Electronic scientific and practical journal

INTELLECTUALIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT

#37(2026)
June '26

WWW.SMART-SCM.ORG
ISSN 2708-3195
DOI.ORG/10.46783/SMART-SCM/2026-37

ISSN 2708-3195

Electronic scientific and practical collection
INTELLECTUALIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Electronic scientific and practical publication in economic sciences

Electronic scientifically and practical journal “Intellectualization of logistics and Supply Chain Management” included in the list of scientific publications of Ukraine in the field of economic sciences (category "B"): **Order of the Ministry of Education and Culture of Ukraine dated June 11, 2026 No. 928 (Appendix 13 item 205).**

Cluster: Economic Transformation, Business and Administration

Specialties: C1 – Economics and International Economic Relations (by specializations)
D3 – Management
D5 – Marketing

ISSN 2708-3195
DOI: https://doi.org/10.46783/smart-scm/2026-37

The electronic magazine is included in the international scientometric databases:
Index Copernicus, Google Scholar

Released 6 times a year

№ 37 (2026)
June 2026

Kyiv - 2026

Founder: Viold Limited Liability Company
Editor in Chief: Hryhorak M. Yu. – Doctor of Economics, Ass. Professor.

Technical editor: Harmash O. M. – PhD (Economics), Ass. Professor.
Assistant editor: Davidenko V. V. – PhD (Economics), Ass. Professor.

The electronic scientific and practical journal is registered in international scientometric data bases, repositories and search engines. The main characteristic of the edition is the index of scientometric data bases, which reflects the importance and effectiveness of scientific publications using indicators such as quotation index, h-index and factor impact (the number of quotations within two years after publishing).

In 2020, the International Center for Periodicals (ISSN International Center, Paris) included the Electronic Scientific and Practical Edition "Intellectualization of logistics and Supply Chain Management" in the international register of periodicals and provided it with a numerical code of international identification: ISSN 2708-3195 (Online).

Recommended for dissemination on the Internet by the Academic Council of the Department of Logistics NAU (No. 7 of February 26, 2020). Released 6 times a year. Editions references are required. The view of the editorial board does not always coincide with that of the authors.

Electronic scientifically and practical journal "Intellectualization of logistics and Supply Chain Management" included in the list of scientific publications of Ukraine in the field of economic sciences (category "B"): ***Order of the Ministry of Education and Culture of Ukraine dated June 11, 2026 No. 928 (Appendix 13 item 205).***

Cluster: Economic Transformation, Business and Administration

Specialties: C1 – Economics and International Economic Relations (by specializations); D3 – Management; D5 – Marketing

facebook.com/Smart.SCM.org
DOI: https://doi.org/10.46783/smart-scm/2026-37
тел.: (063) 593-30-41
e-mail: support@smart-scm.org
https://smart-scm.org

Contents

The electronic scientifically and practical journal
"INTELLECTUALIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT",
ISSN 2708-3195

117-124
v.37 (2026)
https://smart-scm.org

DOI: https://doi.org/10.46783/smart-scm/2026-37-8

UDC 656.7:338.27
JEL Classification: C22, C53, L93, R41.

Received: 2026-05-14
Accepted: 2026-06-27
Published: 2026-06-30

Antonova A.O. PhD, Associate Professor, Professor Transport Technologies and Systems Department of National University "Kyiv Aviation Institute" (Ukraine)

ORCID – 0000-0003-1488-9309
Researcher ID GXM-6759-2022
Scopus author id: – 35222885500
E-Mail: anna.antonova@npp.kai.edu.ua

ON POST-PANDEMIC SHORT-TERM FORECASTING OF QUARTERLY AIR PASSENGER TRAFFIC AT POLISH AIRPORTS

Anna Antonova. "On post-pandemic short-term forecasting of quarterly air passenger traffic at Polish airports". *The COVID-19 pandemic caused a structural break in air passenger traffic dynamics, limiting the reliability of forecasting models based on long pre-pandemic time series. This study addresses the problem of short-term forecasting of quarterly total air passenger traffic at major Polish airports under post-pandemic market conditions. The research focuses on Warsaw Chopin Airport, Kraków-Balice, Gdańsk Lech Wałęsa Airport, Katowice-Pyrzowice, Wrocław-Starachowice, Poznań-Ławica, Rzeszów-Jasionka and Szczecin-Goleniów. The purpose of the article is to assess whether forecasting models based only on recent post-COVID data can provide reliable short-term predictions of passenger traffic.*

The empirical analysis uses quarterly statistical data published by the Polish Civil Aviation Authority. For most airports, the modelling period covers 2021–2024, while forecasts are generated for the four quarters of 2025 and compared with actual observations. For Szczecin-Goleniów Airport, due to the specific traffic dynamics, an additional modelling approach based on 2022–2025 data is considered. Two time-series forecasting methods are applied: ARIMA and ETS models implemented in the R environment. Forecast accuracy is evaluated using standard error metrics, including ME, RMSE, MAE, MAPE and MASE, as well as the Ljung-Box test and the corrected Akaike information criterion.

The results show that post-pandemic quarterly passenger traffic at Polish airports demonstrates a stable seasonal pattern, although its scale and recovery dynamics differ across airports. ARIMA models generally provide better fit and forecasting performance for most airports, while ETS modelling is more appropriate in selected cases. The findings confirm that excluding pre-pandemic observations may improve short-term forecasting accuracy when the market has entered a new structural phase after COVID-19 and subsequent geopolitical disruptions. The study contributes to the methodological discussion on air transport forecasting by demonstrating the practical value of using post-break data windows instead of mechanically extending historical series across structurally incomparable periods.

Keywords*:* air transport, airport, passenger traffic, short-term forecasting, ARIMA, ETS, seasonality, Poland

Анна Антонова. "Короткострокове прогнозування квартального авіапасажирського трафіку в польських аеропортах після пандемії". *Пандемія COVID-19 спричинила структурний*

117-124
v.37 (2026)
https://smart-scm.org

розрив у динаміці авіапасажирських перевезень, що обмежує надійність прогнозних моделей, побудованих на основі довгих допандемічних часових рядів. У статті розглянуто проблему короткострокового прогнозування квартального загального авіапасажиропотоку в основних аеропортах Польщі в умовах постпандемічного розвитку ринку. Дослідження охоплює Warsaw Chopin Airport, Kraków-Balice, Gdańsk Lech Wałęsa Airport, Katowice-Pyrzowice, Wrocław-Starachowice, Poznań-Ławica, Rzeszów-Jasionka та Szczecin-Goleniów. Метою статті є оцінювання того, чи можуть прогнозні моделі, побудовані лише на основі актуальних пост-COVID даних, забезпечувати надійне короткострокове прогнозування пасажиропотоку.

Емпіричний аналіз ґрунтується на квартальних статистичних даних, оприлюднених Управлінням цивільної авіації Польщі. Для більшості аеропортів період моделювання охоплює 2021–2024 роки, тоді як прогнози сформовано для чотирьох кварталів 2025 року та зіставлено з фактичними спостереженнями. Для аеропорту Szczecin-Goleniów, з огляду на специфічну динаміку пасажиропотоку, додатково розглянуто підхід до моделювання на основі даних за 2022–2025 роки. У дослідженні застосовано два методи прогнозування часових рядів: моделі ARIMA та ETS, реалізовані в середовищі R. Точність прогнозування оцінено за допомогою стандартних метрик похибки, зокрема ME, RMSE, MAE, MAPE та MASE, а також тесту Льюнга–Бокса і скоригованого інформаційного критерію Акаіке.

Результати дослідження показали, що постпандемічний квартальний пасажиропотік у польських аеропортах демонструє стійку сезонну структуру, хоча масштаби та темпи відновлення відрізняються між окремими аеропортами. Моделі ARIMA загалом забезпечують кращу якість апроксимації та прогнозування для більшості аеропортів, тоді як моделювання ETS є доцільнішим в окремих випадках. Отримані результати підтверджують, що виключення допандемічних спостережень може підвищити точність короткострокового прогнозування в умовах, коли ринок увійшов у нову структурну фазу після COVID-19 та подальших геополітичних зрушень. Дослідження робить внесок у методологічну дискусію щодо прогнозування в авіаційному транспорті, демонструючи практичну цінність використання посткризових часових вікон замість механічного продовження історичних рядів через структурно непорівнювані періоди

Ключові слова: авіаційний транспорт, аеропорт, пасажиропотік, короткострокове прогнозування, ARIMA, ETS, сезонність, Польща

Introduction. Forecasting air passenger traffic at the present stage is significantly complicated by the existence of gaps during the Covid-19 period. It actually splits the data into two intervals and therefore it is important to stitch them correctly. Such interpolation stitching will certainly affect the forecasting. This can of course be entrusted to smart mathematical packages. Examples of the use of interpolation for the study of air traffic in Poland can be found in [1-5].

However, the post- COVID period is already quite long and one can try to use only recent data for forecasting. Our study deliberately discards retrospective data from 2010–2019 due to the structural breakdown of the Polish air transport market caused by the COVID-19 pandemic and geopolitical changes after February 2022. The use of pre-Covid history is considered inappropriate, as institutional, logistical and behavioral patterns of passengers have undergone significant changes. Instead, the model focuses on the new evolutionary phase of the market (2021–2025), which demonstrates high predictive power in out-of-sample testing.

The purpose of the article: forecast of total air passenger traffic at Polish airports based only on statistical data for the post-COVID period.

117-124
v.37 (2026)
https://smart-scm.org

Presentation of the main research material.

Analysis of statistical data. It should be noted that quarterly data on total (international + domestic) passenger traffic, y, at Polish airports can be found in [6]. A general overview of the dynamics of quarterly air traffic at Polish airports is shown in Fig. 1.

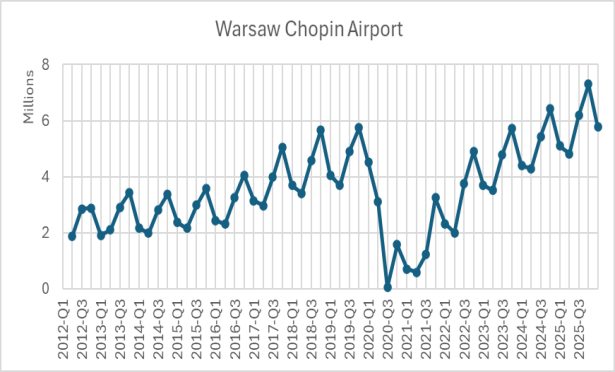

Figure 1a

Figure 1b

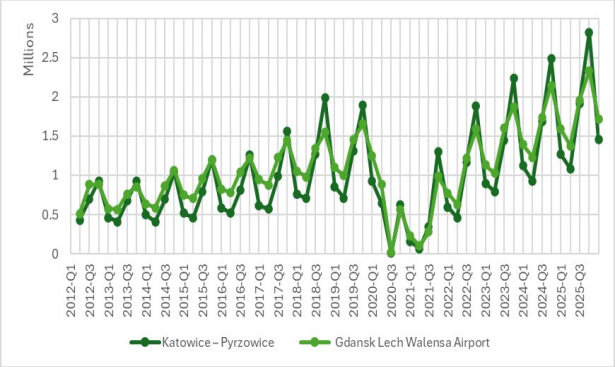

Figure 1c

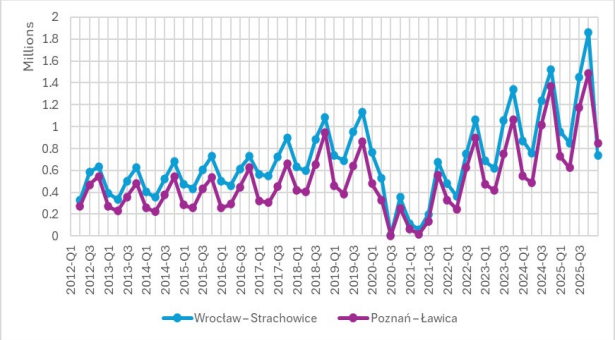

Figure 1d

Figure 1e

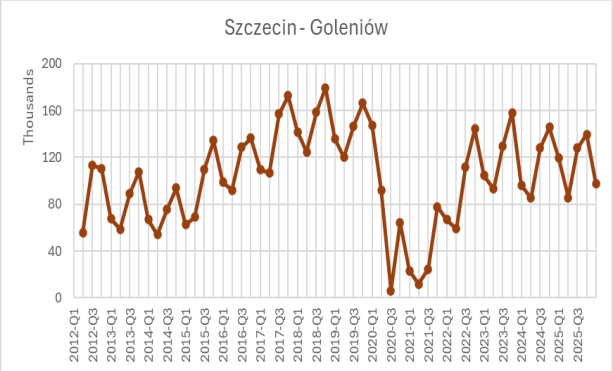

Figure 1f

Figure 1a-1f. Quarterly international + domestic passenger traffic at Polish airports for 2012 - 2025.

Source: Own study based on data from the Civil Aviation Authority, www.ulc.gov.pl.

It is clear from them that for each time series there is a cyclical pattern with periods of 4 quarters both in 2010-2019 and in 2022-2025, but which is strongly disrupted in 2020. With the exception of Szczecin – Goleniów airport, other airports have very similar dynamics after 2020.

In our short-term forecasting, we used only data starting from the first quarter of 2021. We selected 16 quarters of 2021-2024 [6] as a test set and used two different

117-124
v.37 (2026)
https://smart-scm.org

programs for forecasting: ARIMA (Auto Regressive Integrated Moving Average) and ETS (Error, Trend, and Seasonality) from the R package [7]. When analyzing traffic at Szczecin airport, the model was built on the basis of data for 2022-2025 and the forecast was made for 2026. ARIMA results of analysis are given in Table 1.

Table1 – ARIMA models characteristics

	Best fit model	Var ε	Forecast
Warsaw	ARIMA(0,1,0)(0,1,0)[4]	σ^2= 0.22	$\hat{y}_{t+1} = y_t + y_{t-3} - y_{t-4}$
Krakow		σ^2= 0.095	
Katowice		σ^2= 0.033	
Wroclaw		σ^2= 0.013	
Gdansk		σ^2=0.035	
Rzeszow		σ^2=0.0013	
Poznan	ARIMA(0,0,0)(0,1,0)[4] with drift v	v= 0.053, σ^2= 0.014	$\hat{y}_{t+1} = y_{t-4} + \mathrm{v}$
Szczecin	ARIMA(0,0,0)(0,1,0)[4]	σ^2=252.4	$\hat{y}_{t+1} = y_{t-4}$

The ARIMA(0,1,0)(0,1,0)[4] is a seasonal random walk model with a seasonal period of 4. It means that the dynamics of air transportation is described by the following equation.

$$y_{t+1} = y_t + y_{t-3} - y_{t-4} + \varepsilon_t,$$

where ε_t represents the white noise error term with $\mathrm{var}\varepsilon_t = \sigma^2$. Hence, for the forecast value we obtain formula

$$\hat{y}_{t+1} = y_t + y_{t-3} - y_{t-4}\,.$$

ARIMA(0,0,0)(0,1,0)[4] with drift v for Poznan and Szczecin airports means that

$$y_{t+1} = y_{t-4} + \mathrm{v} + \varepsilon_t.$$

ARIMA forecasting results for 2025 are shown in Figure 2. In these figures, the following notation is used: yAR - forecast values, Low and High are lower and upper 95% confidence intervals of the prediction. As can be seen from the Figures 2a-2h, the results of the forecast for 2025 are in very good agreement with the statistical data for 2025.

The results of ETS simulations are close to those obtained by ARIMA simulations shown in Figure 2. All best fit ETS models have the form ETS(A, N, A): additive error (A), no trend (N), and additive seasonality (A).

Table 2 shows standard statistical metrics used to evaluate the accuracy of predictive and forecasting models, p -value for Ljung-Box test and corrected Akaike information criterion AICc values (AICc) [7, 8].

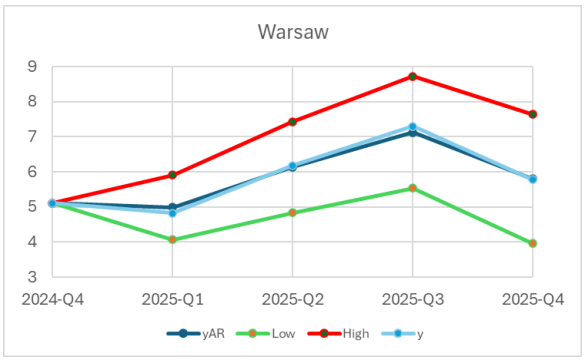

Figure 2a

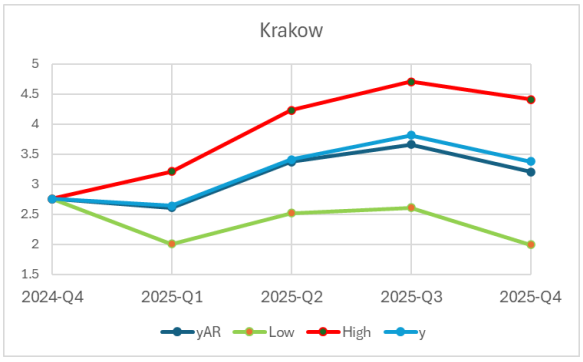

Figure 2b

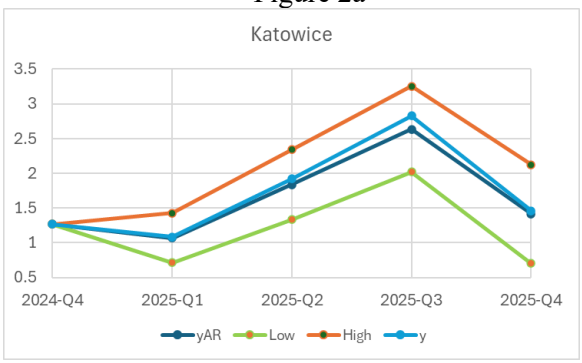

Figure 2c

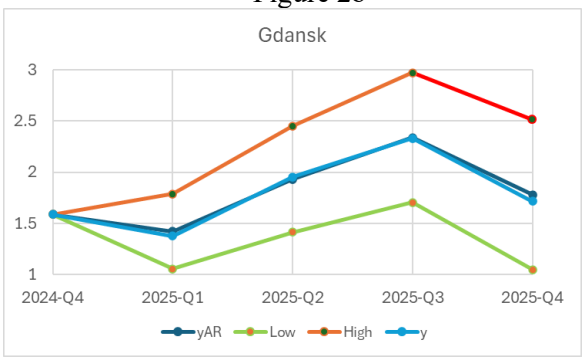

Figure 2d

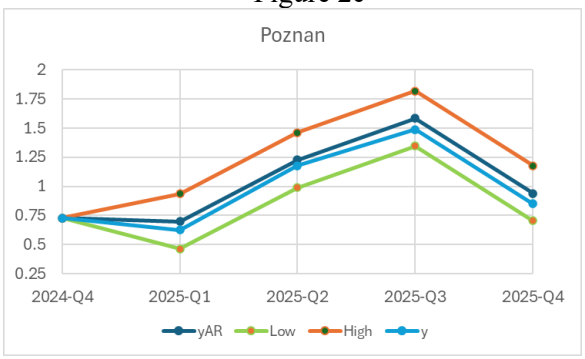

Figure 2e

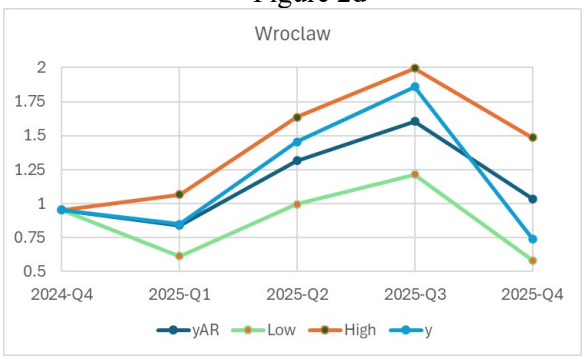

Figure 2f

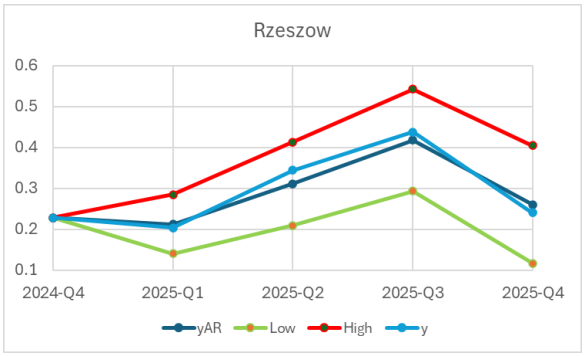

Figure 2g

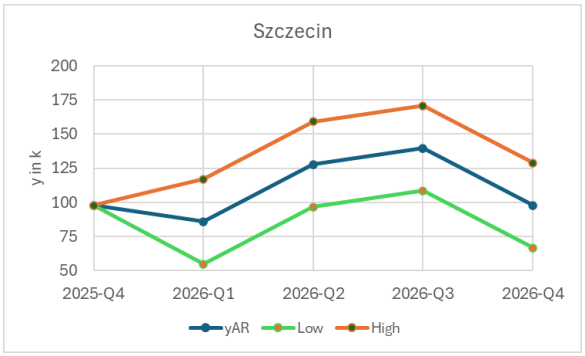

Figure 2h

Figure 2a-2h. Quarterly forecast of total passenger traffic at Polish airports for 2025.
Source: Developed by the author

117-124
v.37 (2026)
https://smart-scm.org

Table 2. Forecast accuracy metrics for the examined models

Airport		ME	RMSE	MAE	MAPE	MASE	Ljung-Box test p -value	AICc
Warsaw	ARIMA	-0.04	0.39	0.22	5.01	0.19	0.31	17
	ETS	0.26	0.42	0.32	11.25	0.28	0.58	44
Krakow	ARIMA	-0.04	0.26	0.15	6.79	0.22	0.51	7.8
	ETS	0.05	0.11	0.09	34.44	0.33	0.14	31.8
Katowice	ARIMA	-0.02	0.15	0.09	7.85	0.28	0.31	-3.89
	ETS	0.07	0.17	0.13	21.34	0.39	0.34	15.3
Wroclaw	ARIMA	-0.01	0.10	0.06	7.44	0.24	0.12	-13.9
	ETS	0.05	0.11	0.09	16.31	0.34	0.23	2.8
Poznan	ARIMA	-0.04	0.10	0.07	11.02	0.33	0.36	-12.5
	ETS	0.06	0.12	0.10	66.44	0.45	0.25	5.1
Gdansk	ARIMA	-0.02	0.15	0.09	6.80	0.25	0.34	-3.3
	ETS	0.09	0.17	0.13	16.76	0.34	0.60	14.91
Rzeszow	ARIMA	0.00	0.03	0.02	10.28	0.31	0.49	-39.00
	ETS	0.01	0.03	0.03	25.86	0.38	0.48	-36.80
Szczecin	ARIMA	1.98	13.76	9.28	8.37	0.75	0.50	103
	ETS	-0.11	9.42	7.63	7.9	0.62	0.50	144

Here: ME is mean error,
MAE - mean absolute error,
RMSE - root mean squared error,
MAPE - mean absolute percentage error;
MASE is mean absolute scaled error.

If MASE < 1, then model performs better than a naive baseline, if MASE > 1, then model performs worse than a naive baseline.

Analyzing the data of Table 2, the following conclusions can be drawn:

1. Irregular components of forecasts for all airports are uncorrelated (Cox-Box Test p - values >0.05)

2. For the airports Warsaw, Krakow, Katowice, Gdansk, Poznan, Szczecin, Wroclaw, the ARIMA model is preferable due to the large difference in Akaike information criterion AICc values.

3. For airport Rzeszow the ETS model is preferable.

4. ARIMA and ETS forecasts are better than naive forecast (MASE<1)

For comparison, consider the results of the work of N. Drop and A. Bohdan [2] . In this article autors examined the quarterly dynamics of the total passenger traffic (domestic + international) y in test set 2010-2024 for Szczecin – Goleniów airport and constructed Holt-Winters additive ETS(A,N,A) and multiplicative ETS(M,N,M) time series models. In [2] the forecast of y for four quarters of 2025 has been made, but no prediction 95% confidence intervals was given.

We performed similar calculations to determine the best-fit models and their metrics. They showed that the best fit ARIMA model is ARIMA(1,0,0)(2,1,0)[4] and the best fit ETS model is ETS(M,N,A). The simulation results based on the ETS(M,N,A) model are shown in the Figure 3.

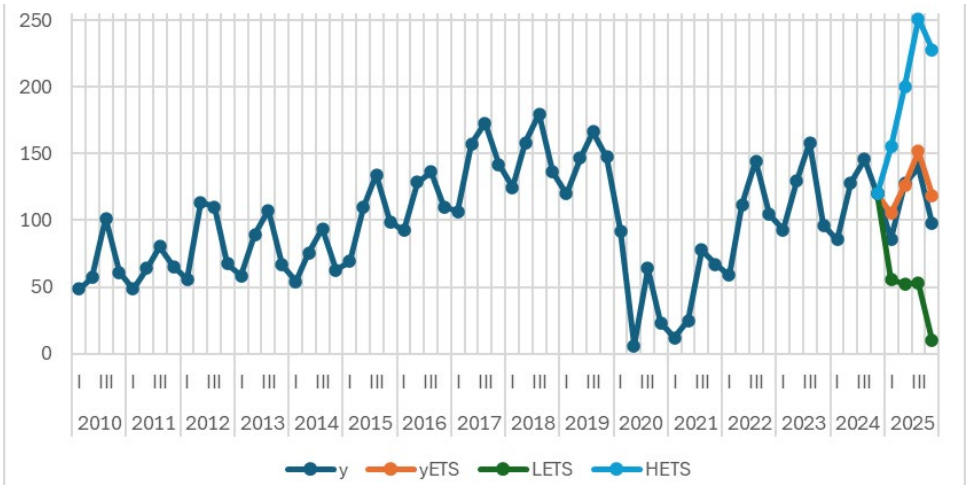

Figure 3. y data, ETS(M,N,A) forecasted y values and 95% forecast confidence intervals for 2025 for Szczecin – Goleniów airport.
Source: Developed by the author

Figure 4. Forecasted y values for 2025 (left); y data and 95% forecast confidence intervals for 2025 (right) for Szczecin – Goleniów airport
Source: Developed by the author

It can be seen that the ARIMA model significantly overestimates the forecast values of y, and the ETS model has an unrealistic behavior of the lower confidence limit of y. All this is a consequence of taking into account the data from the Covid failure. The results of metrics analysis are shown in the Table 3.

Table 3. Forecast accuracy metrics for the examined models

Model	ME	RMSE	MAE	MAPE	MASE	Ljung-Box test p value	AICc
ARIMA(1,0,0)(2,1,0)[4]	1.5	22.9	13.6	49.8	0.52	0.75	524
ETS(M,N,A)	1.0	20.6	12.7	42.9	0.49	0.16	621

Conclusions. In our work, based on quarterly statistical data on total air passenger traffic (domestic + international) for 2021-2024 at the airports of Warsaw Chopin Airport, Kraków-Balice, Gdańsk Lech Wałęsa Airport, Katowice-Pyrzowice, Wrocław-Starachowice, Poznań - Lawica, Rzeszów – Jasionka and Szczecin – Goleniów, ARIMA and ETS time series models were built and air traffic predictions were made for 2025. These predictions are compared with the actual statistical data for 2025 [6] and good agreement of results was obtained.

These results will be useful in making short-term predictions of air passenger traffic.

Acknowledgment. Author would like to thank Dr. S. Reznik for useful discussions and assistance with numerical calculations.

References

1. Borucka, A., Parczewski, R., Kozłowski, E., & Świderski, A. (2022). Evaluation of air traffic in the context of the Covid-19 pandemic. *Archives of Transport*, 64(4), 45-57. https://doi.org/10.5604/01.3001.0016.1048
2. Drop N. and Bohdan A. (2025). Application of the Holt–Winters Model in the Forecasting of Passenger Traffic at Szczecin–Goleniów Airport (Poland). *Sustainability*, 17(14), 6407; https://doi.org/10.3390/su17146407.
3. Hydzik, P., Nycz, M., & Sobolewski, M. (2021). An Estimation of the Number of Lost Airport Passenger Services as a Result of the Covid-19 Pandemic in Poland. *European Research Studies Journal*, 24(4), 753-762. https://doi.org/10.35808/ersj/2625
4. Sobczuk,S., Borucka,A. (2025). Passenger Air Transport in Poland and Selected European Countries in the Face of COVID-19: A Post-Pandemic Comparative Analysis. *Sustainability*, 17, 11026. https://doi.org/10.3390/su172411026
5. Gołda, P., Cur, K., Izdebski, M., Świergolik, S., & Radomyski, A. (2023). Development of aviation infrastructure in selected European countries: statistical analysis and implications. *Aviation and Security* Issues, 4(2), 107-137. https://doi.org/10.55676/asi.v4i2.82
6. Air traffic in Poland: passenger transport, air operations and cargo in 2024. Publisher: Urząd Lotnictwa Cywilnego. Availability date: 11 June 2025. https://dane.gov.pl/en/dataset/4860
7. Hyndman, R. J. (2014). Forecasting: Principles & Practice. https://robjhyndman.com/uwafiles/fpp-notes.pdf
8. ACI Guide to World Airport Traffic Forecasts. (2016). https://store.aci.aero/wp-content/uploads/2017/09/CI_Guide_to_World_Airport_Traffic_Forecasts_2016.pdf