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Retrospective Analysis of Ukrainian Air Transport Activity

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Abstract

Ukraine is an aviation state that has a full cycle of development and serial production of aircraft, commercial operation of civil aviation, training and retraining of professionals for the industry. The level of development of air transport determines not only the country's image, but also the sustainable development of its national economy. The article presents a structural analysis of the trends in the development of world aviation transport, as well as the economic development of aviation transport in Ukraine and its infrastructure. The authors pay special attention to the study of the factors of the seasonality of air transportation and their influence on the results of the operational activities of air transport in Ukraine.

Keywords: Retrospective Analysis, Seasonal Variations, Passenger Air Transportations, sustainable development of the national economy.

1. THE ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The ongoing systematic research on the development of air transportations on global, regional and national levels, which is based on realization of principals of Convention on International Civil Aviation, signed in Chicago on December 7, 1944 [1] is conducted by specialists of the International Civil Aviation Organization (ICAO) [2 – 4], the International Air Transport Association (IATA) [4, 5], the Airport Council International (ACI) [4], the Civil Air Navigation Organization (CANSO) [4], the International Coordinating Council of Aerospace Industries Associations (ICCAIA) [4], the Air Transport Action Group (ATAG) [4], the European Agency for Air Navigation Safety (EUROCONTROL) [6] and other world and regional organizations in the field of civil aviation. Leading manufacturers in the aviation industry, such as Boeing [7] and Airbus [8], make a significant contribution to the process of analyzing integrated aviation safety and forecasting the air transportation market. Periodic monitoring of the national aviation safety & security system is carried out by the Ministry of Infrastructure [9], the Civil Aviation Authorities (CAA) of Ukraine [10] and State Statistics Service of Ukraine [11].

The publications of national and foreign scientists are devoted to the study of economic and technological development of air transport and airports of Ukraine and the world. Among them one can encounter such authors as O. Arefieva, T. Gabrielova, E. Kostromina, Yu. Kulaev, N. Polyanskaia. Analysis of air traffic dynamics in Ukraine has been conducted in publications of K. Marintseva [11], A.Babenko, O. Sokolova, A. Valko [12], T. Oleshko T., I. Heiets[13]. However, their works used annual air traffic statistics and the factors that affect them. An exception is the work of S. Petrovska and A.Gavrilenko [4], which considers quarterly statistics for 2006-2010. At the same time, in the foreign scientific literature, almost most forecast research is based on monthly statistics, which is of interest to many managers. This confirms the relevance and practical value of the seasonality factor introduced into the analysis of the dynamics of air transportation.

The article is a logical continuation of a number of publications on the development of air transportations as essential factor of sustainable development of national economics of Ukrainian scientists (D. Bugayko [16-20], Y. Kharazishvili [17-18], V. Kharchenko [20], A. Antonova [20], M. Hryhorak [20], O. Lishchynsky [19], N. Sokolova [19]), as well as Polish scientists (M. Paweska [20], Z. Zamiar [17, 19]) and many researches from other countries of the world. The unresolved part of the research is to highlight the theoretical foundations of aviation economic security

management in the context of ensuring the sustainable development of the national economy. The proposed article is devoted to solving this problem.

The goal of the article is to determine the tools for proactive economic risks management of civil aviation in order to introduce effective tools for sustainable development of the national economy.

2. WORLD TRENDS OF AVIATION INFRASTRUCTURE DEVELOPMENT

In 2018, airlines worldwide carried about 4.3 billion passengers, registering 8.3 trillion commercial passenger-kilometers (RPK). 58 million tons of cargo, or 231 billion ton-kilometers (FTK), were transported by air. Every day, aircraft carry nearly 12 million passengers and goods worth about $ 18 billion, making more than 100,000 flights.

Civil aviation statistics show that the growth of the main indicators of air traffic doubles every fifteen years. This is much more dynamic than the growth of most other industries. Since 1960, the demand for passenger, luggage, freight and mail has been steadily increasing. The development of technological progress and related investments are combined and make it possible to multiply the output of the aviation industry by a factor of more than 30. Such expansion of air transport is extremely beneficial for world economic growth, especially for world production (global GDP) in real terms multiplied more than five times over the same period.

However, a structural analysis of air traffic volumes suggests that the dynamic growth of air traffic is consistently opposed by recession cycles. The aviation industry is an open system that is affected by a wide range of technical, natural, human and economic threats. For its part, it itself is a generator of significant threats to the environment. Among the most significant threats to civil aviation in the history of development should be noted the following: the fuel crisis (1973), the war between Iran and Iraq (1981), the Gulf War (1991), the Asian crisis (1997-1998), the terrorist attack in the United States on September 11 (2001), SARS (2003), the global recession (2008) [5]. However, one of the most threatening challenges in the history of aviation is the spread of a new deadly infection COVID-19, which in fact leads to a quarantine blockade of entire regions and a sharp reduction in the number of air traffic or even ban [17].

3. PLANNING THE ECONOMIC DEVELOPMENT OF AIR TRANSPORT IN UKRAINE

Ukraine is an aviation state that has a full cycle of development and serial production of aircraft, commercial operation of civil aviation, training and retraining of professionals for the industry. Statistics on the activities of the aviation industry in Ukraine in the period from 2010 to 2018 indicate its stable development. Today, 34 national airlines carry passengers, cargo and mail. The share of aviation in export-import operations of the country is gradually growing: export - 1221610.7 thousand dollars USD (21% of total exports of transport services), imports - 695720.1 thousand dollars. USA (48% of total imports of transport services) [12, 17]. The dynamics of changing of export-import of air transport services in Ukraine is represented in Fig.1.

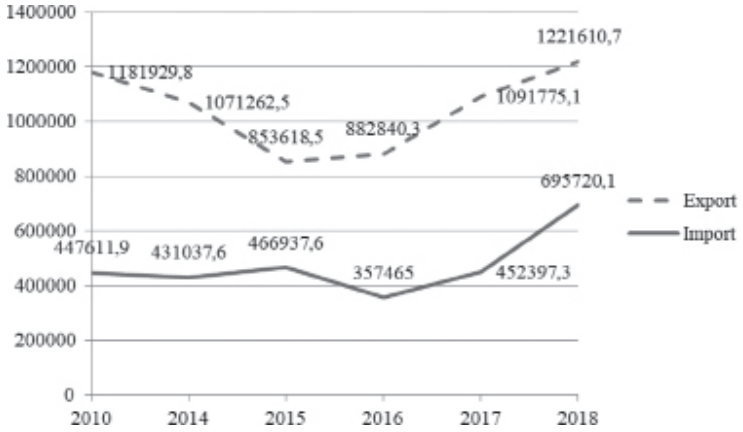

Fig. 1. Export-import of air transport services in Ukraine (thousands USD).
Source: State Statistics Service of Ukraine. Transport and Communications of Ukraine 2018 [12].

Air transport is an effective catalyst for investments. Thus, in just 5 years (2014-2018), even under conditions of political instability and armed conflict in eastern Ukraine, UAH 4,503.6 million of capital investments were attracted to the industry. Although the total population involved in air transport is not very large (8,100 people, or less than 1% of the total population involved in transport), aviation accumulates highly educated people with a high level of competence with one of the highest levels of average monthly wages, which is 3.6 times higher than the

average monthly wage in transport. The dynamics of capital investments changes in Ukrainian air transport represented in Fig. 2.

Fig. 2. Capital investments of Ukrainian air transport (millions UAH).
Source: State Statistics Service of Ukraine. Transport and Communications of Ukraine 2018 [12].

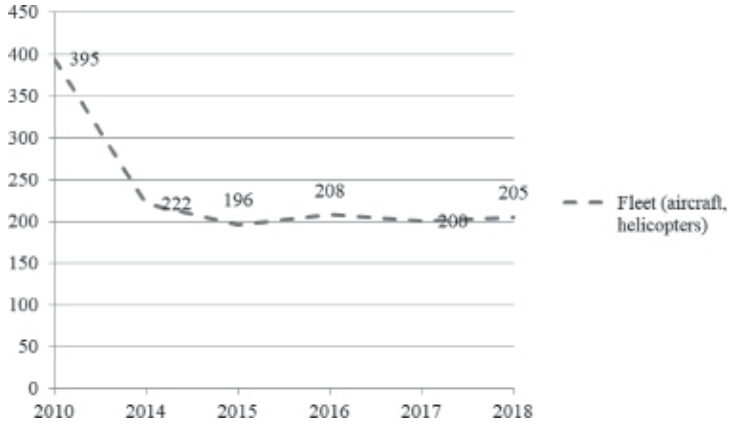

Fig. 3. Fleet of Ukrainian Airlines.
Source: State Statistics Service of Ukraine. Transport and Communications of Ukraine 2018 [12].

However, as it has been mentioned above, aviation has not only direct but also indirect and inductive effects. That is, it creates jobs in various sectors of the economy. The dynamics of change in the number of aircraft fleets reflects not so much quantitative as qualitative change. The dynamic decrease in the number of aircraft in the period from 2000 to 2015 is mainly due to the gradual decommissioning of economically unprofitable and obsolete aircraft manufactured during the Soviet era. This trend was offset by the renewal of the fleet with the latest economic and environmental modifications of Western-made aircraft (Boeing, Airbus, Embraer, etc.). The dynamics of fleet changing of Ukrainian airlines is represented in Fig. 3.

At the same time, the airlines did not aim to maximize the fleet of aircraft, but to implement the policy of optimizing the fleet of aircraft and mass departure from direct purchases of their own aircraft to the development of leasing agreements. This is one of the protective mechanisms to respond to sudden changes in demand for transportation [17].

4. TRENDS IN THE DEVELOPMENT OF AVIATION INFRASTRUCTURE IN UKRAINE

Passenger air transportation of Ukraine. Statistics on the activities of the aviation industry indicate its stable development. Transportation of passengers, cargo and mail call 34 national airlines, which performed 100.3 thousand commercial flights. At the same time, the number of transported passengers has increased since 2017 by 18.7% and 12,529,000 people [11].

As well as at the global level, there is a direct dependence of the industry's production indicators on the negative impact of external factors that caused the most significant decline in passenger air traffic, namely: annexation of Crimea, armed conflict in eastern Ukraine, downing of Malaysia Airlines Boeing 777, airspace closure over a large territory of Ukraine, refusal to fly over the Russian Federation, etc. However, civil aviation is not only an open system, but also an adaptive system. And these biggest recessionary tendencies have been overcome due to the development of infrastructure taking into account the newly created constraints. The indicator of 12,529 thousand air passengers is 10.7 times higher than in 2000, and 2 times higher than in 2015 [17]. The dynamics of changes in air passenger turnover of Ukraine is represented in Fig. 4.

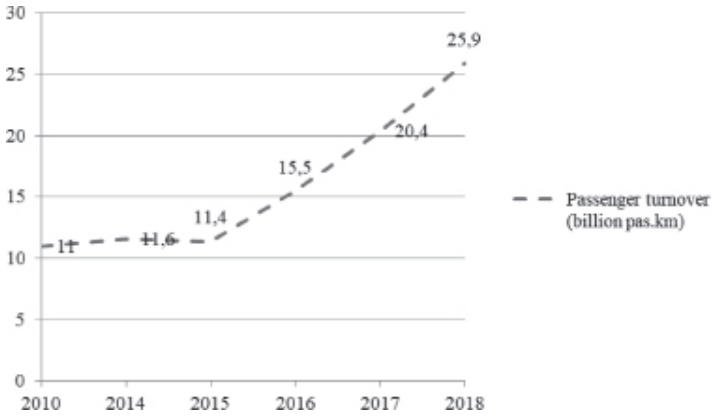

Fig. 4. Air passenger turnover of Ukraine.
Source: State Statistics Service of Ukraine. Transport and Communications of Ukraine 2018 [12].

One of the most serious crises in the world aviation associated with the COVID-19 pandemic is currently underway. The air transport economy is extremely vulnerable to external factors, so it has a low fixed cost item that must be paid regardless of standard or force majeure conditions. First of all, it is the payment of lease payments for the fleet of aircraft which now consists mainly of leased aircraft. Airlines pay an average of 10 thousand dollars per day for leasing one Boeing 737-800 or Airbus-320. Thus, the daily leasing budget of UIA can be about 300 thousand dollars, SkyUp and Wind Roses - up to 100 thousand dollars. To these costs are added other fixed items: staff salaries, insurance, maintenance of airworthiness of aircraft, etc. Subject to advanced risk management and consolidation measures by the state, operators of such aircraft or helicopters, approved maintenance organizations, organizations, relevant structures of the type or production of aircraft and leasing organizations, air traffic service providers, operators of certified airfields, approved educational institutions organizations can interfere with the overall defeat of the industry. Thus, the specificity of open systems is the phenomenon of "domino effect". If the market leads to the organization of one segment, it systematically affects the performance of others, as well as the overall synergy of the industry [17].

Cargo air transportation of Ukraine. Volumes of cargo and mail transportation by air transport of Ukraine in 2018 became 99.1 thousand tons. There are 2 airlines operating in Ukraine, which carry out cargo transportation. Today, regular purely

cargo air services in Ukraine are not developed. The priority of cargo air transportation is charter flights to other countries within the framework of UN humanitarian and peace programs, in accordance with contracts and agreements with other customers and dosing of passenger aircraft operating regular passenger flights [11].

In 2018, 20 Ukrainian airports and airfields provided services to 182.8 thousand units of departing and arriving aircraft and provided passenger traffic in the amount of 20,545.4 thousand people. In 2018, aviation enterprises cultivated 569.2 thousand hectares of agricultural land, the total raid during aviation work in the economy of the population was 11.8 thousand hours. In 2018, UkSATSE provided 300.9 thousand flights [17].

5. QUARTERLY DYNAMICS ANALYSIS OF PASSENGER AIR TRANSPORTATION IN UKRAINE

Over the last 15 years, the dynamics of passenger air traffic in Ukraine has been quite complex. First of all, the trend changed significantly. This issue has been discussed in many works by Ukrainian authors but based on the analysis of the annual dynamics of changes in the number of passengers. However, seasonal effects were not considered at all. We will discuss this issue further on the example of quarterly air transportation. Data for analysis were obtained from the website of the State Statistics Service of Ukraine [22]. They are shown in Table 1. Figs. 5 and 6 show the annual and quarterly dependences of the number of air passenger traffic during 2006-2019.

Table 1. Quarterly data of air passenger traffic for 2006-2019 in Ukraine.

Y/Q	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	0.8	0.9	1.1	0.9	0.9	1.2	1.4	1.1	1.4	1.1	1.3	1.9	2.1	2.4
2	1.1	1.2	1.5	1.3	1.6	1.9	2.1	2.1	1.6	1.6	2	2.7	3.2	3.7
3	1.5	1.7	2.1	1.9	2.2	2.7	3	3	2.2	2.2	2.9	3.6	4.2	4.6
4	1	1.1	1.5	1	1.4	1.7	1.7	1.9	1.3	1.4	2.1	2.4	3	3
$\sum$	4.4	4.9	6.2	5.1	6.1	7.5	8.2	8.1	6.5	6.3	8.3	10.6	12.5	13.7

Source: author's calculations.

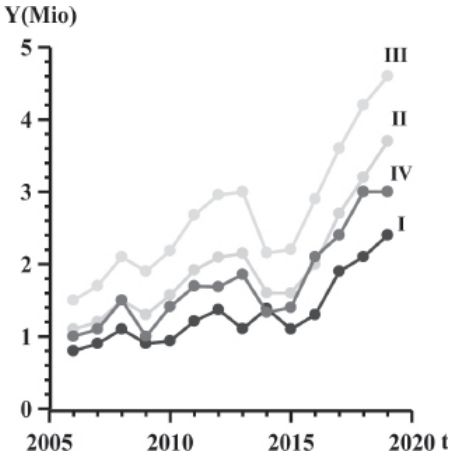

Fig. 5. Annual dependences of quarterly traffic $YQ(t)$: for first quartal - I line, for second – II line, for third – III line, for fourth – IV line.
Source: author's calculations.

Additional useful information can be obtained by analysing the annual increments $dYQ_i(t) = YQ_i(t+1) - YQ_i(t),\ i = 1,2,3,4.$ These dependences are shown in Fig. 6-9. The dependences $Y(t)$ and it increment $dY(t) = Y(t+1) - Y(t)$ are shown in Fig. 10-11. These figures clearly show the existence of time intervals with positive increments. The last two intervals are 2010-2013 and 2015-2019. It is natural to assume that there are several time series. Although they are relatively short, their analysis can provide information on the trend and seasonal components of passenger air traffic.

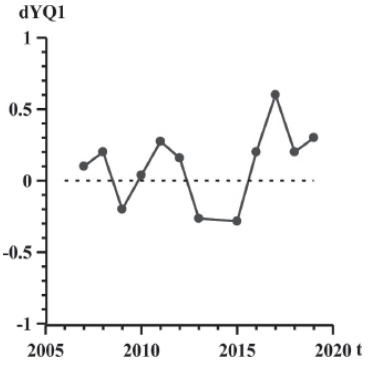

Fig. 6. Annual dependence of quarterly increment $dYQ1(t)$.
Source: author's calculations.

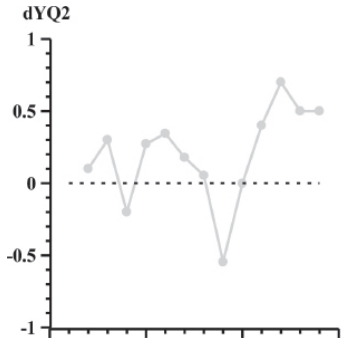

Fig. 7. Annual dependence of quarterly increment $dYQ2(t)$.
Source: author's calculations.

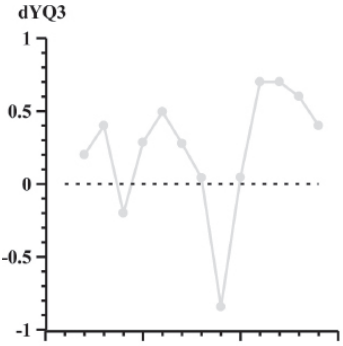

Fig. 8. Annual dependence of quarterly increment .
Source: author's calculations.

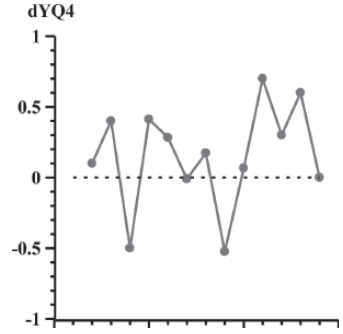

Fig. 9. Annual dependence of quarterly increment $dYQ4(t)$.
Source: author's calculations.

Let's proceed to analysing the properties of time series $Y(t)$.Time series for 56 quarters 2006-2019 shown in Fig. 12 (I line). Its characteristics can be estimated using the applied package **TimeSeries** from the Mathematica 11 package [23]. Using **TimeSeriesModelFit** program we find that this series is best fitted by the SARIMA model {{1,0,1}, $\{0,1,0\}_4$}. Process parameters and their errors are shown in Tab. 2.

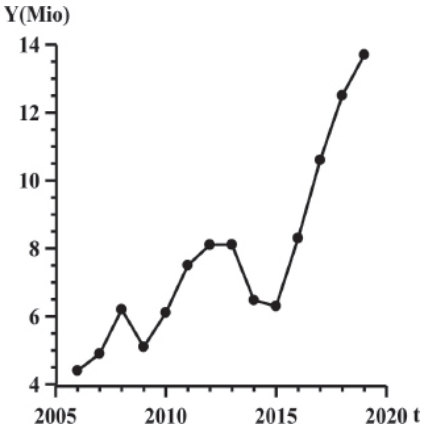

Fig. 10. Annual dependence of $Y(t)$.
Source: author's calculations.

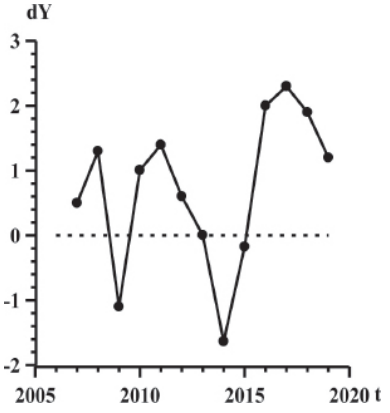

Fig. 11. Annual dependence of increment dY(t).
Source: author's calculations.

Tab. 2.

SARIMA{{1,0,1},{0,1,0}$_4$}				
	Estimate	Standard Error	t-Statistic	P-Value
a_1	0.558	0.113	4.944	3.10^{-6}
b_1	0.939	0.047	20.05	0

Source: author's calculations

It can be seen that time series has a period of 4 quarters and contains autocorrelation both in the trend and in the errors. The black line in Fig. 12 corresponds to the four-quarter moving average, i.e. nonlinear trend

$$Y_{tr}(t)=\frac{1}{4}\left(\frac{1}{2}Y(t-2)+Y(t-1)+Y(t)+Y(t+1)+\frac{1}{2}Y(t+2)\right),\ 3\le t\le 54$$

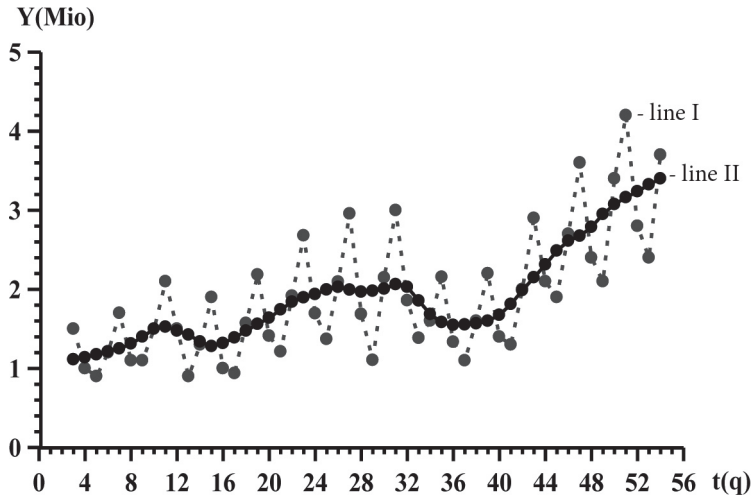

Fig. 12.Time series for $Y(t)$ (line I) and $Y_{tr}(t)$ (line II).
Source: author's calculations

Let us try to carry out the predictions using Mathematica 11 applied package **TimeSeries** [23] based on information about all previous quarters. The simulation results for the forecast for 2019, 2018, 2017 and 2016 are shown in Tables 3-7 along with the parameters of the best suggested by **TimeSeriesModelFit** from Mathematica 11.

Table 3a

SARIMA{ {{1, 0, 2}, {0, 1, 1}4}}				
	Estimate	Standard Error	t-Statistic	P-Value
a1	0.816	0.374	2.183	0.017
b1	0.390	0.397	0.982	0.165
b2	-0.395	0.475	-0.832	0.205
α1	-0.073	0.243	-0.301	0.382

Table 3b

2019	1	II	III	IV	total
Data Y	2.4	3.7	4.6	3	13.7
Prediction Y	2.53	3.72	4.49	3.08	13.82

Source: author's calculations.

Table 4a

SARIMA{ {{1, 0, 1}, {1, 1, 0}4}}				
	Estimate	Standard Error	t-Statistic	P-Value
a1	0.623	0.171	3.632	0
b1	0.879	0.101	8.665	0
α1	-0.175	0.197	-0.889	0.189

Table 4b

2018	1	II	III	IV	total
Data Y	2.1	3.2	4.2	3	12.5
Prediction Y	1.9	2.71	3.63	2.51	10.74

Source: author's calculations.

Table 5a

SARIMA{ {{1, 0, 1}, {0, 1, 1}4}}				
	Estimate	Standard Error	t-Statistic	P-Value
a1	0.643	0.853	0.753	0.228
b1	0.686	0.842	0.815	0.21
α1	-0.31	0.481	-0.645	0.261

Table 5b

2017	1	II	III	IV	total
Data	1.9	2.7	3.6	2.4	10.6
Prediction	1.77	2.27	3	2.13	9.17

Source: author's calculations.

Table 6a

SARIMA{ {{1, 0, 1}, {1, 1, 0}$_4$}}				
	Estimate	Standard Error	t-Statistic	P-Value
a_1	0.489	0.197	2.49	0.009
b_1	0.841	0.131	6.39	0
α_1	-0.292	0.195	-1.5	0.071

Table 6b

2016	1	II	III	IV	total
Data	1.3	2	2.9	2.1	8.3
Prediction	1.2	1.64	2.24	1.44	6.52

Source: author's calculations

The simulation results show that although the type of processes changes with the length of the time series, *Y* data are in good agreement with the its prediction. We analyzed the possibility of forecasting air passenger traffic for 2019 for the case when data from 2015 -2018 are used. It turned out that **TimeSeriesModelFit** gives satisfactory forecast for 2019 (Tables 7a and 7b).

Table 7a

2015-2018 data ARIMA{ {2, 1, 1}				
	Estimate	Standard Error	t-Statistic	P-Value
a_1	0.074	0.091	0.808	0.214
a_2	-0.916	0.09	-10.13	0
b_1	-0.78	0.143	-5.45	0

Table 7b

2019	1	II	III	IV	total
Data	2.4	3.7	4.6	3	13.7
Prediction	2.04	3.4	4.34	3.29	13.07

Source: author's calculations

Therefore, it is possible to assume that the analysis of the trend and seasonal phenomena in air passenger traffic can be described by simpler model based only on the latest data (2010- 2012 or 2016-2018). We assume that the time series $Y(t)$ can be represented by an additive model

$$Y(t) = Y_{tr}(t) + S(t) + E(t),$$

where
$S(t)$ is the seasonal component, $E(t)$ is a random variable. Then, using the moving average for the period (four quarters), we will exclude both the seasonal component and the random one.

As a result, we find the trend component shown in Fig. 13 with a black line.

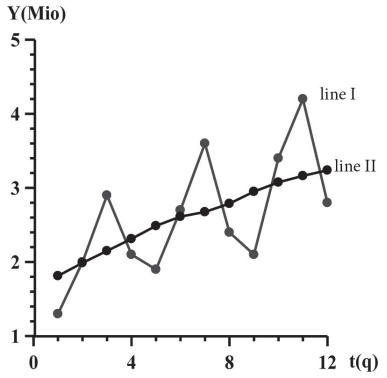

Fig. 13. Time series for $Y(t)$ (line I) and for $Y_{tr}(t)$ (line II)
Source: author's calculations

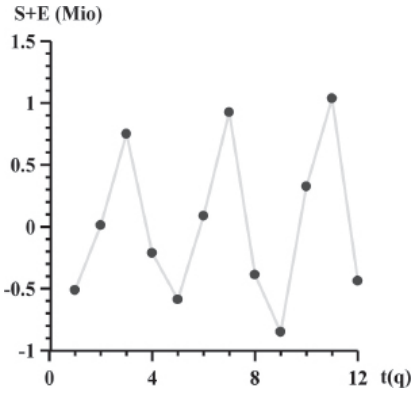

Fig. 14. Time series for $S(t) + E(t)$.
Source: author's calculations

Subtracting the trend $Y_{tr}(t)$ from the data $Y(t)$, we get $S(t)+E(t)$ shown in Fig. 13.

Further, we extract from $S(t)+E(t)$ the seasonal component using the Fourier expansion

$$S \approx a + b\sin\left(\frac{\pi t}{4} + f\right)$$

where a, b and f are unknown parameters. These parameters can be determined using the **NonlinearModelFit** procedure in Mathematica 11. As a result, we get the values of a, b and f and their errors, which are shown in table 7a. It can be seen from table 7a that the parameter a is insignificant due to the large p-value. The estimates of the amplitude of seasonal fluctuations b and phase f are practically reliable. In Fig. 14 the green curve represents the seasonal component $S(t)$ and the magenta curve represents the error $E(t) = Y(t) - Y_{tr}(t) - S(t)$.

As can be seen from Fig. 15, the range of seasonal fluctuations is almost 1.6 Mio. The quantitative results obtained using this model for predicting 2019 traffic are presented in Table 7a and 7b. Good agreement is seen both in quarters and in total traffic for 2019. **NonlinearModelFit** procedure also gives good results for the time series corresponding to 2010-2012.

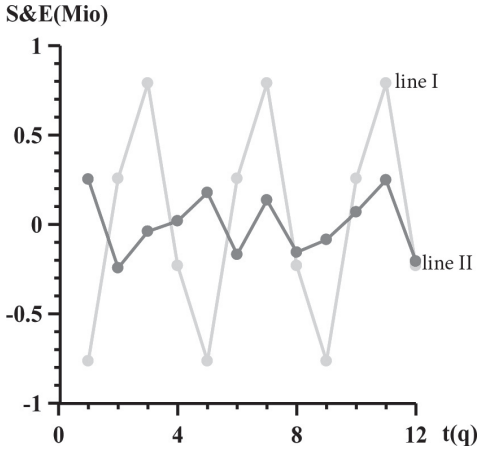

Fig. 15. Time series for $S(t)$ (line I) and for $E(t)$ (line II)
Source: author's calculations

Table 8a

	Estimate	Standard Error	P-Value
a	0.013	0.06	0.83
b	-0.81	0.08	0
f	0.30	0.1	0.01

Table 8b

2019	1	II	III	IV	total
Data Y	2.4	3.7	4.6	3	13.7
Prediction Ytr	3.33	3.41	3.47	3.53	
Prediction S	-0.77	0.26	0.79	-0.23	
Prediction Y	2.56	3.67	4.26	3.3	13.79

Source: author's calculations.

From the performed analysis it follows that the dynamics of air transportation in Ukraine in 2006-2019 had a nonlinear trend of a rather complex structure. It is shown that in the intervals of the time series Y, where the increments of Y_{tr} are positive, it is possible to make sufficient quality predictions for next four quarters using the applied package TimeSeries. For these intervals, it also possible to use the NonlinearModelFit procedure described above to find the seasonal component of air passenger traffic.

6. CONCLUSIONS

The aviation transport plays significant role in activity of the transport complex of Ukraine, and has direct impact on sustainable development of the national economy. The share of aviation transport in export-import operations of Ukraine is gradually growing: export – 1,221,610.7 thousand dollars (21% of total exports of transport services), imports – 695,720.1 thousand dollars. Air transport is an effective catalyst for investment. Thus, in just 5 years (2014-2018), even under conditions of political instability and armed conflict in eastern Ukraine, UAH 4,503.6 million of capital investments were attracted to the industry. Transportation of passengers, cargo and mail call 34 national airlines, which performed 100.3 thousand commercial flights. The indicator of 12,529 thousand air passengers is 10.7 times higher than in 2000. Volumes of cargo and mail transportation by air transport of Ukraine in 2018 became 99.1 thousand tons.

The problem of allocating seasonal effects in a time series is mathematically quite complex. However, there are approximate methods that allow giving short-term forecasts

for cases where it can be assumed that air transport corresponds to the additive or multiplicative model. The use of seasonal influence adjustments in the analysis of air traffic allows to increase the accuracy and reliability of the information obtained, which will be used to support the management decisions of aviation specialists.

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