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The Prediction of Suburban Passenger Traffic with Econometric Models

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Abstract. This article provides the population and the developing economy of the Far East of Russia with information regarding passenger transportation needs. The study assesses the condition of the passenger railway complex and customer satisfaction with transportation services. Suggested prospects for the development and reform of the passenger railway complex of the Far Eastern Federal District.

1. Introduction

In addition, the article considers the authors' approach to estimating passenger turnover and revenue of suburban passenger companies using the level of fares and applying the coefficients of elasticity. This calculation technique allows for the assessment of passenger turnover and revenues, as well as establishing the fares that meet the solvent demand of the population for suburban transportation; therefore, the customer and the contractor will be able to conclude mutually acceptable contracts for the provision of the transportation services. This technique helps calculate the coefficients of elasticity and on this basis predict the passenger turnover and revenues of suburban passenger companies. Moreover, it helps form the terms of contracts for the provision of public transport services on a scientific basis for the federal subjects of the Russian Federation and public institutions working in the field of public transport.

2. Relevance of the research

One of the main rights of a citizen enshrined in the Constitution of the Russian Federation is the right to transportation, including short distance journeys on suburban railway traffic, carried out by the passenger railway companies. The measures of transport market capacity, as well as its demand, are calculated from the natural indicators - passengers parameters (sent passengers, passenger turnover) and cost parameters obtained by multiplying natural indicators by the transportation fares. The demand for suburban transportation is formed under the influence of various motivational factors [1, 2].

Nowadays, the planning of suburban passenger traffic is usually carried out through the method of planning "from what has been achieved" or the method of expert assessment. However, these approaches to planning often provide incorrect figures when it comes to passenger flow, which can lead to the incorrect assessment of possible income and the cost of transportation. This can occasionally result in lawsuits being brought by subjects of the Russian Federation (customers of suburban traffic) against suburban passenger companies and are based on the false calculation of subvention. In this article, the authors propose an approach to the planning of suburban passenger traffic based on a two-factor regression equation and elasticity coefficients that show the dependence of the resulting factor (passenger turnover) on both the population and fares. Planning the suburban passenger flow using economic and mathematical models will allow one to scientifically substantiate the volume of passenger flow, and, consequently, establish a reasonable level of fares, revenue and the cost of transportation.

3. Research part

Demand in the passenger segment for transportation services estimated according to general models (see formula 1) [1-8]:

$$Y_n = f(x_1, x_2, ... x_n), \tag{1}$$

Yn– forecast passenger traffic; x1,x2…xn – factors affecting the amount of suburban passenger traffic.

The first-order factors affecting the amount of suburban passenger traffic are population and its mobility. In turn, the mobility of the population is affected by the second-order and third-order factors, namely socioeconomic factors (the transportation fares, the growth of real incomes within the population, the level of urbanization of the territory and the increase of the production and economic potential of the region), as well as the development of other types of transport engaged in suburban passenger transportation etc.

In a number of works, the authors have proposed econometric models which help plan operational suburban passenger flows according to the seasonal factor [9, 10]. In addition, a number of studies have proposed various models which help plan suburban passenger flows for a period of between one to five years, using elasticity coefficients and altering the passenger train fares [11, 12].

Consider forecasting of suburban passenger flows depending not only on the level of fares but also on the population, in other words, using a two-factor econometric model. Calculations have been made for one of the regions of the Far Eastern Federal District of Russia, Khabarovsk Krai, based on the data from 2008-2017 on population and transportation fares.

The elasticity of demand (passenger turnover) to price (average rate of return) is measured with the coefficient of arc elasticity, which is calculated from formula 2 (see Table 2.) [13]:

$$K_p^d = \frac{\sum al_1 - \sum al_0}{ROR_1 - ROR_0} \cdot \frac{ROR_0}{\sum al_0}, \tag{2}$$

$\sum al_1 - \sum al_0$ – demand variation (passenger turnover); $ROR_1 - ROR_0$ – rate of return variation.

Table 1. Calculation of coefficients of elasticity for suburban passenger turnover in Khabarovsk Krai based on the value of the income rate [23,24].

#	Year	Passenger turnover (∑al), mln. pass. km	Revenues, mln. rubles	Income tax rate (ITR), rubles/10 pass.km	Elasticity coefficient (E)	Population (P), people
1	2008	110,35	79,847	7,24	–	1 403 712
2	2009	73,71	80,660	10,94	0,65	1 401 915
3	2010	56,54	85,898	15,19	0,60	1 343 869
4	2011	53,86	85,708	15,91	1,00	1 342 887
5	2012	49,44	86,302	17,46	0,85	1 342 475
6	2013	45,42	87,517	19,27	0,78	1 342 083
7	2014	43,71	88,427	20,23	0,75	1 339 912
8	2015	40,80	100,544	24,64	0,31	1 338 305
9	2016	31,34	82,076	26,19	3,69	1 334 552
10	2017	30,54	86,298	28,25	0,32	1 333 294

Calculating the parameters of the correlation between the passenger turnover and the rate of return using the method of least squares, with the help of the standard means of MS Excel, it is possible to obtain the parameters of the hyperbolic and power model [11, 12, 14-17].

Analysis of the data from Table 1 and the growth of paired correlation between the coefficients (their value by factors: income and population of more than 0.9) allow us to conclude that it is possible to plan passenger flows using not only one, but several factors. For this purpose, we will use the mathematical apparatus of production functions. The production function is the dependency between the number of resources consumed in the production (independent variables x_1, x_2,..., x_n, the number n of which is equal to the number of resources) and the amount of output goods Y [14-22].

The mathematical apparatus of production functions can be used not only for developing macroeconomic models but also for creating the requisite models at a micro level. In particular, in some works [17,18] the toolkit of production functions has been used for planning the demand for different products, depending on the price and income of the population. If we denote the volume of passenger turnover with Y, the rate of return (ROR) and the population in the region (P), then the regression equation can be presented in the following form (see formula 3):

$$Y=f(ROR, P) \text{ or } Y = ROR^{a_1} \cdot P^{a_2} \quad (3)$$

This equation means that passenger turnover is a function of income rate and population. To build a model, it is necessary to linearize the variables [16]. For this purpose, we need to log both parts of equation 3 using the data from Table 1 (see formula 4):

$$\ln Y = \ln a_0 + a_1 \ln ROR + a_2 \ln P \quad (4)$$

At the stage of modeling, the free term $\ln_{a0}$ is excluded (as a parameter that worsens the statistical properties of the model). In the initial multiplicative model, a_0 is considered equal to 1 [16]. The results of the calculations are obtained by estimating the parameters of the regression model without a free term, using the tool "Data analysis" in MS Excel. Substituting the obtained values of regression coefficients, we get the following equation (see formula 5):

$$Y = ROR^{-0,852} \cdot P^{1,427} \quad (5)$$

When assessing the quality of this model, all the main characteristics show a good approximation. Thus, the coefficient of determination R^2 is equal to 0.99, therefore, more than 99 % of the variation of the dependent variable is taken into account in the model and is determined by the influence of the included factors. The calculated values of F-criteria (F = 345 113.2), and t-statistics (RTD = 9,8, RT = 80) are higher than the table standard values at the given degrees of freedom, which confirms the reliability of the econometric model. Economic interpretation of parameters a_1 and a_2 is as following [14]: a_1 is the elasticity of passenger turnover in terms of income rate, it is equal -0.852, i.e. with the increase of income rate by 1% of passenger turnover, it will decrease by 0.852 %; a_2 is elasticity of passenger turnover in terms of population of the region, it is equal 1.427, i.e. with the increase of population of the region by 1% of passenger turnover, it will increase by 1.427 %.

Compare the volume of passenger turnover built on the data from the formula 5 with the initial data. Calculations are presented in Table 2.

Table 2. Prediction of passenger flow using a two-factor econometric model.

#	Year	Passenger turnover actual, M. pass. km	Passenger turnover by model, mln. pass. km	Absolute deviation by model, mln.pass.km	Model deviation, %
1	2008	110,35	110,40	0,05	100,05
2	2009	73,71	77,48	3,77	105,12
3	2010	56,54	55,16	-1,38	97,56
4	2011	53,86	52,97	-0,89	98,35
5	2012	49,44	48,94	-0,50	98,98
6	2013	45,42	44,97	-0,45	99,01
7	2014	43,71	43,04	-0,67	98,47
8	2015	40,80	36,32	-4,48	89,03
9	2016	31,34	34,35	3,01	109,61
10	2017	30,54	32,16	1,61	105,28

Analysis of Table.2 shows that the error in passenger traffic forecast does not exceed 10%. The results show the adequacy of this approach for predicting suburban passenger flows.

4. Conclusions

The suburban railway passenger complex of the Far Eastern Federal District of Russia and Khabarovsk Krai, in particular, is characterized by a significant drop of passenger traffic and multiple increases of fares over the period 2008-2017 (see Table 1). Passenger traffic planning is an important element for the determination of the cost of transportation, and therefore for estimating the suburban fare and the amount of subvention required [11,12].

The proposed methodology for predicting suburban passenger turnover, according to the level of fares and population, can be implemented in a specific suburban area or on a particular destination. In addition, the use of this method will allow one to form the terms of contracts for the provision of public transport services mutually acceptable for both the customer and the provider, to conclude transport service contracts based on adequate assessment of passenger turnover and income, as well as the ability to establish the cost of fares. All of these factors go towards satisfying the solvent demand of the population for suburban passenger transportation [10-12].

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