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Economic and Mathematical Model for Forecasting Passenger Traffic on a Long Term Basis Case of Study Russia

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Abstract: In this study weinvestigate approaches to the prediction of passenger traffic on annual basis with a time horizon of up to 5 years. The data for Russian Federation was used. The factors that may be used to construct a regression model were investigated. The ability to predict passenger traffic on the basis official statistics (forecast GRP population, per capita income) is shown. The proposed models allow to solve the problem of forecasting the passenger traffic volumes done by public transport at the different long-term levels. Thus, the start of its usage at least at the annual long-term perspective is possible from the present moment. The information collection about region's passenger trafficmay be the basis of such decomposition. Such information also allows to define the well-established proportions of distribution of the total passenger traffic volumes in the region on the separate routes within the dedicated transport districts and between districts. These proportions can be used to distribute the expected passenger traffic in the directions of interest.

Key words: Long-term forecasting, passenger traffic, economic and mathematical modelling, official statistics, well-established, models

INTRODUCTION

Actuality of the problem: Programs of social and economic development and in particular "The Strategy of the socio-economic development of Russian Federation for the period up to 2020" (hereinafter, the strategy) envisage further development of the regional economy which is impossible without transport system modernization.

At the same time, it is noted in the strategy that the insufficient rate of transport infrastructure development is the weak point of Russian Federation and its regions. For example: "... according to indexes of transport infrastructure and effectiveness of its usage the Sverdlovsk Region lags significantly behind other subjects of the Russian Federation and takes 30-50 places. And the rates of regional economic development are ahead the transport infrastructure development rates. Thus, the state of transport infrastructure becomes a brake for the industrial development of the Sverdlovsk Region". (Cited according to the text of the document "The strategy of the social and economic development of the Sverdlovsk Region for the period up to 2020").

It is necessary to take into consideration the fact that problems with passenger transportation and cargo shipping may become a source of social tension and impede or make impossible solution oftasks stipulated by thesocio-economic development. Ipso facto the task of mutual balancing of goals in the sphere of economic, social and cultural development, building-up human capital and objectives in the field of transport infrastructure development becomes the urgent problem (Vikharev, 2013a-d). Passenger traffic forecasting, defining a demand for transport services should provide necessary initial information for determination aims and goals of transport infrastructure development (Brusyanin *et al*., 2016; Vikharev *et al*., 2017a, b; Vikharev, 2014a, b). Separately safety reasons of public transportation must take into account a passenger traffic forecast (Brusyanin and Vikharev, 2014a, b).

All mentioned above determines the necessity to develop approaches for forecasting passenger traffic in order to solve both: the transport and the socio-economic problems of the regions.

The most successful model predicting passenger traffic in our opinion will be a model oriented towards the macro-economic indicators such as GDP, population size, the volume of non-current assets of the enterprises (the latter is to some degree characteristic of the level of economic development). The effectiveness of this model is caused by thefollowing reasons.

Since, the classical works of Leontief (1986) it is known that interdependencies between different branches of a national economy are sustained. The consequence can be a stable relationship between the passenger'straffic on public transport and for example, the planned GDP.

There are reliable methods of forecasting of macroeconomic parameters which are also under the scrutiny of state structures. In this connection,

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we can expect that forecasts of passenger traffic based on macro-economic datawill also be reliable.

FORECASTING PROBLEM STATEMENT

Let's formulate the forecasting problem in the following way: Forecasting should be carried out onthe long-term basis-forthe next few years with the forecast time unit-one year.

Within forecasting the macroeconomic factors characterizing long-term development trends should be taken into account, the large economic and social projects (creation of new industries, infrastructure objects and etc.) have an impact onthe transportation via. macroeconomic factors changing.

Information required for forecasting should be accumulated and used for regular (annual) corrections of the planned forecasting method.

TRENDS IN THE SPHERE OF PASSENGER TRAFFIC EVOLUTION

Analysis of available statistical data has revealed the following problem: both at the level of separate regions and at the level of Russian Federation in general there is no information required to check all statistical hypothesis arising within creation ofstatistical modelthat links passenger traffic at the main means of public transport and relevant factors in the field of socio-economic regional development. In particular, there is no data allowing to track seasonal and cyclical fluctuations in passenger traffic, there are no public opinion polls allowing to evaluate public preferences concerning different kinds of transport.

At the same time the existing information on the Russian Federation (11), the experience of solving similar problems, described in the literature (Hanke, 2001), allow to reveal a number of trends and formulate reasonable statistical hypotheses that serve thebasis for the development of the forecasting method.

Main trends in the change of passenger traffic volumes and statistical hypothesis: Figure 1 shows data for passenger traffic volumes doneby railway transport and buses peryears. Here, the trends to the volumes decrease for both kinds of public transport are seen clearly. This trend is evidently described by a linear trend (the determination coefficient R^2 has significantly high values close to 1).

In order to identify factors influencing the volume of passenger traffic done by bus and railway transport we should consider all potential factors separately. All the data were taken from official database of federal state statistics service (Brusyanin *et al*., 2016).

Change of the passenger traffic volumes in dependence of population is shown at the Fig. 2 and 3. As it is seen from the Fig. 2 and 3, the passenger traffic volume can be approximately described by linear function of population, however, incase of bus traffic the determination coefficient of such linear model is significantly higher.

Gross Domestic (Regional) Product (GDP/GRP) is a main macroeconomic index, set by strategic conceptions and plans of socio-economic development at both levels: the federal and the regional. Due to this fact, the dependence of passenger traffic volumes done by public transport from this index present certain interest. Proceeding from the planned GDP (GRP) values, it allows to carry out the evaluation of expected passenger traffic volume. The graphs of corresponding dependences for railway transport and bus traffics are presented at the

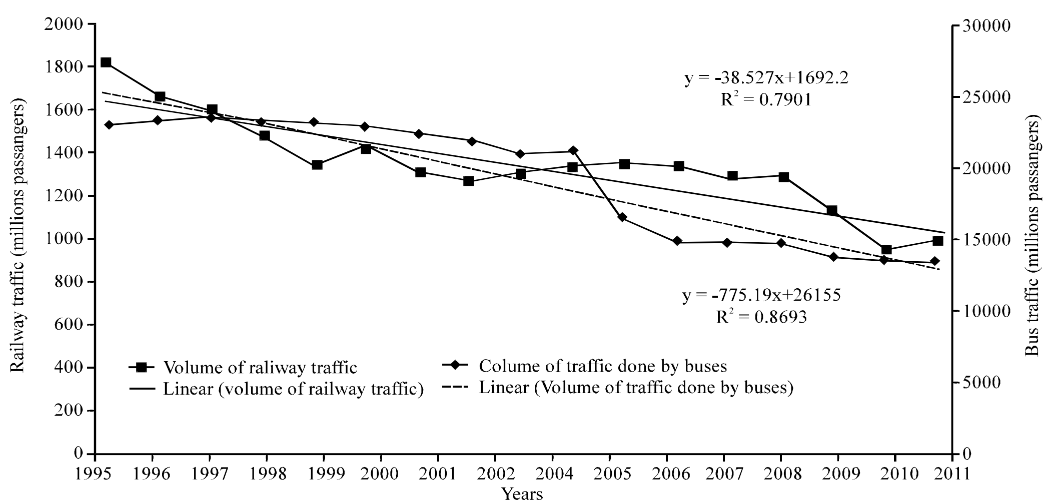

Fig. 1: Trends in the change of the volume of passenger trafficdone by publicbuses and railway transport (Russia)

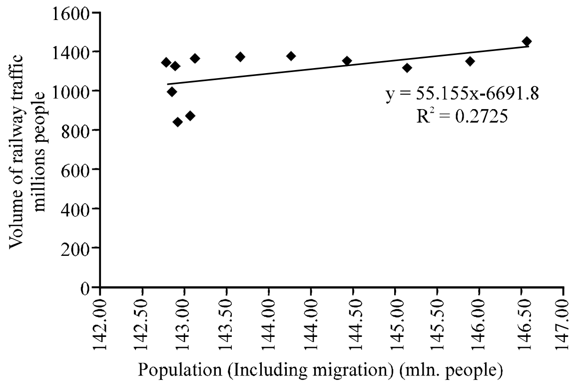

Fig. 2: Dependence of the passenger traffic volumes done by railway transport from the permanent population (annual average), Russian Federation

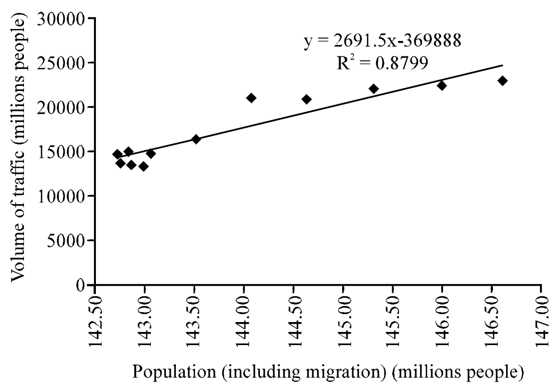

Fig. 3: Dependence of the passenger traffic volumes done by publicbuses from the permanent population (annual average), Russian Federation

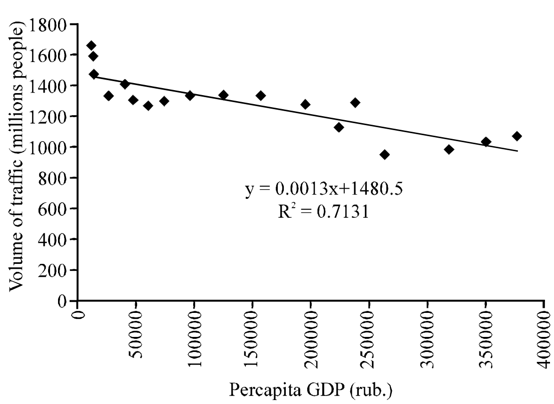

Fig. 4: Dependence of volume of passenger traffic done by railway transport from GDP per capita, RF. GDP is presented in current prices

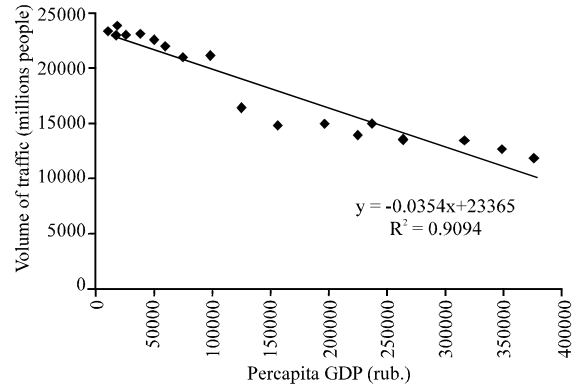

Fig. 5: Dependence of volume of passenger trafficdone by publicbuses from GDP per capita, RF. GDP is presented in current prices

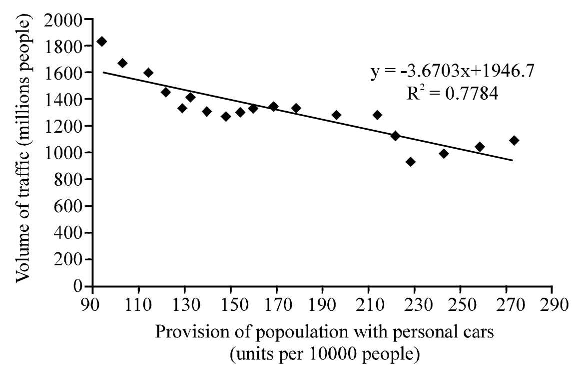

Fig. 6: Dependence of volume of passenger traffic done by railway transport from the provision of population with personal cars (RF)

Fig. 4 and 5. It is evident that in this case the linear model has higher determination coefficient for bus traffic, though in the case of railway transport the determination coefficient of linear approximation is high enough.

We should pay attention to the fact that increasing GDP per capita leads to decrease of traffic's volume done by public transport and for bus traffic this effect is much higher than for railway traffic. Probably, this is a reflection of increasing role of alternative transportation variants with increasing GDP per capita, (use of personal transport, for instances) to certain extent reflecting the welfare level. More details on this issue are shown in Fig. 6 and 7.

Dependence of traffic by public transport (done by buses and railway transport) from the index "The provision of thepopulation with the personal cars" is shown at the Fig. 6 and 7.

As it is seen from the Fig. 6 and 7, the linear model has a high determination coefficient in each case and what is more, in the case of bus traffic it is higher than in the case of railway traffic.

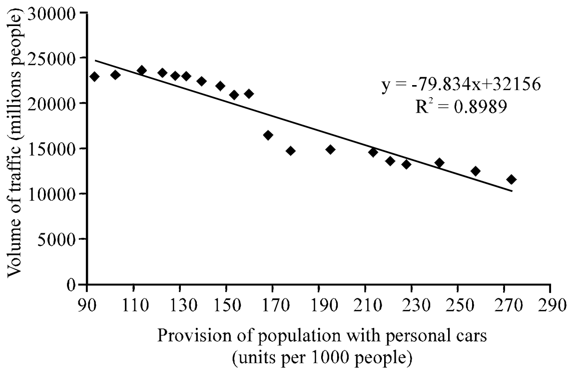

Fig. 7: Dependence of volume of passenger traffic doneby public buses from the provision of population with personalcars (RF)

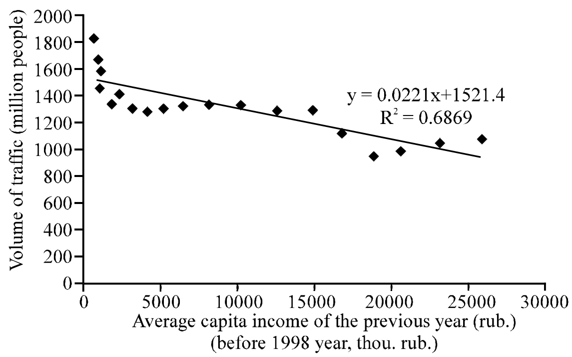

Fig. 8: Dependence of the railway traffic volume from the average per capita income of the previous year, RF

Per capita income, defining an opportunity of potential passenger to have funds forusage oftransport services should also influence the passenger traffic volume. Also, it is reasonable to suggest that already achieved income level should influence the decision of potential passengerto use transport services (or alternative possibilities of transportation). Therefore, Fig. 8 and 9 show dependence of traffic volumes from the average per capita income of the previous year.

As it is observed from the Fig. 7 and 8, the analysed dependences can be represented by linear model with a relatively high determination coefficient and for bus transportation the determination coefficient is higher.

The volume of fixed assets that belong to enterprises located in the research area is one more parameter that can influencethe passenger traffic volume. On the one hand, the higher the amount of fixed assets is, the more likely the labour inflow on the analysed territory is, that can cause additional demand for transport. On the other hand, the rise of fixed assets is a sign of economic growth, increasing per capita income and thus reducing the demand for transportation by public transport as it was mentioned above.

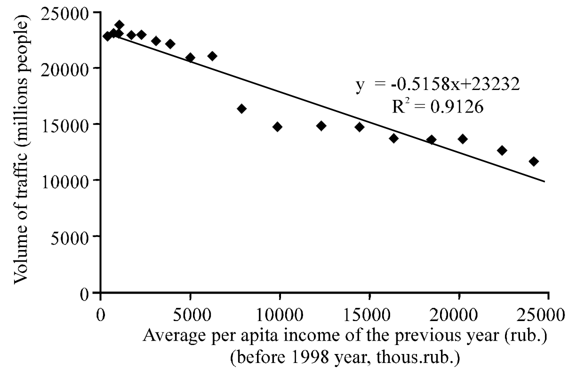

Fig. 9: Dependence of the public bus traffic volume from the average per capita income of the previous year (RF)

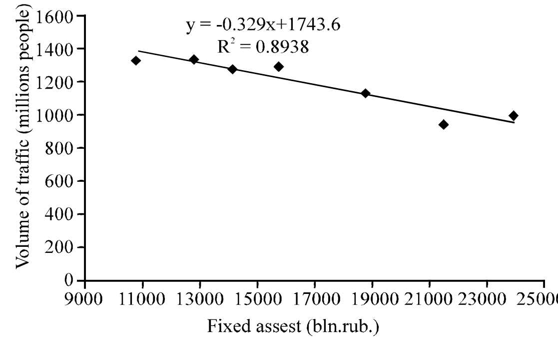

Fig. 10: The volume of railway transportation in dependence on fixed assets amount of RF'senterprises

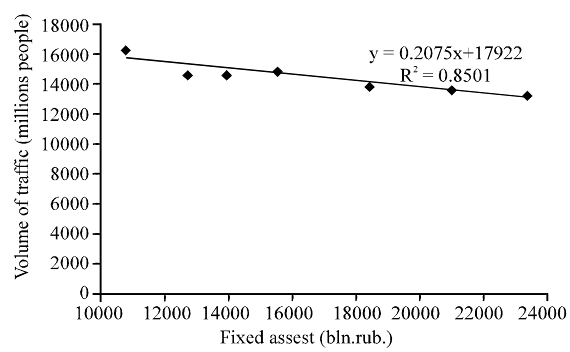

Fig. 11: The volume of public bus transportation in dependence on the fixed assets amount of RF's enterprises

The results of Fig. 10 and 11 shows that the second trend prevails and the linear model has the high determination coefficient.

Variables selection and model description: Not all variables described above may be independent. To

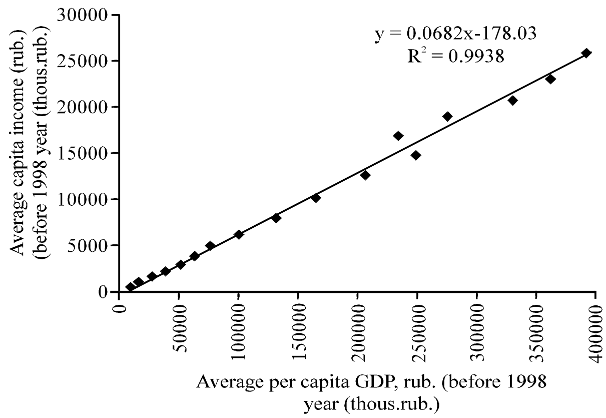

Fig. 12: Average per capita incomes in dependence of average per capita GDP (RF)

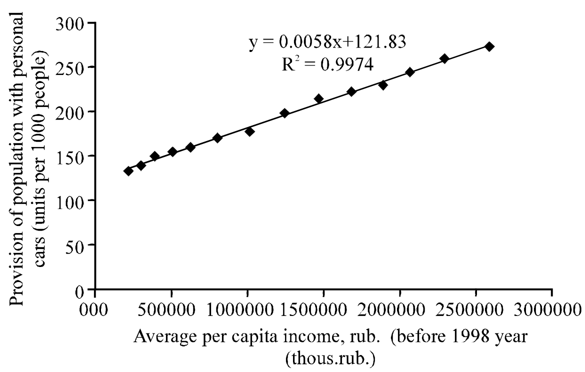

Fig. 13: Provision of population by personal cars in dependence of the average per capita incomes (RF)

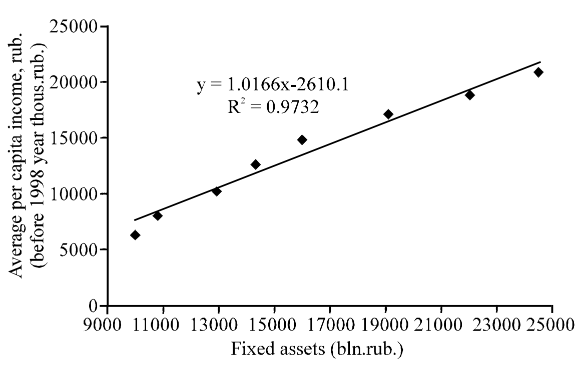

Fig. 14: Average per capita incomes in dependence ofthe fixed assets amount of RF's enterprises

exclude the multicollinearity effect (Hanke *et al*., 2001) the analysis of interdependence of various factors was held. The results presented at the Fig. 12-14 show that such factors like "Average per capita incomes", "Provision of population by personal cars", "Gross Domestic Product per capita", "Fixed assets" are almost linear dependent. According to this, the factor "Average per capita income" will be saved because its data collection is the simplest and the most operative in comparison with all other listed parameters.

Thus, to predict passenger traffic volume by railway transport and public buses the following multivariate linear regression model will be used:

$$Y^{i}(t+1) = \beta^{i}_{0} + \beta^{i}_{1} \cdot X^{i}_{1}(t+1) + \beta^{i}_{2} \cdot X^{i}_{2}(t+1) + \beta^{i}_{3} \cdot X^{i}_{3}(t) \quad (1)$$

Here, for railway transport i = 1 and i = 0 for bus passenger transportation (in million people):

- X_1 the permanent population (in millions of people, average per year)
- X_2 GDP (in bln. of rub. and fixed prices of 2008)
- X_3 average per capita income (as it was noted above, here is used a value of index in the year before predicted one) in rub.
- T an year for which the value is considered
- Y(t+1); the value of the forecasting volume for the year (t+1), in millions of people

Using data (The data source is Federal State Statistics Service's web-site ww.gks.ru) in respect to the variables X_1,-X_3 for the 1996-2011 years (exactly for this period all data required to analysis are available) we obtain that passenger transportation by railway transport is truly described by the following multivariate regression model:

$$Y(t) = -0.0511 \cdot X_{3}(t-1) + 0.0589 \cdot X_{2}(t) + 143.308 \cdot X_{1}(t) - 20933.793 \quad (2)$$

Comparison of the model with the actual data is shown at the Fig. 15. The determination coefficient of the model is R^2 = 0.86. The Durbin-Watson test verification indicates the absence of the serial correlation with 99% probability. The verification based on the t-statistics indicates the significance of each of the factors X_1-X_3 included in the model with at least 95% significance level.

A similar calculation for passenger traffic by bus after exclusion of the factors proved to be insignificant leads to the following model according to testing on the t-statistics:

$$Y(t) = -0.192 \cdot X_3(t-1) - 0.395 \cdot X_2(t) + 32505.333, \text{ millions people} \quad (3)$$

The determination coefficient of the model is R^2 = 0.94. The Durbin-Watson test verification indicates

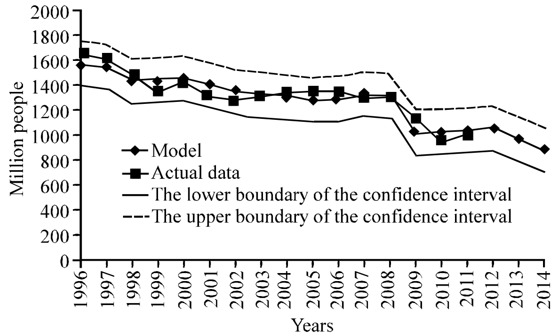

Fig. 15: Comparison of the Model (2) data and the actual data of the passenger transportation done by railway transport in the RF. The lower and the upper boundaries of the confidence interval of the Model (2) with a significance level of 95% are also presented at the figure

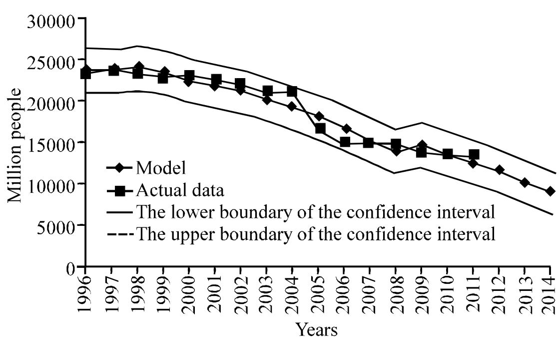

Fig. 16: Comparison of the Model (3) data and the actual data on the passenger transportation by buses in the RF. The lower and the upper boundaries of the confidence interval of the Model (3) with a significance level of 95% are also presented at the figure

the absence of the serial correlation with 99% probability. Comparison of the model with the actual data is shown at the Fig. 16.

Certainly in the previous chapters the datafor the Russian Federation were used firstly to illustrate the proposed model and to define factors the model can be based on and secondly because of the absence of necessary information for the regions (in particular, Sverdlovsk Region at the present moment. At the same time the advantage of the proposed factors isthat they permit decomposition up to any regional level (Federation subject, city district, municipality).

Forecasting of passenger traffic volume at the level of the Russian Federation orits region in generalis based on the Models (2 and 3) proposed in the research. In this case the values of the parameters X_1-X_3 are used for

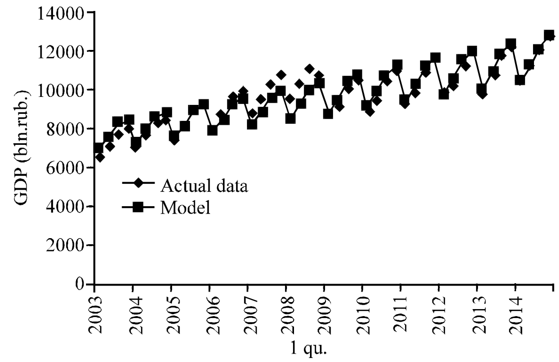

Fig. 17: Comparison of the actual data for the GDP of RF (in fixed prices of 2008) and the proposed model with trend and seasonable components marking

the RF or region (say, Sverdlovsk Region), respectively. It should be noted that the values of the Models (2, 3) parameters have to be detrminated after transportation data collection.

Figure 15 and 16 show the values proposed by the model for 2012 year (the actual data for this year at the moment of research was absent) and the forecasting values for 2013 and 2014 years. For prediction, the demographic forecasts of the population changes for the period up to 2030, presented at [11] were used. Average per capita incomes (at the moment of research the data up to 2011 incl. were available) were defined by means of extrapolation of the available data for the 1996-2011 years using polinomials of at most the second degree. To forecast the GDP (in fixed prices of 2008 year) the available quarterly datafrom the first quarter of 2003 to the first quarter of of 2013 and the model emphasizing clearly visible trend and seasonable components (A more detailed discussion of the GDP forecasting model and discussion of the achieved results are beyond the scope of the goals of this research and will be published later) were used. Comparison of the data of this model that is used for the GDP forecasting and the actual data is shown at the Fig. 17 where the data for the predicted GDP used for forecasting passenger traffic at the Fig. 15 and 16 are shown too.

CONCLUSION

The proposed models allowto solve the problem of forecasting the passenger traffic volumes done by public transport at the different long-term levels. Thus, the start of its usageat least at the annual long-term perspective is possible from the present moment, basing on the Models (2, 3) and carrying out data decomposition for the necessary (say, Sverdlovsk) region. The information collection about region's passenger traffic may be the basis of such decomposition. Such information also allows to define the well-established proportions of distribution of the total passenger traffic volumes in the region on the separate routes within the dedicated transport districts and between districts. These proportions can be used to distribute the expected passenger traffic inthe directions of interest.

However, the problem related toprovision of a valid method of forecasting at the different time horizons from the long-term to the operative one is still actual. The method of decomposing the data for forecasting the passenger traffic volume at the level of separate routes requires a detailed description. This is a topic for further researches.

Note that the Model (2 and 3) can also be used as by Worsley (2012) to estimate the elasticity of demand for passenger traffic by public transport (for example, the elasticity in respect per capita income). Such estimates may be used to evaluate the optimal passenger traffic, the required transport infrastructure, etc. which may also be studied in the future. Moreover, in the next, the accuracy and detail of the forecasting of passenger traffic can be enhanced by applying the graph theory as it done, for example in Siziy and Vikharev (2018).

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