecast, local transport market, demand trends.

Background. *The information technology used to build the forecast in the automated control system «Express» [1, 2], operating on the Russian railways, received in 2016 a new impetus regarding regional aspects. Within the framework of the new «Regional passenger flows» functionality, the first task was to create analytical reports on interregional (emerging within one region and extinguishing within the borders of another region) and intraregional (transport flows are closed within the borders of the same region of the Russian Federation) correspondence of passenger flows and their development trends for the future [3].*

The construction of a model of transport mobility between and within regions of the Russian Federation is based on a unified methodology. To increase the accuracy of demand calculation, a study of the scope of application has been carried out and a selection of methods has been implemented to ensure the recording of characteristics and specifics of the formation of intra-regional passenger flows.

Objective. *The objective of the authors is to consider choice of methods for forecasting regional passenger flows.*

Methods. *The authors use general scientific methods, mathematical analysis, evaluation approach.*

Results.

Dynamics of intraregional correspondence

The share of intraregional passenger flows in the total volume of long distance transportation is 12 mln pass./year or 11,4 %. In this segment of the transport market, there is a tendency to decreasing demand. For 10 years (2006–2016) the volume of passenger traffic in the regions (without taking into account the suburban traffic) decreased more than by 2 times – from 28 to 12 million pass./year. The most significant rates of decline were recorded in 2009 (22 %) and 2013 (29 %). In 2016, there was a slight increase in demand: 3 % of the 2015 indicator [3].

Based on the studies carried out, the following main characteristics of regional traffic were obtained:

- *dynamics of volumes of transport within the borders of the region;*
- *share of domestic regional demand in the total volume of passenger shipments by rail;*
- *trends in development of passenger flows;*
- *nature of distribution of regional demand along the lines;*
- *features of formation of the annual cycle in terms of passenger traffic.*

The volume of regional passenger transportation is uneven across the regional of the Russian Federation. The largest in this indicator are:

Table 1

Grouping of subjects of the Russian Federation in accordance with the dynamics of changes in passenger flows

Trends in regional demand		
Decline	Growth	Stable state
Republics: Bashkiria, Buryatia, Kabardino-Balkaria, Karelia, Komi, Mordovia, Yakutia, Udmurtia, Khakasia	Republics: Dagestan, Crimea, Mari El, North Ossetia-Alania, Tatarstan, Chechnya, Chuvashia	Republic: Kalmykia
Krais: Altai, Zabaikalskiy, Krasnodar, Krasnoyarsk, Perm, Primorsky, Khabarovsk	Krai: Stavropol	
Regions: Amur, Arkhangelsk, Astrakhan, Bryansk, Volgograd, Vologda, Voronezh, Ivanovo, Irkutsk, Kemerovo, Kirov, Kostroma, Kurgan, Leningrad, Murmansk, Novosibirsk, Omsk, Pskov, Rostov, Saratov, Sakhalin, Sverdlovsk, Tambov, Tver, Tomsk, Tyumen, Ulyanovsk, Chelyabinsk, Yaroslavl	Regions: Belgorod, Vladimir, Kaliningrad, Kaluga, Kursk, Lipetsk, Moscow, Nizhny Novgorod, Novgorod, Orel, Ryazan, Smolensk, Tula	Regions: Orenburg, Penza, Samara
Autonomous region: Jewish		
Autonomous district: Khanty-Mansiysky		Autonomous district: Yamalo-Nenetsky

1 ***Regional passenger flow is formed by one major direction*** *Republics:* Dagestan, Kabardino-Balkaria, Kalmykia, Sakha (Yakutia), North Osetia-Alania, Tatarstan, Chechnya, Chuvashia *Krais:* Perm, Stavropol *Regions:* Astrakhan, Kaliningrad, Nizhny Novgorod, Novgorod, Omsk, Samara, Sakhalin, Smolensk, Tambov, Tver, Tomsk, Tula, Tyumen	2 ***Regional passenger flow is represented by several major directions, which in total absorb the largest share of transportation within the subject of the Russian Federation*** *Republics:* Crimea, Mari El *Krai:* Krasnodar *Regions:* Vladimir, Kaluga, Kirov, Leningrad, Murmansk, Ryazan, Yaroslavl
3 ***Regional passenger flow is distributed between small number of directions, which share is less than 1/4 of the passenger flow*** *Republics:* Bashkiria, Buryatia, Karelia, MOrdovia, Udmurtia *Krais:* Altai, Krasnoyarsk, Primorsky, Khabarovsk *Regions:* Bryansk, Volgograd, Kursk, Lipetsk, Novosibirsk, Orenburg, Oryol, Penza, Pskov, Saratov, Sverdlovsk, Ulyanovsk *Autonomous region:* Jewish *Autonomous districts:* Khanty-Mansiisky, Yamalo-Nenetsky	4 ***There are no pronounced regional directions with a large volume of passenger flows*** *Republics:* Komi, Khakasia *Krai:* Zabaikalsky *Regions:* Amur, Arkhangelsk, Belgorod, Volodga, Voronezh, Ivanovo, Irkutsk, Kemerovo, Kostroma, Kurgan, Moscow, Rostov, Chelyabinsk

Pic. 1. Grouping of regions of the Russian Federation according to the territorial distribution of passenger flows (authors' version).

Krasnoyarsk krai (about 2 mln pass./year), the Republic of Komi (2 mln pass./year), Khabarovsk krai (about 1 mln pass./year).

Transport mobility is determined by intraregional and interregional correspondence. The interregional size of demand largely depends on macroeconomic factors and territorial remoteness of the region from the capital centers. The volume of domestic traffic is most influenced by factors of territorial and economic development [4, 5]. On the basis of analytical calculations, the values of the share of domestic regional traffic from the total passenger traffic distributed by regions of the Russian Federation were obtained. The largest share of regional demand in the total volume of shipments was recorded in Sakhalin and Amur regions, the Republic of Komi.

According to the trends in development of domestic passenger traffic (growth, decline, stable state) in the period 2006–2016, a grouping of regions was carried out (Table 1).

Analysis of regional demand made it possible to identify the main trends in distribution of passenger flows along the lines within the boundaries of the regions of the Russian Federation (Pic. 1) and to group them according to the following criteria:

- *the largest part of passenger traffic (more than 50 %) is closed within the boundaries of one main direction, the rest of the transport flows are «sprayed» along a multitude of «small» directions;*
- *regional passenger flow is concentrated in several major directions, which, in total, absorb more than 50 % of demand;*
- *local demand is characterized by the presence of several major directions in the region, however, in the total volume of transportation, the share of them is no more than 25 %;*
- *there is no large regional correspondence, demand is distributed among numerous segments of the regional transport market.*

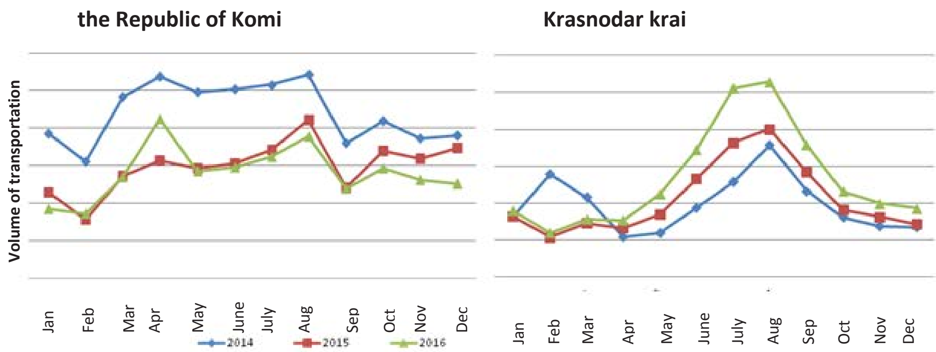
For regional transportation, annual cyclicity is characteristic. With the use of the data of ACS «Express-3», cycles with a successive alternation of bursts and falls (the Republic of Komi, Khabarovsk region, Tyumen region, etc.) and dome-shaped distribution (the Republic of Karelia, Zabaikalsky krai, Irkutsk region, etc.) of volumes of demand are allocated. The general view of the dome-shaped cycle includes the stages: a small increase in the volume of transportation compared to the average annual values in January, in February – a decline to the minimum value for the year. From March to June there is a smooth growth and in July-August the maximum value of regional passenger flows is observed. During September-December, there is a gradual decrease in transportation volumes by the end of the year (Pic. 2).

Summarizing the obtained results of the passenger transport market research, it should be noted that there are significant differences in the dynamics of development and the nature of distribution of domestic passenger flows in the regions of the Russian Federation. To calculate the perspective values of demand, a strictly differentiated approach to construction of forecast models is required.

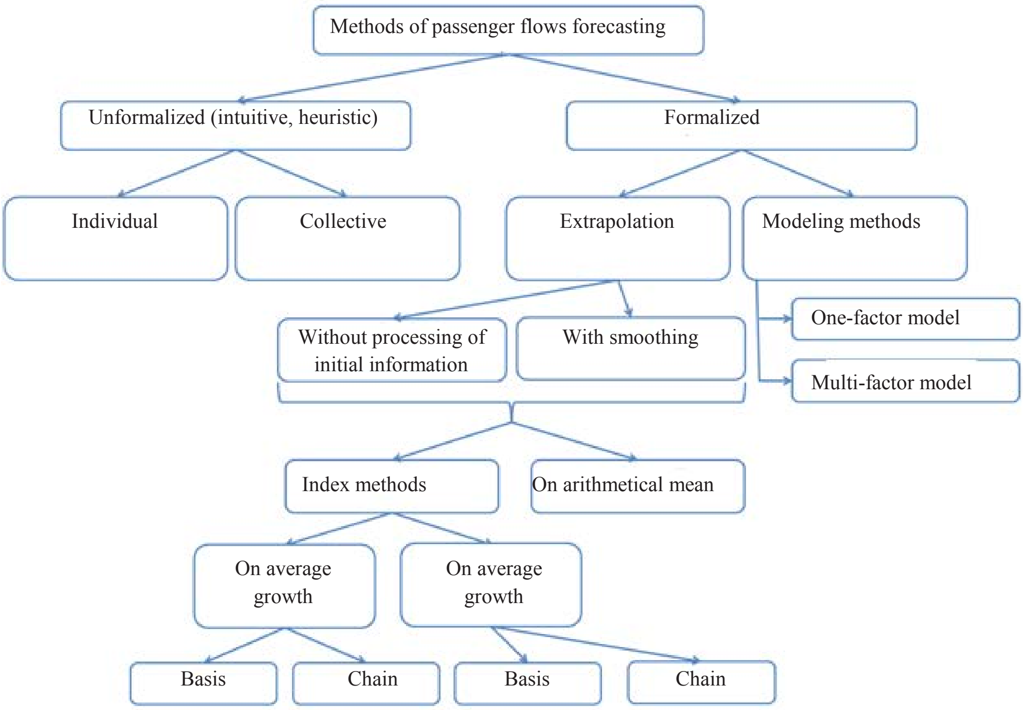
Analysis of forecast methods

Methodical approaches [6] have been worked out for constructing the forecast of passenger transportation volumes [6], which differ in theoretical positions, the degree of complexity of the applied mathematical apparatus, the areas and scale of implementation, and the volume of initial data (Pic. 3).

Unformalized methods are based on the use of intuition and experience of specialists of the passenger complex. Usually they are not connected with the use



Pic. 2. Annual cyclicity of regional transportation (author's version).



Pic. 3. Classification of methods for passenger flows forecasting (author's version).

of a complex mathematical apparatus and the preparation of a large volume of primary information on passenger flows. Unformalized methods are widely used in the system of organizing passenger transportation while making operational decisions. On the basis of expert assessments, regulatory measures are carried out to ensure the correspondence between the volume of transportation means and the amount of demand for transport services.

Formalized methods are based on mathematical calculations, statistical research, identification of features and trends in the development of passenger flows. Among them there are two blocks: extrapolation and modeling. The model is a simplified object of research, endowed with the properties of the existing prototype, with the aim of studying it when changing various kinds of input parameters. In accordance with the number of parameters considered, the one-factor and multifactor models are identified.

The construction of a multifactor model is an extremely time-consuming task, requiring a large amount of external (outside transport) information. The source of the data (usually) is the reference material of the Federal State Statistics Service (Rosstat) [7]. The Rosstat information base forms indicators for a calendar year, without detailed information by quarters and months. In this connection, it is not possible to build and carry out calculations of transport mobility taking into account the intra-annual unevenness of transportation on the basis of the multifactor analysis method. In contrast to this approach, trend models provide details of indicators on long-term demand by months. It does not require information on exogenous factors. The series of regional traffic dynamics over a period of at least five years is considered. As calculations have shown, the level of forecast quality of regional passenger flows with the help of trend models is

Table 2

SWOT analysis of trend extrapolation methods for forecasting regional passenger flows

Advantages: • a small amount of initial data is required (in comparison with the method of multifactor modeling); • less laboriousness in collecting primary information; • does not require complex mathematical calculations; • it is possible to apply the «spasmodic» trends in the development of the region's economy.	**Disadvantages:** • a continuous time series is required; • the influence of macroeconomic factors is not taken into account.
Possibilities of application: • initial information on development of the facility should be provided for a period exceeding 2–3 times the depth of the forecast; • application is allowed in case of «spasmodic» changes in economic indicators.	**Threats:** • the lack of consideration of the influence of external factors can adversely affect the quality of the forecast.

Table 3

Objects of the control sample

Constitutional and legal status	List of regions
Republics:	Buryatia, Karelia, Mordovia, Tatarstan, Chuvashia
Krais:	Altai, Zabaikalsky, Krasnoyarsk, Khabarovsk
Regions:	Amur, Arkhangelsk, Bryansk, Vladimir, Volgograd, Vologda, Voronezh, Irkutsk, Kaliningrad, Kaluga, Kirov, Kostroma, Leningrad, Moscow, Murmansk, Novgorod, Novosibirsk, Omsk, Penza, Rostov, Ryazan, Samara, Saratov, Sakhalin, Tambov, Tver, Tomsk, Ulyanovsk, Yaroslavl
Autonomous districts:	Khanty-Mansiisky, Yamalo-Nenetsy

not inferior in accuracy to multifactor modeling at a depth of 2–3 years [8].

Methods of trend extrapolation are based on statistical observation of the dynamics of the volume of passenger transportation in long-distance trains within the borders of the region, determining its development trend and continuing this trend for the future period. In other words, by means of extrapolation of trends, the laws of the past development of an object are transferred to the future. When using this method, it is necessary to have information on stability of trends over a period 2–3 times greater than the period of the forecast depth.

Assessment of regional perspectives

The process of selecting forecasting methods included the sequence of actions:

• clear definition of the task, hypothesis about possible development of the projected object, analysis of retrospective information, search for extrapolation options;

• selection of a system of forecast parameters, unification of various units of measure relating to each parameter separately;

• collection and systematization of data, verification of their homogeneity and comparability;

• identification of trends in the changes in the studied variables during statistical analysis and direct extrapolation of data.

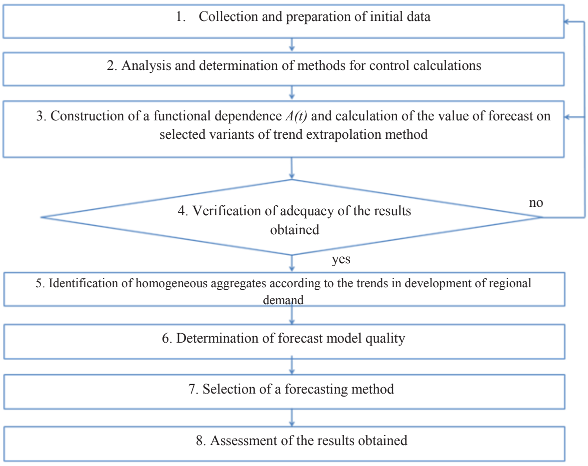
Practical application of methods of extrapolation of trends (index, calculated by the chain method, and by the arithmetic mean), has a number of advantages and disadvantages (Table 2).

The algorithm for selecting the trend extrapolation method for regional conditions includes eight consecutive stages (Pic. 4).

Step 1. Collection and preparation of initial data includes:

• choice of a forecast period;

• determination of a list of objects and the scope of the control sample, provided that it meets the



Pic. 4. The enlarged block diagram of the process of selection of a trend extrapolation method for forecasting the volumes of intraregional passenger flows.

Table 4

Signs of association of regions in homogeneous groups

Grouping sign	Groups
Nature of development of demand in the period of observation	Growth in transportation volume
	Decrease in intraregional demand
	Stable or insignificant change
Territorial configuration of passenger transport flows	1st group Concentration of passenger flows in the zone of one major direction
	2nd group Concentration of transportation volumes within the boundaries of 2–3 main directions
	3rd group Unevenly distributed across transport segments of a region
	4th group Evenly distributed along the railway infrastructure lines

requirements of sufficiency and representativeness and ensures coverage of all studied characteristics of regional demand;

- *calculation of retrospective volumes of intraregional transportation, construction of dynamic data series reflecting the volumes of passenger flows by years in chronological order;*
- *verification of data unification.*

Control calculations are based on data on intraregional passenger flows in 40 regions of the Russian Federation (Table 3) and ensure that all characteristics of regional demand are taken into account.

Steps 2–3. Analysis of methods and construction of a functional dependence of transportation volumes on the time factor. The use of index extrapolation methods is based on determination of the coefficients whose magnitude corrects the last value of the dynamic series.

The method of extrapolation of trends based on the average growth rate assumes the calculation of the average growth rate of regional passenger flows over a number of years and multiplying it by the last value of the dynamic series:

$$A_{forec\_t} = A_{t-1} \cdot K_g ,$$

where A_{forec_t} is forecast value of volumes of intraregional transportations for the period t; A_{t-1} – actual volume of regional passenger flows in the pre-forecast year t-1; K_g – coefficient of growth.

The growth coefficient is calculated on the basis of the growth rates of regional passenger flows over a number of years:

$$K_g = \frac{\sum T_{g\_i}}{n-1} ,$$

where n – number of periods in the dynamic series.

The growth rate shows how much (in fractions of 1) the volume of regional transportation varies in comparison with the previous period (chain mode):

$$T^{chain}_{g\_i} = \frac{A_i}{A_{i-1}} ,$$

where $T^{chain}_{g\_i}$ – growth rate of regional passenger flows, for the i-th level of the series; A_i – value of intraregional transportation volumes in the i-th period; A_{i-1} – value of volumes of transportation within the borders of the region at the point i-1.

The method of extrapolation of trends on the average growth provides for calculating the average increase in the volume of regional passenger flows over a number of years and adding it to the last value of the series:

$$A_{forec\_t} = A_{t-1} + K_{in} ,$$

where K_{in} – coefficient of increment.

The increment coefficient is calculated on the basis of increment of passenger flows over a number of years:

$$K_{in} = \frac{\sum T_{in\_i}}{n-1} .$$

The increment shows how much (in absolute values) the volume of intraregional passenger flows varies in comparison with the previous period (chain mode):

$$T^{chain}_{in\_i} = A_i - A_{i-1} ,$$

where $T^{chain}_{in\_i}$ – rate of increment of regional passenger flows of the i-th level of the series.

The method of extrapolation on the arithmetic mean is based on the assumption that the average arithmetic value of intraregional transportation volumes over several years is a predicted value for the following period:

$$A_{forec\_t} = \frac{A_{t-1} + A_{t-2} + \ldots + A_{t-n}}{n} ,$$

Table 5

Example of presentation of MAPE indicator (fragment)

Subjects of the Russian Federation	Demand characteristics	Method of the arithmetic mean		
		Retrospective data		
		5 years	4 years	3 years
Khabarovsk krai	decline	9,3	7,2	5,9
Tambov region	decline	6,4	4,9	1,2
Ulyanovsk region	decline	2,7	1,9	1,1

Table 6

Scoring system for the results of control calculations

Grouping feature	Forecast on growth rates			Forecast on increment rates			Forecast on the arithmetic mean		
	Retrospective information								
	5 years	4 years	3 years	5 years	4 years	3 years	5 years	4 года	3 года
Nature of development of demand over the years of the observation period									
Decline	7	2	2	2	1	1	3	3	8
Growth	1	0	2	1	0	1	0	1	2
Stable state	0	1	0	0	2	0	0	1	0
Territorial configuration of passenger transport flows									
1st group	2	1	0	1	1	1	0	2	2
2nd group	1	0	1	1	0	1	1	0	2
3rd group	2	2	1	0	2	0	2	2	4
4th group	3	0	2	1	0	0	0	1	2

where $A_{t-1}, A_{t-2}, A_{t-n}$ – actual value of regional passenger flow for the periods t-1, t-2, ... t–n, preceding the forecast period t.

Step 4. Verification of adequacy of the results obtained includes an assessment of the values of forecast values of intraregional passenger flows for reliability.

Step 5. Identification of homogeneous sets according to the trends of regional demand development.

An important part of construction of forecast models is selection of homogeneous aggregates and grouping of the studied objects according to certain criteria. Statistical aggregate is a complex of socioeconomic objects (in this case – regions of the Russian Federation), united by any basis or common link, but differing from each other by individual features signs. The aggregate of subjects is called homogeneous if the trends in the volume of passenger transportation are common for all units of the aggregate. In the classification group, each region of the Russian Federation is considered as such. The unit of the aggregate is a separate, primary, indivisible system part that has characteristics that are subject to statistical observation.

On the basis of the analytical work performed, the subjects were grouped (Table 4) according to two criteria:

- *nature of development of demand over the years of the observation period;*
- *territorial configuration of passenger transport flows.*

For regions belonging to the same classification group, a single algorithm for selecting the forecast method can be applied due to the fact that they have the same trend in development and territorial distribution of demand along the lines.

Step 6. Determination of forecast model quality.

The forecasting accuracy is measured by the magnitude of the forecast error, which reflects the a posteriori value of deviation of the forecast value of the volume of transportation within the region of the Russian Federation from the actual value. When

Table 7

Methods of regional passenger flows forecasting

Groups of regions		Forecast on growth rates	Forecast on increment rates	Forecast on the arithmetic mean
Nature of demand development	**Decline**			■
	Growth	■		■
	Stable state		■	
Territorial configuration of passenger transport flows	**1st group**			■
	2nd group			■
	3rd group			■
	4th group	■		

■ The application of the method ensures the forecast of passenger flows with a minimum error.

performing control calculations, the following formula is used:

$$MAPE = \frac{|A_{a-t} - A_{forec\_t}|}{A_{a\_t}} \cdot 100 ,$$

where A_{a_t} is actual value of passenger flow in the reporting period t; A_{forec_t} – forecast value of a passenger flow in the reporting period t; t – reporting period.

The results of calculations are presented in the form of table 5, where the lines indicate regions of the Russian Federation that belong to the same group, and the columns – the values of the forecast error (MAPE).

Step 7. Selection of a method of regional passenger flows forecasting.

The choice of the method was made using a scoring of the results of control calculations. For each group of regions, they included the following set of works: determination of the forecast values of passenger flows by various methods of trend extrapolation trends with a depth of 1–2 years (A_{forec_t}), monitoring the volumes of transportation in the base (reporting) period (A_{a_t}), calculating the magnitude of the «forecast error» (MAPE) on all set of the used methods.

The points are calculated in the following order. One group of regions is selected, which reflects one characteristic of demand. For example, the aggregate of entities that demonstrate a trend towards decline in demand volumes. For each region, a method is defined that shows the minimum forecast error. The method is assigned 1 point. Similarly, a continuous calculation is performed for all units of a homogeneous aggregate. The final score is the sum of the scores of all the regions forming the group (Table 6). In particular, for a group with regions that have a tendency to decline/decrease in demand, the greatest accuracy of the forecast is achieved by extrapolating trends by the arithmetic mean (the sample of data is three years, the total is 8 points).

The largest value of the scoring in absolute value shows that the application of the analyzed method allows to obtain the minimum error MAPE.

Step 8. Assessment of the results obtained.

Within the framework of the studies performed, the criterion for choosing the forecast method is the indicator of the mean forecast error (MAPE). According to the given criterion, the methods of trend extrapolation have been chosen, which make it possible to calculate the prospective volumes of regional passenger flows with a minimum error not exceeding 3–5 %, in accordance with the proposed classification criteria (Table 7).

Conclusions.

1. The performed analytical studies showed that in 2006–2016 the volume of domestic passenger transportation (excluding suburban traffic) in the regions of the Russian Federation was halved. Specialists of the passenger complex of JSC Russian Railways are developing measures to overcome the negative trend and stimulate regional demand. The information and analytical basis for their implementation is the forecast of passenger flows and the dynamics of distribution of volumes of shipments along the railway directions.

2. The system of classification of the regions of the Russian Federation in accordance with the trends in development of demand and the characteristics of territorial distribution of passenger flows has been developed. For regions of one classification group, a single algorithm for choosing the forecast method is applied.

3. The effectiveness of applying trend extrapolation methods for predicting passenger flows at regional management levels is proved. The control calculations performed according to the groups of the proposed classification confirm the high accuracy and minimum deviation of the forecast value from the actual demand values at the prospect depth of 1–2 years.

REFERENCES

1. ACS «Express» – Automated system of passenger transportation management in railway transport [*ASU «Ekspress» – Avtomatizirovannaja sistema upravlenija passazhirskimi perevozkami na zheleznodorozhnom transporte*]. Ed. by A. V. Komissarov. Noginsk, Analitika Rodis publ., 2016, 128 p.

2. Makarova, E. A., Elizarov, S. B., Muktepavel, S. V. Automated system for forecasting of passenger transport flows on the basis of the automated control system «Express» [*Avtomatizirovannaja sistema prognozirovanija passazhirskih transportnyh potokov na baze ASU «Ekspress»*]. *Vestnik VNIIZhT*, 2011, Iss. 4, pp. 21–27.

3. Makarova, E. A., Muktepavel, S. V. Development of a system of calculation and analytical indicators characterizing regional passenger transportation [*Razrabotka sistemy raschjotno-analiticheskih pokazatelej, harakterizujushhih regional'nye passazhirskie perevozki*]. *Vestnik VNIIZhT*, 2016, Iss. 3, pp. 169–173.

4. Surzhin, K. V., Muktepavel, S. V. Evaluation of the influence of the population factor on the volume of passenger transportation [*Ocenka vlijanija faktora chislennosti naselenija na ob'jom passazhirskih perevozok*]. *Vestnik VNIIZhT*, 2015, Iss. 4, pp. 59–64.

5. Lapidus, B. M., Pekhterev, F. S., Makhlin, E. M. Regional studies: study guide [*Regionalistika: Ucheb. posobie*]. 2nd ed., rev. Moscow, MIIT publ., 2010, 400 p.

6. Pazoisky, Yu. O., Shubko, V. G., Vakulenko, S. P. Passenger transportations by rail (examples, tasks, models and methods for their solution): study guide [*Passazhirskie perevozki na zheleznodorozhnom transporte (primery, zadachi, modeli i metody ih reshenija): Ucheb. posobie*]. Moscow, TMC for education on railway transport, 2009, 342 p.

7. Transport and communications in Russia. 2016: Stat. collection [*Transport i svjaz' v Rossii. 2016: Stat. sb.*] // Rosstat. Moscow, 2016. [Electronic resource]: http://www.gks.ru/bgd/regl/B16_5563/Main.htm. Last accessed 11.12.2017.

8. Makarova, E. A., Surzhin, K. V., Elizarov, S. B., Morozov, S. S. Forecasting of passenger flows in long-distance traffic on the infrastructure of JSC Russian Railways by regions of the Russian Federation [*Prognozirovanie passazhiropotokov v dal'nem soobshhenii na infrastrukture OAO «RZD» po regionam Rossijskoj Federacii*]. *Transport: nauka, tehnika, upravlenie*, 2017, Iss. 2, pp. 34–39.

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