Study of the Dynamics of Railway Passenger Traffic, Identification of Trends

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Abstract. Changes in passenger traffic and the choice of vehicle affect the country's environment, economic and social situation, as well as the operating costs of the transport infrastructure. Rail transport is more environmentally friendly (the CO_2 footprint of a train passenger per kilometre is about 14 g CO_2), more economical than road transport (the CO_2 footprint of a car passenger varies between 42 and 158 g/km, depending on the performance of the car and the number of passengers), but it is still inferior to it in terms of popularity (comparing them, in Lithuania only 10.41% cent (1st quarter of 2022) of passengers chose the railway, comparing the data of passenger traffic in 2019 with 2013, an increase of only about 13% is recorded). The aim of the article is to identify the dynamics of railway passenger traffic, the determining factors and make future forecasts. After carrying out a systematic and comparative analysis of the concepts published in the scientific literature, the factors determining the dynamics of railway passenger traffic have been identified. Forecasts for the year 2022 were made as a result of the empirical study. Secondary data analysis, statistical processing, correlation regression analysis, forecasting methods were used to achieve the aim.

Keywords: Passenger traffic · Railway · Forecast · Correlation regression analysis

1 Railway Passenger Traffic and Their Determining Factors

The significance of passenger transport for the economic and social life of the country is recognized by many scientists [1–4]. According to Tomasz Nowakowski, the main function of transportation is to realize the movement of people and goods from one place to another in a safe and efficient way with minimum negative impact on the environment [1]. G. Kos et al. in the study reviewed public passenger transport have been defined, all County transport lines of schoolchildren and other passengers have been analysed as well as actual deficiencies in the city, County and school transport needs. Road transport infrastructure, carriers, and transportation vehicles have been analysed. These have a large impact on the economy and social life in cities. A. Žvirblis et al. in the study described the impact of technological factors on the system of passenger transportation, the emphasis is placed on competitiveness as a criterion of evaluation the efficiency of its performance and provide a number of actions which improve passenger carriage

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by railway is also described. The goal of the European Union's sustainable transport policy is to create transport systems that meet economic, social, and environmental needs [4]. It should be emphasized that globalization processes lead to the growth of the transport services market. Thus, to predict the future prospects of passenger flows by rail, it is necessary not only to observe changes in the number of transported passengers, but also to find the factors influencing the change. Railway passenger traffic is one of the most compliant with environmental requirements modes of transportation, which is characterised not only by low emissions, but also by high transport capacity. These characteristics of railway transport are one of the main reasons why the EU White Paper [5] emphasises its importance in medium-distance transport for an efficient multimodal network of transport between cities [6]. A large variety of railway rolling stock – trains, interconnected wagons [7] – helps to develop this, which can be divided into: intercity, suburban, urban, steep-hill trains [8]. Such a supply of passenger trains can adapt well to the needs of the user and provide the required service. Based on the detailed analysis of the technical characteristics of railway vehicles presented by C. N. Pyrgidis, it is possible to single out the most important aspects of each type. Intercity trains can offer one of the most modern ways to travel by rail – high-speed trains, thanks to which, the travel time is shortened and the level of comfort is increased accordingly. Suburban and urban trains offer traditional services – transportation of passengers on short, in-demand routes at normal speed; however, urban railways are also distinguished by their integrated infrastructure: tram tracks are laid on the streets, and the subway becomes part of the underground urban transport system. The unique steep-hill railway requires an appropriate geographical condition: mountainous areas. This means that it is not used in all countries; however, in Slovakia. it is a vehicle in demand both in the tourism and transportation sectors. In countries with plains as their main land surface, funiculars are mostly operated for tourism purposes – to go up to the visited object.

All these advantages of vehicles contribute to the main objectives of rail passenger transport, which are related to [9]:

- Increasing mobility;
- Shortening the travel time;
- Reduction of transportation costs;
- Increasing the number of passengers transported.

Scientists A. Jaržemskis and V. Jaržemskis also emphasise the importance of passenger transportation planning: correctly planned stopping places, planned routes, structured presentation of relevant information for passengers, and drawing up a schedule. After completing all these steps, traveling by rail transport becomes more attractive and efficient; therefore, users choose it more often, and the number of passengers transported by rail transport increases accordingly. In the scientific and legal literature, railway passenger traffic is described as a business, a social function and a service, the common main purpose of which is the transportation of passengers, ensuring their basic needs. This reveals a direct link between railway infrastructure and economic and social sectors. According to scientists V. Lingaitis and G. Sinkevičius, transport activity and the development of its infrastructure depend precisely on the development of these sectors [10]. Thus, economic and social factors have the greatest impact on rail transport, respectively.

According to the scientist S. Stoilova, it can be stated that the number of passengers per year describes the most accurate way of transporting passengers by railways; therefore, the influence of factors must be examined specifically for this indicator. The factors influencing passenger flows by rail are named differently by different researchers. J. Danis at all [11] separates the average wage. Other researchers [12] distinguish: GDP, the number of people who emigrated, the unemployment rate, the number of people and tourism. Scientist Stoilova supplemented the mentioned list with several more factors, i.e. length of railway and number of accidents [9]. The scientists Lingaitis and Sinkevičius [10] added the following factors to the list of influencing factors: the number of people of retirement age, the number of residents living in the countryside, the number of cars, and consumption costs.

GDP is usually mentioned in scientific articles and singled out as the most important factor that shows the level of economic development of the country. According to scientists V. Lingaitis and G. Sinkevičius, transport is one of the most important – the second or third – sectors that make up the GDP structure [10]. This can be justified based on statistics provided by the European Union, that on average 13.2% of each household's budget is spent on transportation services and goods related to this sector [13]. The direct relationship between the transport sector, more specifically, the number of passengers transported by railways, and the level of economic development of the country, is shown in the diagram below (Fig. 1).

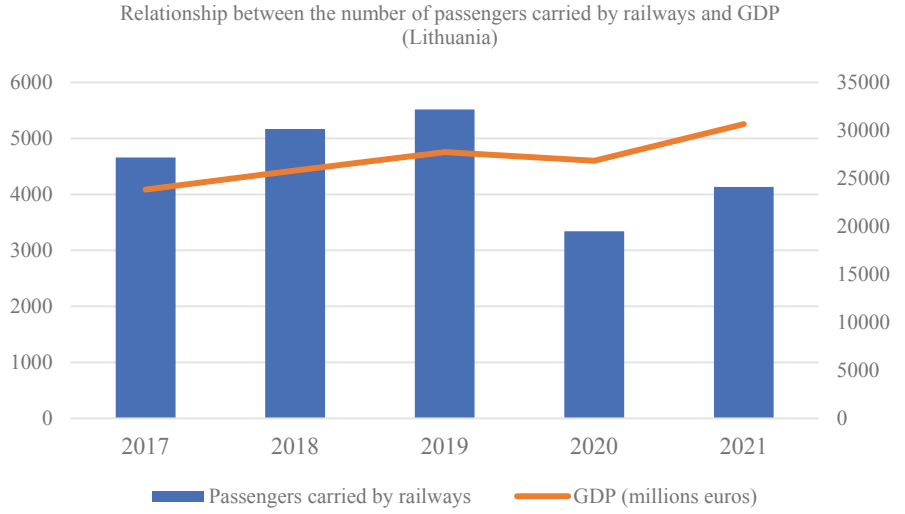

Fig. 1. Relationship between the number of passengers carried by railways and GDP.

Another factor often mentioned in scientific sources influencing railway passenger traffic is the number of accidents [9]. This factor is significant because it describes the safety and security of passenger rail transport. Although the infrastructure of passenger railway transport is constantly being improved, and the number of accidents is decreasing, one of their main causes is still suicide, the human factor, lack of caution on the

part of pedestrians and drivers, and train derailment [14]. This can be substantiated by the statistics of 2019, which show that 1,516 railway transport accidents occurred in the European Union, and the majority of them, 61%, were caused by an unidentified person on the tracks [15]. The length of railways is also a determining factor [9], which shows not only the level of infrastructure development, but also flexibility and adaptation to passenger needs: the better developed the railway network, the more attractive it becomes to existing and potential passengers. Scientists [12] distinguished tourism as an influencing factor. In the study, this factor is characterised by the hotel occupancy rate (the more intense the inbound tourism with overnight stays, the stronger it affects passenger transportation by rail). And, of course, changes in the population. Although we are not currently experiencing a demographic explosion, the population is gradually growing and requires a better public transport system, in this case railways, which is a more efficient means of public transportation and provides competitive services. Researchers [10, 12] singled out this factor because its changes directly react with the number of passengers transported by railways: the more the population in the state, the more traveling and potential passengers.

2 Methodology

In order to determine the influence of independent factors: GDP, average monthly salary, the number of cars per 1,000 inhabitants, the level of unemployment, and the number of inhabitants, on the dependent factor, the number of passengers transported by railways, a study will be conducted, which will consist of two steps. In the first step, a correlational regression analysis will be performed whose purpose is to determine causal relationships between factors. To achieve this goal, it is necessary to calculate:

1. Correlation coefficient, which shows whether there is a relationship between factors [16].

$$r = \frac{\left(\frac{1}{n-1}\right)\sum(x_i - \overline{x})(y_i - \overline{y})}{S_x S_y}, \tag{1}$$

   where n – amount of measured values; x_i – indicator values; y_i – indicator values; $\overline{x}$ – the arithmetic mean of the values of the indicators; $\overline{y}$ – the arithmetic mean of the values of the indicators; S_x – the variance of the value of the indicators; S_y - the variance of the value of the indicators.
2. Create a pairwise regression equation, the purpose of which is to determine the analytical expression of the dependence between the random variables X and Y [16].

$$y = a_0 + a_1 x, \tag{2}$$

   where a_0 and a_1 – linear coefficients.
3. Create the multivariate correlational regression equation, the purpose of which is to determine the relationship between the dependent factor Y and several independent factors $X_1, X_2, \ldots, X_n$ [16].

$$\hat{y} = a_0 + a_1 x_1 + \ldots + a_n x_n, \tag{3}$$

where a_0,a_1 …, a_n – linear coefficients.

In the second step, a forecast of passenger flows by railway will be prepared using several methods [16]:

1. Forecasting using the moving average method:

$$Moving\ average = \frac{the\ sum\ of\ \ the\ last\ n\ values}{n}, \tag{4}$$

where n – the duration of the selected period.

2. Forecasting by exponential smoothing method:

$$F_{t+1} = \alpha Y_t + (1 - \alpha)F_t, \tag{5}$$

where F_{t+1} – time series forecast for period t + 1; Y_t – relevant serial value in the period t; F_t – time series value in period t; α – smoothing constant ($0 < \alpha < 1$).

Forecast errors are calculated and the most accurate forecast of railway passenger traffic is determined. The research was carried out using two programs: MS Excel and SPSS.

3 Research Results

After analysing the scientific literature, it was found that the level of unemployment, GDP, the number of cars per 1,000 inhabitants, the number of inhabitants and the average monthly salary influence the transportation of passengers by railways (Y of this research). These factors will be denoted as X_1, X_2, X_3, X_4 and X_5 respectively below. Their significance, influence and connection with passenger traffic railways in Lithuania in the period 2015–2021.

In the first step, using the methods of correlational, paired regression and multivariate correlational regression analysis, we determine the existing relationships between passenger traffic on railways and the previously mentioned factors. The correlation coefficients obtained during it are presented in the table below (see Table 1).

Table 1. Correlation coefficients.

Correlation coefficients	r_1	r_2	r_3	r_4	r_5
Value of correlation coefficients	0.97	0.95	−0.92	0.84	0.92

Based on the data in Table 1, it can be said that there is a strong dependence between the listed factors (because all the values of the correlation coefficients are greater than 0.5). There is a direct relationship between rail passenger traffic and factors such as unemployment rate, GDP, population, and average monthly wages, while there is a

Table 2. Coefficients of the paired regression line.

Coefficients of the paired regression line	a0	a0	a0	a0	a0
Value of coefficients of the paired regression line	−4670808.40	−91767.60	115729.42	−27478589.71	−6399.62
Coefficients of the paired regression line	a1	a1	a1	a1	a1
Value of coefficients of the paired regression line	871853.67	1.70	−662.33	17357.07	0.01

strong inverse relationship between rail passenger traffic and the number of cars per 1,000 inhabitants. A paired regression analysis is performed to determine causality and possible prediction (see Table 2).

After compiling these equations, it became clear that the only factor that has a significant negative impact on passenger transportation by railways is the number of cars per 1,000 inhabitants. The graphical representation of the line $Y_3 = 115729.42 + (-662.33)*X_3$ in the diagram below demonstrates this well. The negative influence of the number of cars per 1,000 inhabitants is also proven by the inverse linear dependence equation, because when the independent variable increases by 10%, the value of Y decreases by 15.45%.

Multivariate correlational regression analysis is performed in order to establish a linear equation for determining causal relationships and possible prediction (see Table 3).

Table 3. Multivariate Linear model coefficients.

Multivariate linear model coefficients	a5	a4	a3	a2	a1	a0
Value of multivariate linear model coefficients	−0.0064	3512.50	−267.39	0.55	627190.89	−8907639.50

The value of the coefficient of determination is 0.997221348, therefore it can be stated that 99% of the behaviour of the dependent variable is explained by the behaviour of all X. After calculating the a0 and a1 coefficients, I made the expression of the linear model of multivariate correlation regression analysis: $Y_n = -8907639.50 + 627190.89 * X_1 + 0.55 * X_2 + (-267.39) * X_3 + 3512.50 * X_4 + (-0.0064) * X_5$.

However, this equation does not meet all the necessary characteristics confirming its usability in reality[17]:

- $R^2 \geq 0.20$.
- ANOVA $p < 0.05$.
- All t criteria $p < 0.05$.
- VIF ≤ 4.
- Meanings of the KUKO measure ≤ 1.
- The signs of the coefficients match the signs of the correlation coefficients.
- Judging from the histogram and the P-P graph, the residual errors are normal.
- Šapiro–Vilk criterion $p \geq 0.05$.
- Breuš–Pagan criterion $p \geq 0.05$.

Therefore, after performing a deeper analysis in the SPSS program, it was found that the multivariate regression model with independent variables number of cars per 1000 inhabitants and average monthly salary (X_3 and X_4) is suitable and can be used for analysing the influence of factors on railway passenger traffic: $Y = -10591957.26 + (-476.46)^* X_3 + 6738.82^* X_4$.

The second step of the research aims to use different forecasting methods to make a future forecast of passenger flows by train. For the first forecast, 2 years were chosen for the calculation of the last values, and for the second forecast 3 years. To determine which prediction is more accurate, the mean absolute relative errors of both were calculated. Data forecast using the moving average method). The error of the first prediction is equal to 0.126539, and the error of the second is 0.17771, which is larger and less accurate. Therefore, it can be said that the forecast is more accurate when two years were chosen for the calculation of the last values. A moving average chart (see Fig. 2) also illustrates this conclusion.

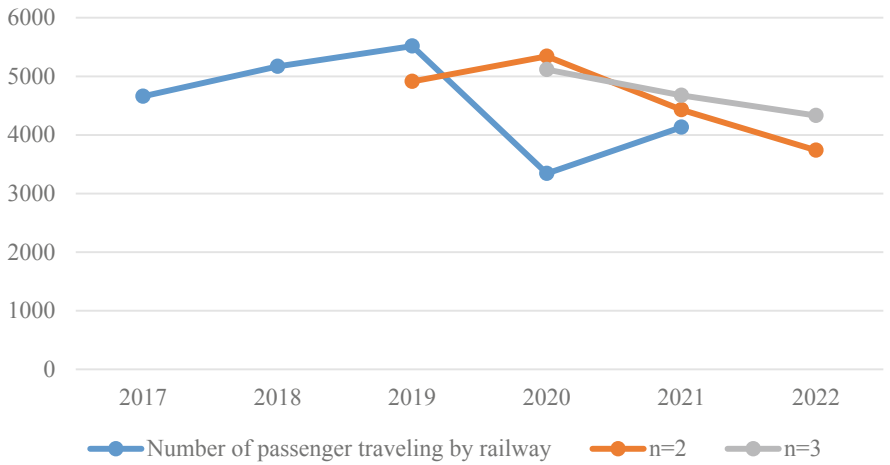

Fig. 2. Results of the Moving Average Method.

We forecast passenger flows by rail using the exponential smoothing method. To make a forecast, the smoothing constant values, 0.2 and 0.4, respectively, were chosen for the first and second forecasts. To determine which prediction is more accurate, mean

absolute relative errors were calculated with values of 0.2073 and 0.1541, respectively. Based on the results obtained, we claim that when calculating the forecast using this method, it is more accurate when alpha is equal to 0.4. This is also illustrated by the exponential smoothing graph (see Fig. 3).

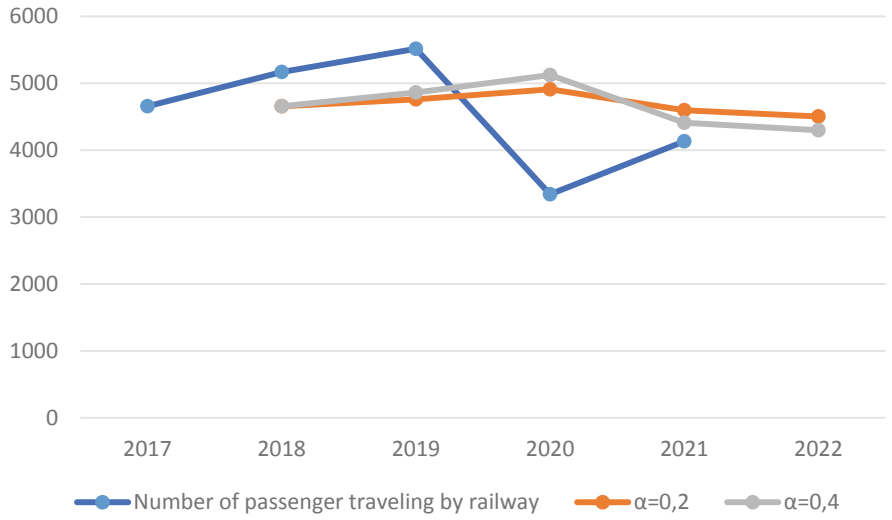

Fig. 3. Results of the Exponential Smoothing Method.

Thus, after forecasting passenger flows using the moving average and exponential smoothing methods, it was observed that passenger flows on the railway in 2022 must be higher than in 2021.

4 Conclusions

According to scientific sources, factors affecting passenger flows in rails have been identified. The most significant factor is GDP, unemployment rate, number of cars per 1,000 inhabitants, population average monthly salary. The results of the empirical study showed that 3 out of 5 factors (unemployment rate, GDP, and average monthly salary) were not appropriate, so the regression model needed to be improved. The inadequacy of the factors was determined based on the necessary criteria specified in the scientific sources (ANOVA $p < 0.05$; all t criteria $p < 0.05$; VIF ≤ 4; meanings of the KUKO measure ≤ 1), which resulted in a suitable regression model with the remaining two factors, the number of cars per 1,000 inhabitants, and the number of inhabitants. After these analyzes, I made a prediction of the change in the Y data, which determined the most accurate predictions with the smallest errors. After the forecast was made, it was found that the passenger flows by trains will increase.

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