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THE FORECASTING OF TRANSPORTATION OF PEOPLE BY RAIL IN POLAND FOR 2024 IN TERMS OF ECONOMIC SECURITY IN THE REPUBLIC OF POLAND

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Abstract. The multidimensional comparative analyzes of transportation of people by rail were used in the article. The time series was analyzed and evaluated in order to detect the following phenomena: trend, seasonality and random factor. The initial time series was divided into parts in order to remove data that, due to the impact of a random phenomenon such as the COVID-19 pandemic, lost trends visible in the past (from January 2012 to December 2019). The Winters' exponential smoothing method was used for the forecasting. The obtained forecast for 2024 is 390 380 000 passengers transported by rail in Poland. The mean absolute forecast error is 2,18.

Keywords: security; economic security; COVID-19; Russia-Ukraine war; rail passenger transport

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JEL Classifications: O18

1. Introduction

The following research problem was outlined in the article: what time range of retrospective data on the transport of people by rail in Poland should be selected for examining the regularities governing the entire phenomenon in terms of selecting a method for their forecasting for the future? The purpose of the research was outlined for the research problem. It is an attempt to forecast data on the transport of people by rail in Poland for the period from November 2023 to December 2024. For the research problem and purpose of the study thus adopted, a research hypothesis is presented: it is assumed that the detection of regularities in the analyzed retrospective data from January 2012 to December 2019 and the evaluation of their trends from January 2020 to October 2023 will enable the selection of a method for the forecasting of transport of passengers by rail from November 2023 to December 2024. The research methods used in the article are analysis and comparison.

2. Analysis of the literature on the research subject

In the 21st century, the term "security" has particular importance in the Republic of Poland. This was influenced by both the COVID-19 pandemic and the war between Russia and Ukraine (Kozicki, 2022). Security is treated as the most important value, need and priority goal of the activities of the state in terms of sovereignty, autonomy and national independence (Ficoń, 2020, p. 11). There are many of security facets, e.g. terrorism

(Kriviņš et al., 2021), kidnaping (Agbaje, 2022), insecurity of critical infrastructure (Sikimić, M. 2022) etc. One of the types of security discussed in the study is economic security (Kozicki, 2022, p. 16, Błaszczak et al, 2023a, 2023b). Economic security is considered a nonhomogeneous term related to the standard of living and existence of individuals and social groups in the local, national and international dimensions (Ficoń, 2020, p. 83). It is shaped by continuous growth of one's own economic potential and reduction of the impact of negative external factors (Radchenko, Tulush, Leontovych, 2023; Vennemo, 2023). A typical example of an external factor was the COVID-19 infectious disease pandemic which was particularly noticeable between 2000-2022 (Piwowarski, Kozicki, Jurgilewicz, Malec, 2021; Jurgilewicz, Kozicki, Piwowarski, Grabowska, 2022; Kozicki, Kalwasiński, 2021). In the first phase, it caused the passenger air transport sector to stop, followed by long-term declines in the number of passengers transported. Cascading declines began to appear in other sectors, such as rail passenger transport.

Rail transport is the process of relocating cargo and passengers using locomotives and wagons on railway tracks from a starting point to destination. Locomotives are used to transport railway trains such as wagons, most often connected together. They are divided into: electric, combustion, steam, passenger, cargo, universal and maneuvering ones (Staszkiewicz, 2022). Wagons are means of railway transport designed to relocate goods and people. Until the end of 2019, the transport of passengers by rail in Europe showed a growing trend. It collapsed in 2020 due to a random factor: the COVID-19 pandemic. Pre-pandemic forecasts based on retrospective data for 2020 and 2021 showed a continuing upward trend in this type of transport (Kozicki, Mizura, 2020). Due to the COVID-19 pandemic, in 2020 there was a decline in the number of passengers transported by rail in Poland. 126,7 million fewer people were transported than in 2019 (Railway Transport Office, 2021; Szmajda, 2021). On the other hand, in 2021, there was an increase in the number of passengers transported compared to the previous year to 245,1 million people (Central Statistical Office, 2021; Railway Market, 2022). In 2022, there was a high passenger growth of 342 million people. The increase in rail transport was certainly influenced by the enormous number of Ukrainian migrants in Poland, as well as investments in the modernization of railway lines, the purchase of modern rolling stock and the improvement of ticket sales channels (Ministry of Infrastructure, 2023; Śmietana, 2022). The investments included the construction of approximately 30 new stations and stops in 2023, the modernization of approximately 120 existing ones, and the purchase of approximately 20 electric locomotives. The National Railway Program (KPK) included over 240 railway investment projects until 2023 with a total value of approximately PLN 77 billion (Planradar, 2023). From 2016 to 2023, PLK restored approximately 800 km of railway lines and approximately 7,000 km have been rebuilt (wnp.pl; 2023). This contributed to the fact that in 2023 there was a visible increase in the number of passengers transported by rail compared to the previous year (Bojanowicz, 2023; Local Government News PAP Service, 2023; Polskie Radio 24, 2023, wnp.pl, 2023; Nakolei, 2023; Transinfo, 2023; Money.pl, 2023).

Huge changes in the number of passengers transported by rail in Poland caused by the COVID-19 pandemic and the migration of people from Ukraine became the premise for an attempt to forecast it for 2024. The forecasting was preceded in the article by the analysis and evaluation of the time series of data on the number of people transported by rail in Poland from January 2012 to October 2023. It should be emphasized that the time series is an arbitrary process limited by a non-random variable which is time. In order to observe the regularities in the considered retrospective data, the original time series was shortened to remove the random factor that influenced it, i.e., the COVID-19 pandemic (data from January 2020 to October 2023 were removed for research). Then, in the series obtained after shortening, regularities were searched for as the following phenomena: trend, seasonality and random factor. The second substantive point will be devoted to the analysis and evaluation of the original time series.

3. Analysis and evaluation of the original time series

The research began by the outlining of the data on transport of people by rail in the Republic of Poland from January 2012 to October 2023 in millions of people in Figure 1.

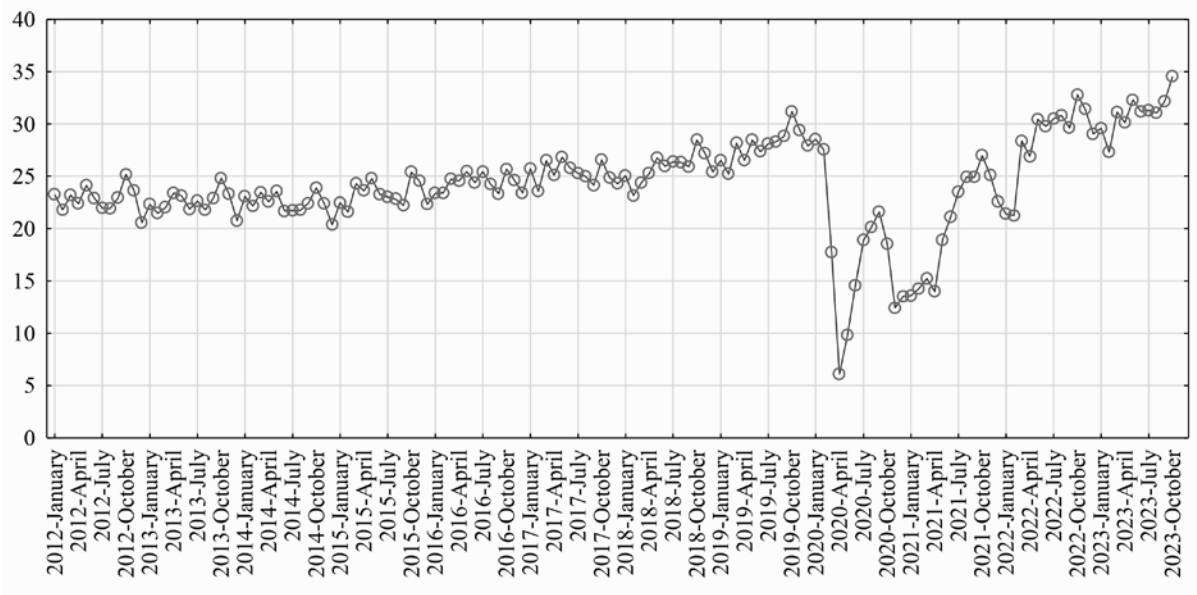

Fig. 1. Line chart of passenger transport by rail in the Republic of Poland from January 2012 to October 2023 in millions of people

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIK I, as of 5.12.2023

In Figure 1, a total of 142 variables as months were examined. It was observed that from January 2012 to October 2023, a total of 3 443 316 000 passengers were transported by rail in Poland. Since 2012 (273 904 000 passengers) to 2019 (335 900 000 passengers) there had been an increasing trend in the number of passengers transported. This trend was disrupted by the impact of the COVID-19 pandemic. In 2020, a decrease in the number of passengers transported was observed to 209 399 000 people. In 2021 (245 060 000 passengers transported) and 2022 (342 226 passengers transported) in the territory of the Republic of Poland increases in rail passenger transport were recorded compared to 2020. The upward trend in the transport of passengers by rail in Poland is also visible in 2023 (number of passengers from January to October 2023: 310 662 000) and exceeds the same period in 2019 (278 620 638 passengers transported), i.e., the time when there was no announcement of COVID-19 pandemic. Therefore, it can be assumed that the impact of the pandemic related to a reduced number of transported passengers ended in 2022.

In order to select properly a method for data forecasting on rail passenger transport in Poland, it was decided to examine the existence of trends in the time series of the data, which was not affected by the COVID-19 pandemic, i.e., from January 2012 to December 2019. The research results are presented in Figure 2.

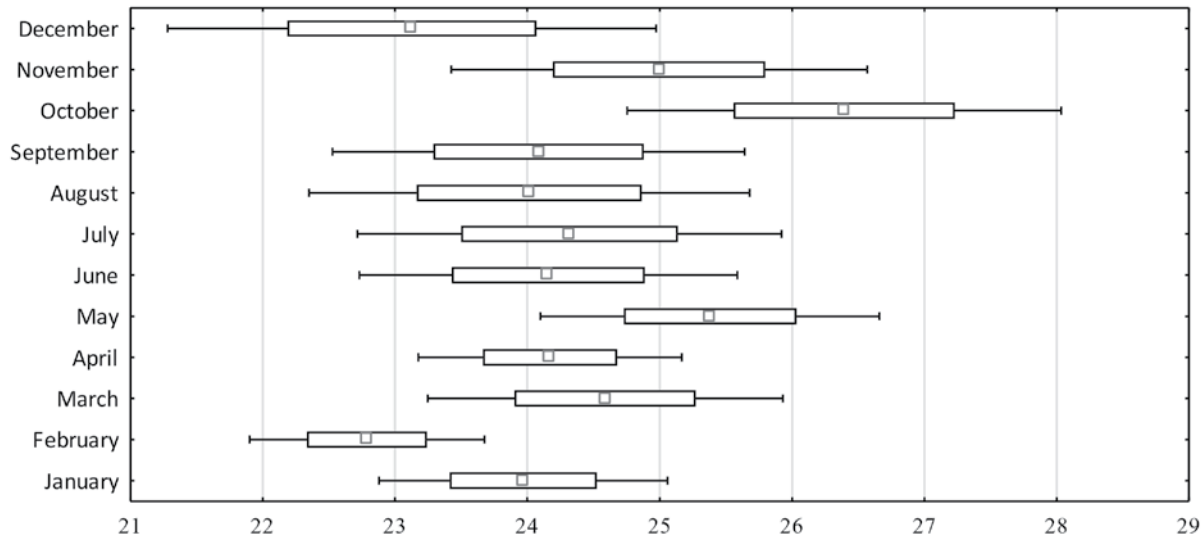

Fig. 2. Categorized box plot of the number of passengers transported by rail from January 2012 to December 2019, with outliers and means of the same periods in months (in millions of people)

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIKI, as of 5.12.2023

The data presented in Figure 2 indicates that February was the same month with the lowest number of passengers. The arithmetic mean of the number of passengers transported by rail in the same month - February from 2012 to 2019 is 22 790 000 people. The month in which the most passengers were transported during the period in question was October, with an arithmetic mean of 26 390 000 people.

The observation of the data allows one to see regularities as seasonality on a monthly basis.

Then, an attempt was made to confirm the existence of two observed trends such as monthly seasonality, a growing trend and a random factor. Autocorrelation and partial autocorrelation were outlined to achieve this goal.

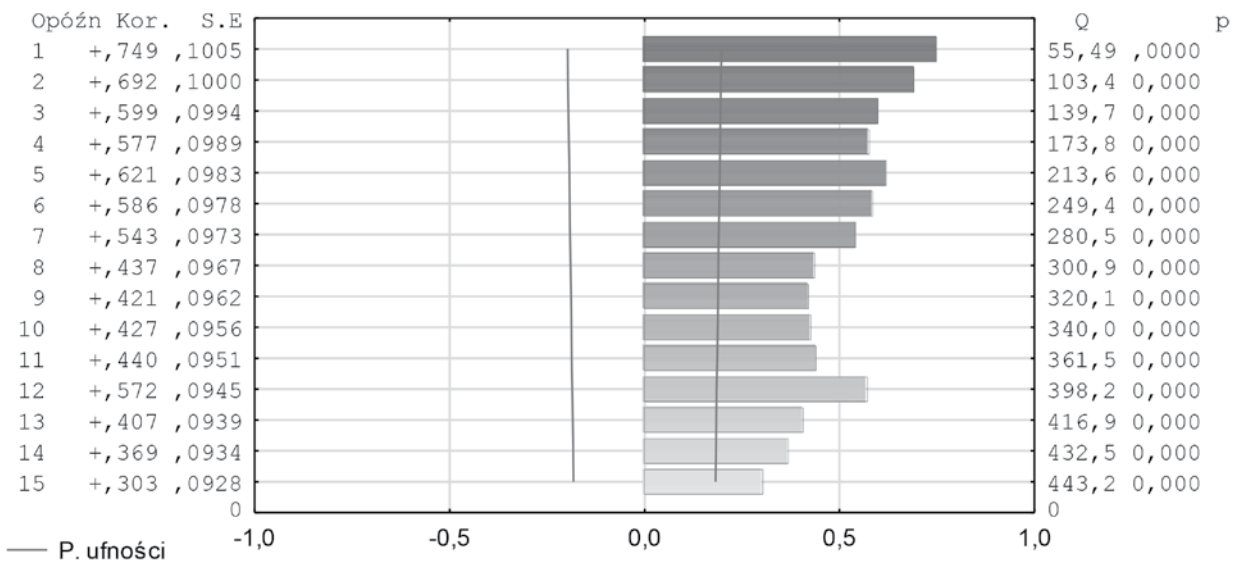

Fig. 3. Autocorrelation of the time series of rail passenger transport in Poland from January 2012 to December 2019

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIKI, as of 5.12.2023

The data presented in Figure 3 shows that the time series in question is non-stationary and there is a trend and a random factor in it. The probability of occurrence is below the significance level. The Q statistic increases rapidly in the first lags, and the standard deviation of the remainder term shows a slight decreasing tendency, as does the autocorrelation coefficient of each of the subsequent lags of the analyzed time series.

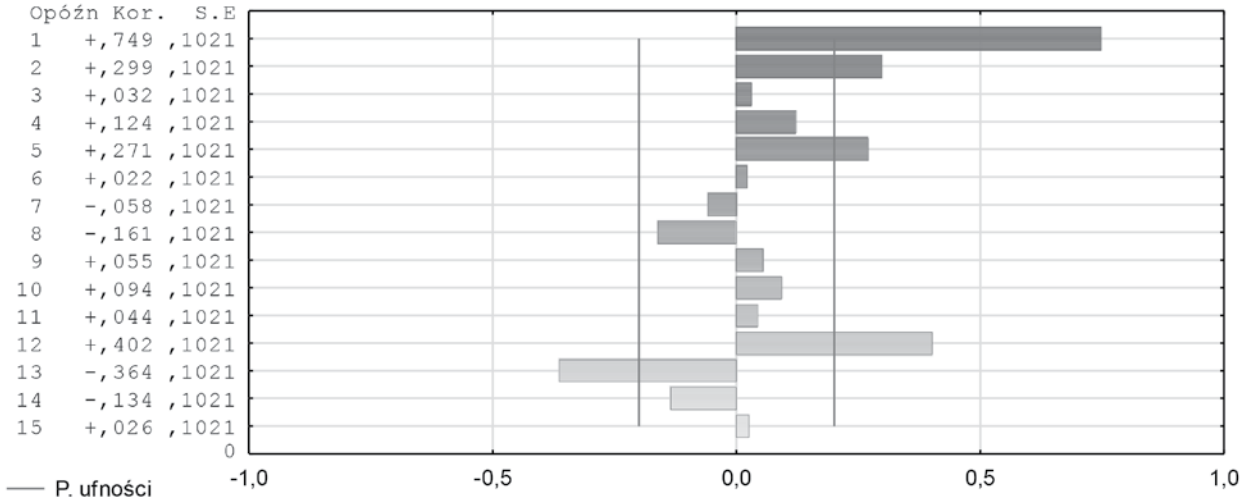

Fig. 4. Partial autocorrelation of the time series of rail passenger transport in Poland from January 2012 to December 2019

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663,Przewozy-pasazerskie.html#PLIKI, as of 5.12.2023

The strong first coefficient of partial autocorrelation confirms the existence of a trend, while the twelfth one confirms the phenomenon of seasonality (see Fig. 4). The distribution of the retrospective data was then examined (Fig. 5).

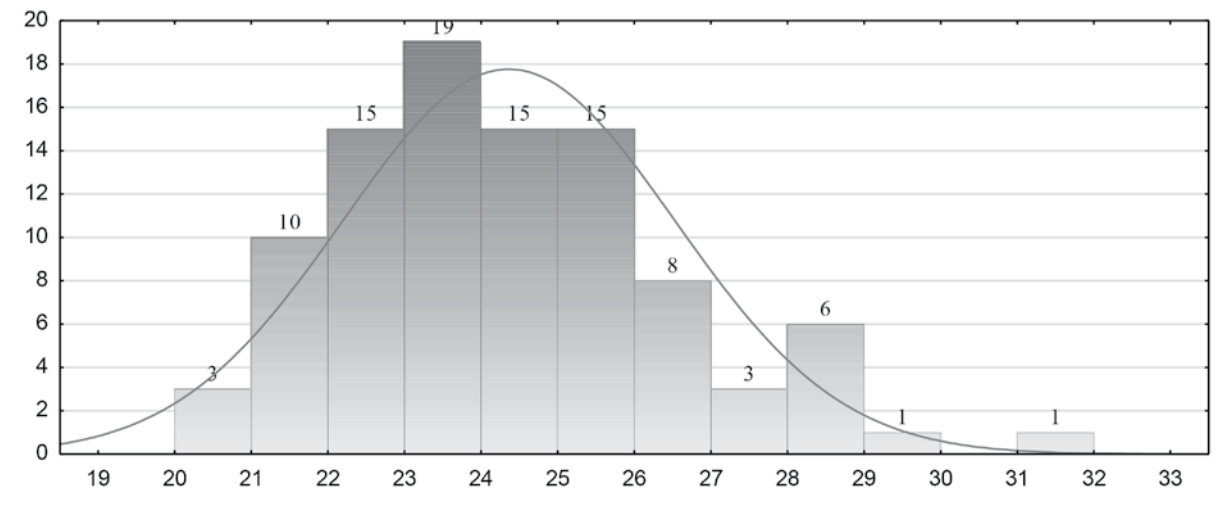

Fig. 5. Histogram with the distribution function of the time series of passenger transport by rail in Poland from January 2012 to December 2019

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIKI, as of 5.12.2023

The arrangement of the histogram in relation to the distribution function indicates a distribution close to normal. The distribution is more slender than normal (kurtosis 0,19) and more right-skewed (skewness 0,66).

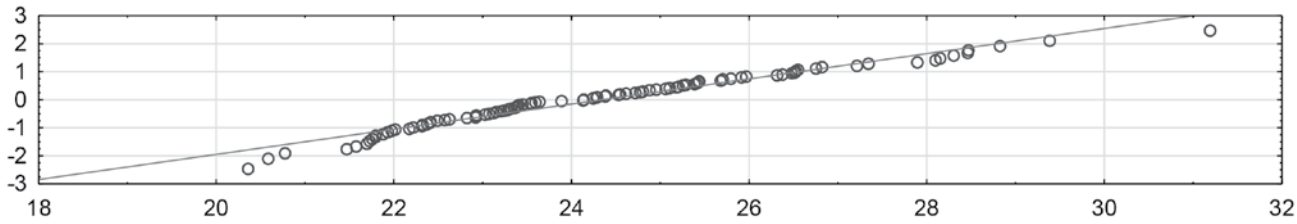

Fig. 6. Quantile-quantile chart with the Shapiro-Wilk test of the time series of passenger transport by rail in Poland from January 2012 to December 2019

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663,Przewozy-pasazerskie.html#PLIKI, as of 5.12.2023

The lack of a normal distribution was confirmed with the use of the Shapiro-Wilk test. The *P value* was 0,0128 and the Shapiro-Wilk test reached 0,97 (see Figure 6). The research on the primary time series indicates that from January 2012 to December 2019, three trends were visible: a growing trend, monthly seasonality and a random factor. From 2020 to 2022, there was a visible impact on the considered time series of the COVID-19 pandemic, which resulted in a reduction in the number of passengers transported by rail. From 2023, a growing trend in the number of passengers can be noticed, including the phenomenon of seasonality monthly, reflecting the identical series of repetitions as in the same visible months listed in Figure 2.

4. Forecasting

This became the premise for modelling. The original time series was shortened by data considered random by the author, i.e., from January 2020 to December 2022. The Winters' additive exponential smoothing model was used for the forecasting for 14 future periods from November 2023 to December 2024. The obtained forecasting was outlined in Figure 7.

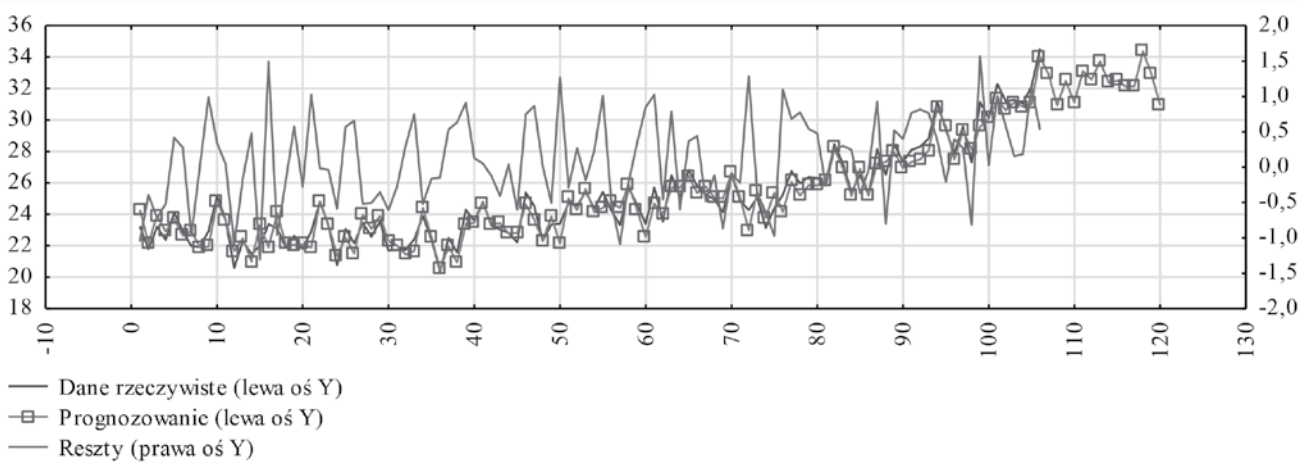

Fig. 7. Categorized line chart of the forecasting for passenger transport by rail from November 2023 to December 2024, along with actual data and forecast remainders

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIKI, as of 5.12.2023

The forecast obtained for the period from November 2023 to December 2024 indicates the maintenance of seasonal trends on a monthly basis and a growing trend. Then, in Table 1, an analysis of forecasting errors was conducted, using the most frequently used indices in the literature.

Tab. 1. Analysis of forecast error indices

Forecasting error index	Value
Mean error	0,11
Mean absolute error	0,54
Root mean square error	0,42
Mean percentage error	0,36
Mean absolute percentage error	2,18

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIKI , as of 5.12.2023

The mean absolute percentage error was 2,18, which means that the obtained match between the predicted and observed values was particularly good. On the other hand, the mean percentage error is 0,36, which indicates that the obtained forecast is good. The mean error reached 0,11, the mean absolute error was 0,54, and the root mean square error was 0,42. This allows one to conclude that the forecasts obtained are good.

For illustrative purposes, the last stage of the research was to outline the obtained forecasts regarding the planned number of passengers from November 2023 to December 2024 on a bar chart (Fig. 8)

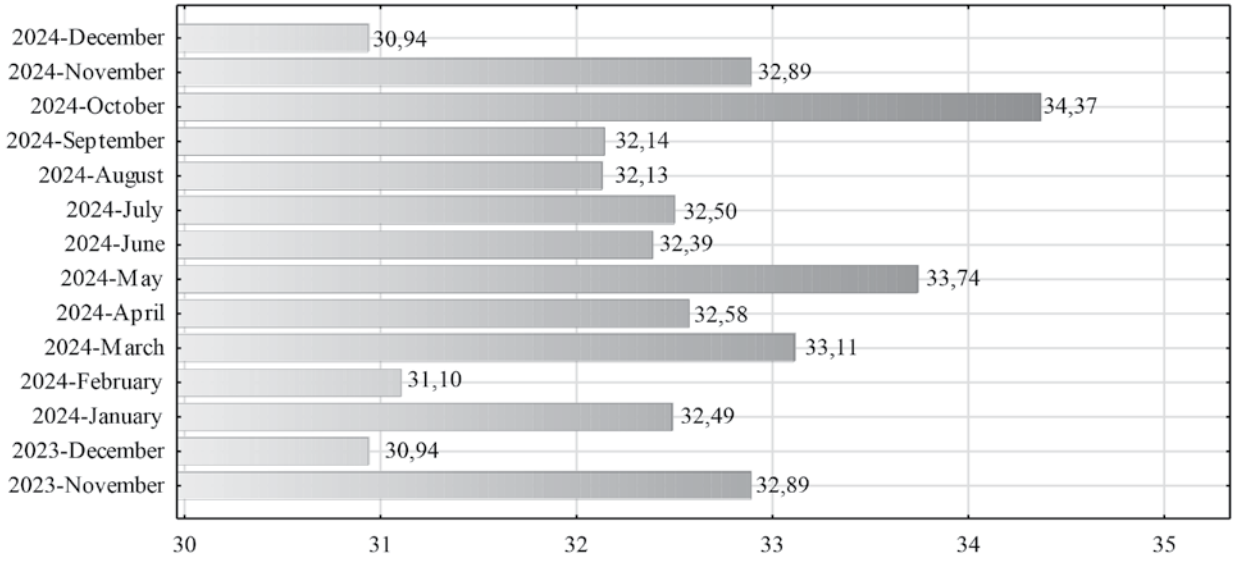

Fig. 8. Bar chart of forecasts obtained after applying the Winters' method – additive model for 14 future periods (from November 2023 to December 2024) of the time series of passengers transported by rail in Poland

Source: own study based on: https://dane.utk.gov.pl/sts/przewozy-pasazerskie/dane-wykatacyjne/20663, Przewozy-pasazerskie.html#PLIKI , as of 5.12.2023

The obtained forecasts show that in November-December 2023, a total of 68 830 000 passengers will be transported by rail in Poland. However, the forecast for 2024 is 390 380 000 passengers. The most passengers in 2024 will be transported in October (34 370 000), and least in December: 30 940 000.

5. Summary and conclusions

From 2012 to 2019, there was a visible increasing trend in the number of passengers transported by rail in Poland. In 2012, 273 904 000 passengers were transported by rail, and in 2019, 335 900 000 people. Due to the impact of the COVID-19 pandemic, in 2020 the number of passengers decreased to 209 399 000, and in 2021 it amounted to 245 060 000. In the following 2022, it increased to 342 226 000. However, from January to October 2023, it reached 310 662 000 passengers.

In the research, it was decided to use modelling to examine the regularities governing the time series of the number of passengers transported by rail in Poland before the emergence of the COVID-19 pandemic.

The research with the use of a categorized box plot, autocorrelation, partial autocorrelation, histogram, and normality graph with the Shapiro-Wilk test enabled the detection of three regularities: a growing trend, seasonality and a random factor. The distribution of the analyzed data was close to normal. Additionally, it was observed that from 2023 there is a visible increasing trend in the number of passengers transported, including seasonal phenomena monthly, reflecting the identical series of repetitions as in the same visible months listed in Figure 2.

This became the premise for forecasting. The Winters' model was used for it. The research goal was achieved and the hypothesis was verified. The mean absolute percentage error was 2,18, which means that the obtained match between the predicted and observed values was particularly good. The received forecasts indicate that a total of 68 830 000 passengers will be transported by rail in Poland in November-December 2023. In 2024, the number of passengers transported by rail will reach 390 380 000. The most passengers in 2024 will be transported in October (34 370 000), and least in December: 30 940 000.

The development of railway infrastructure improves the general transport organization, which results in an increase in demand for this type of services. When planning and implementing investments, it becomes important to forecast the number of passengers transported by rail in the future, so as to predict future revenues from the services provided in a dynamic approach, and thus effectively manage the available financial resources.

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