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ANALYSIS OF USING TIME SERIES METHOD FOR PREDICTION OF NUMBER OF PASSENGERS AT THE AIRPORT

Analiza wykorzystywania metod serii czasowych do przewidywania liczby pasażerów na lotnisku

Abstract: *At present, one of the most frequently discussed topics, not only at international conferences, but also within the EU, is the issue of airport financing, as well as the thresholds at which airports can cover their operational costs and when the need for support is justified. The Strategic Airport Development Plan and the Airport Business Plan are one of the most important support documents for making the right decision for airport financing and prepare the project for operational and investment aid. For preparing these documents is significant the category of the airport, that means the number of passengers. This paper is focused on the methodology how can be predict the number of passengers from previous data by used the time series method.*

Keywords: statistic data, one-dimensional time series, collection of time variations, transport trends, calendar distribution, period, passenger transport trend

Streszczenie: *Obecnie jednym z najczęściej dyskutowanych tematów, nie tylko na konferencjach międzynarodowych, ale także w UE, jest kwestia finansowania portów lotniczych, a także progi dochodowości, przy których lotniska mogą pokryć swoje koszty operacyjne oraz kiedy potrzeba zewnętrznego wsparcia jest usprawiedliwiona. Strategiczny plan rozwoju portu lotniczego i jego biznesplan są jednym z najważniejszych dokumentów pomocniczych przy podejmowaniu właściwej decyzji w sprawie finansowania portu lotniczego i przygotowania projektu do pomocy operacyjnej i inwestycyjnej. Do przygotowania tych dokumentów istotna jest kategoria lotniska, czyli liczba pasażerów. W niniejszym artykule skupiono się na metodologii przewidywania liczby pasażerów na podstawie wcześniejszych danych za pomocą metody szeregów czasowych.*

Słowa kluczowe: dane statystyczne, jednowymiarowe szeregi czasowe, zbieranie zmian czasu, trendy transportowe, rozkład kalendarza, okres, trend transportu pasażerskiego

1. Introduction

Nowadays, financial situation of regional airports in Europe is very complicated. For many years EU was discussing about the limitations of state aid for the airports in EU and their limits. Finally, in 2017 was created the Commission Regulation (EU) 2017/1084 amending Regulation (EU) No 651/2014 as regards aid for port and airport infrastructure. Regulation (EU) No 651/2014 (2) declares that certain categories of aid are compatible with the internal market and exempted from the requirement that they must be notified to the Commission before they are granted. In the light of the experience acquired by the Commission and in order to simplify and clarify the State aid rules, as well as to reduce the administrative burden of notifying straightforward State aid measures and to allow the Commission to focus on the potentially most distortive cases, aid for port and airport infrastructure should be included in the scope of Regulation (EU) No 651/2014. Investment aid to regional airports with average annual passenger traffic of up to 3 mil. passengers can improve both the accessibility of certain regions and local development, depending on the specificities of each airport. Such investment aid therefore supports the priorities of the Europe 2020 strategy contributing to further economic growth and objectives of common Union interest (Commission Regulation EU 2017/1084). The experience shows that investment aid to regional airports does not give rise to undue distortion of trade and competition, provided certain two conditions. The aid intensity should not exceed a maximum permissible aid intensity, which varies according to the size of the airport. In addition, the aid amount should not exceed the difference between the eligible costs and the operating profit of the investment. For very small airports of up to 200 000 passengers per annum, the investment aid should only be required to fulfil one of those conditions. The compatibility conditions should ensure open and non-discriminatory access to the infrastructure. The exemption should not apply to investment aid granted to airports located in the vicinity of an existing airport from which scheduled air services are operated, because aid to such airports entails a higher risk of distortion of competition and should therefore be notified to the Commission, with the exception of aid granted to very small airports with up to 200 000 passengers per annum, which is unlikely to result in significant distortion of competition (Commission Regulation EU 2017/1084).

The same conditions are in the case of operating aid to very small airports with up to 200 000 passengers per annum. In addition, the aid should not be granted under the condition that the airport operator concludes arrangements with one or more airlines relating to airport charges, marketing payments or other financial aspects of the airline's operations at that airport (Commission Regulation EU 2017/1084). If we want to imagine this complex situation in EU, we need to be friendly with the background of this field, which was Communication from the Commission-Guidelines on State aid to airports and airlines 2014/C 99/03, which classified the airports on the basis of which purpose the state aid is provided, to three categories: Investment aid to airports, Operating aid to airports and Start-up aid to airlines. The five categories of airports were identified according to this Guidelines (see fig. 1) and the maximum permissible aid intensity depending on the size of the airport as measured by the number of passengers per annum.

Fig. 1. Airport categories of investment aid to airports

For our research focused on regional airports and their definition are the first three categories the most important. State aid should be targeted towards situations where such aid can bring about a material improvement that the market itself cannot deliver. The five categories of airports were identified according these guidelines for operating aid to airports (see fig. 2).

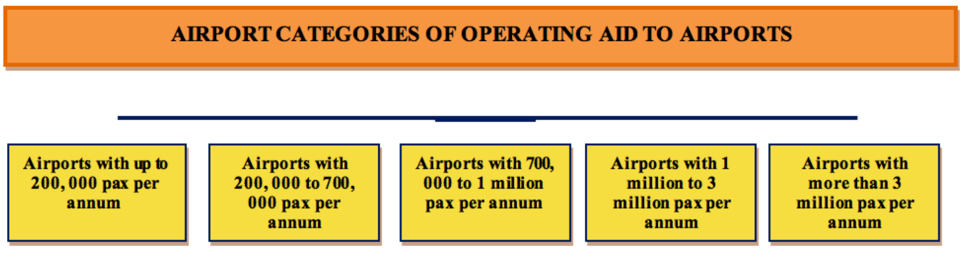

Fig. 2. Airport categories of operating aid to airports

According to Guidelines (2014) the start-up aid to airlines was divided into three categories (see fig. 3).

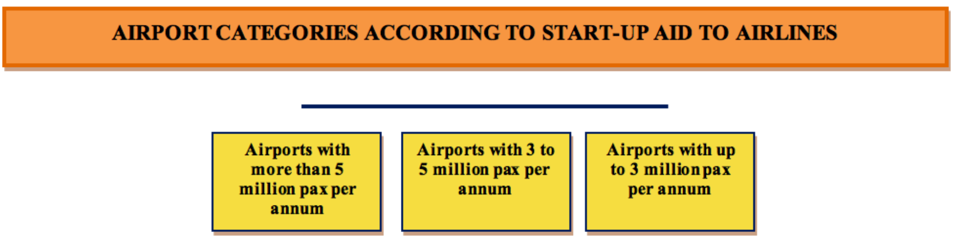

Fig. 3. Airport categories according to start-up aid to airlines

As a result of these cases can be identified the need to track the data of number of passengers per year (annum) at the airport. All six international airports in Slovakia are characterized as regional airport according to Commission Regulation (EU) 2017/1084. Piešťany, Žilina, Sliač and Poprad Tatry airports are the airports which handled every year not more than 200 000 passengers, so the State (or responsible subject in connection with Slovak legislation Act No. 213/2019 Coll. on charges and financial aid in civil aviation, which are Regions or Cities) doesn't need the notification of the EC for operating or investment aid. This act is the framework for State scheme in this field. Bratislava airport handled 2 152 000 passengers in 2018 that represents 18 percent increase compared to the previous year (Ministry of Transport, 2018), so the operating and investments aid projects have to be notified by EC. Very interesting situation is at the airport Košice, which become one of the fastest growing airports in Slovakia, as it has an almost ideal ´mix´ of passengers and furthermore, during the summer season, passengers from eastern Slovakia flew to various sea destinations, while the services of the low-cost carrier Wizz Air are used by all groups of travelers. Moreover, with transfer in Istanbul, the exceptional offer of Turkish Airlines provides connections from Košice to almost 300 destinations around the world. Last year handled 542 016 passengers, that means 9% increase [1]. At this airport the number of handled passengers in years 2007–2018 is 235 754 passengers per annum in 2012 to 590 919 passengers per annum. From previous research and analysis of the legislative framework and real data of each Slovak international airport, we have understood the necessity of tracking of the number of passengers per annum and prediction of these data. If the airport want to prepare the project of investment development with the ideal of investment aid or if they want to declare the necessity of the operating aid, the most important information or data are number of passengers per annum and future prediction of these data. If the airport is at the top or bottom level of the interval (category), the prediction is much more important. This is why we focused on the principle of time series enable to observe of air transport. It enables to prognoses the growth/ decrease of passengers in personal transport connected with its prognosis in the observed time period and perspectives into future by the resulting criterion of comparing the presented attributes on the principle of regression [2]. The use of time series shows the connection of mathematic, statistic, economic and IT theories for the purpose of measuring and empirical evaluation of the success of airports, which obviously depends on the number of passengers per annum. Seasonal character of air transport is observable through time series and shows its non-homogeneity. The growth of the market has enabled the development and growth of airports, which developed information systems which enable to create quality inputs into models enabling to create the prognosis of the development airports in the long-time horizon. An important condition of the correction of time series models is the quality of social demand on the growth and the importance in the social system [6]. From the viewpoint of science, the positive effect of time series is that they have become the means which enable to eliminate the influence of accidentalness [15]. In econometrics [3], as a scientific discipline for the connection of economics and statistical analysis, three approaches can be observed [3, 14]: Analytical research of specific research methods, Analytical-synthetic research of econometric models which present economic demands of science and practice [10] and application of econometrics in statistical analysis of particular economic data. The applied statistic is frequently used [8] in the analysis of economic data, namely:

- Statistics of random quality;
- Multivariable statistical analysis [8];
- Statistics of time series [3, 8];
- Statistics of non-numeric objects [7] including interval data statistics.

The presented four areas are given by mathematical principles, the selection of which is determined by the focus of research on the creation of econometric models. From the presented facts, it can be seen that it is possible to predict the future data with the use of tools of scientific analysis and modeling [9]. The paper is focused on the construction of suggested econometric models with the use of time series. The general theory of the economic models' construction enables to use a particular formula as a performance of variable regularity Y, in which X1, …, Xk are the selected variables influencing the quality which present certain different interest [11].

2. Econometric analysis using time series

The method of such an analysis as is used in our paper is applied to obtain the statistical data. The source of information is used to measure the necessary data on the examined object. The data are the registered values over time and are fixed at the moment of measurement of the respective characteristic values

$$y_i^j(t_k), (j = 1, 2, \dots, m),\ i = (1, 2, \dots, n),\ k = (1, 2, \dots, \infty). \quad (1)$$

If the variable number j and tracking object statistics number i are fixed, the sequence arrangements (1) of the measured characteristic values $y(t)$ creates a chronological (i.e. temporal) sequence of values:

$$y_i^j(t_1),\ y_i^j(t_2), \dots ,\ y_i^j(t_k). \quad (2)$$

The arrangement of the values according to (2) has the naming of one-way time series. At the same time, we observe y of one-time time series of the kind (2), i.e. when we follow their patterns in reciprocity for $j = 1, 2, \dots n$, we get an idea of the dynamics of y variables measured on any object. In this case, we are talking about the statistical analysis of multivariable time series:

$$y(t) = [y_1(t_k),\ y_1(t_k),\ \dots,\ y_1(t_k)]^T,\ (k = 1, 2, \dots, \infty). \quad (3)$$

Indeed, all the tasks associated with the need to conduct the analysis are associated with knowledge of economic dynamics and its base. Therefore, further consideration should be given to the method of identification design (i.e. statistical evaluation of parameters) as well as their verification. Describing these methods, we leave aside serious problems such as, for example, transmission functions of the systems used in designing control dynamic feedback circuits [7]. The analysis is performed with discrete one-time time series, whose shape corresponds to the moment of the observed (measured) value:

$$t_2 - t_1 = t_3 - t_2 = \cdots = t_k - t_{k-1} = \Delta t. \tag{4}$$

Therefore, the time series will appear in the following form:

$$y_{(1)}, y_{(2)}, \cdots, y_{(k)}. \tag{5}$$

In our research we applicated short-term and even medium-term view. A long-term view requires the implementation of variants and methods of organizing outgoing functions and the need for a subsequent expert estimate. The principles' description of the time series construction is a description of its signs. For this reason, a further notice of their class highlights the importance of time. Certain classes are determined by dynamic observation schemes for which elements (5) can be accurately identified as the expression of some random function at the same time difference Δt (4). It means that the rules of statistical analysis, including random variables, will be of a special character. On the other side, the consistency of the time series elements creates a specific base useful for predicting the values of the monitored pointer in tracking values $y(1)$, $y(2)$, ... This example illustrates the application, which presents an econometric basis for prediction of number of passengers per annum [12].

3. Time series analysis

The randomness of passenger can be adequately expressed by stationary time series. The evidence is the matrix whose rows represent the seasonality of passenger in the months of the year in the timeframe from 2007 to 2018. Let the set of a_{ij}, where i-row is the serial number of the month and j-column it the serial number of the year, represented by tab. 1 [1].

Table 1

Volume of passengers transported monthly from 2007 to 2018 at Airport Kosice [1]

YEARS	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
2007	21702	21358	25943	25431	30933	44315	58266	57110	42370	37505	42035	36480	443448
2008	36316	36169	40937	41649	45255	64108	84760	76365	61427	41900	32521	29512	590919
2009	26086	23813	27048	27960	27729	42274	50613	48075	29525	19240	15585	14512	352460
2010	12982	13228	16705	12293	17055	32545	44753	41713	30984	18115	14382	12305	267 060
2011	11954	12700	14095	13816	16848	30962	50299	46228	29869	14696	12951	12003	266421
2012	10308	11018	13401	12991	13424	27709	44134	42661	25473	14082	11228	9325	235754
2013	9641	10374	11822	11959	12180	27457	45989	41646	22893	14583	14217	14404	237165
2014	16137	14412	16689	17454	18876	40481	69830	64732	40428	21515	18792	17404	356750
2015	17006	16649	20650	20517	21134	47537	71656	69146	44139	29619	26677	25719	410449
2016	23515	21573	25849	27390	29766	40649	66740	67502	43690	31437	29079	29506	436696
2017	25529	23043	28261	30797	32419	47076	79569	80403	52620	34600	31584	30807	496708
2018	29625	29373	33058	35373	33525	52830	90008	89990	54493	34472	30472	29026	542026

Then, the analysis and synthesis of the model time series for monitoring passengers at regional airport Kosice is presented in fig. 4:

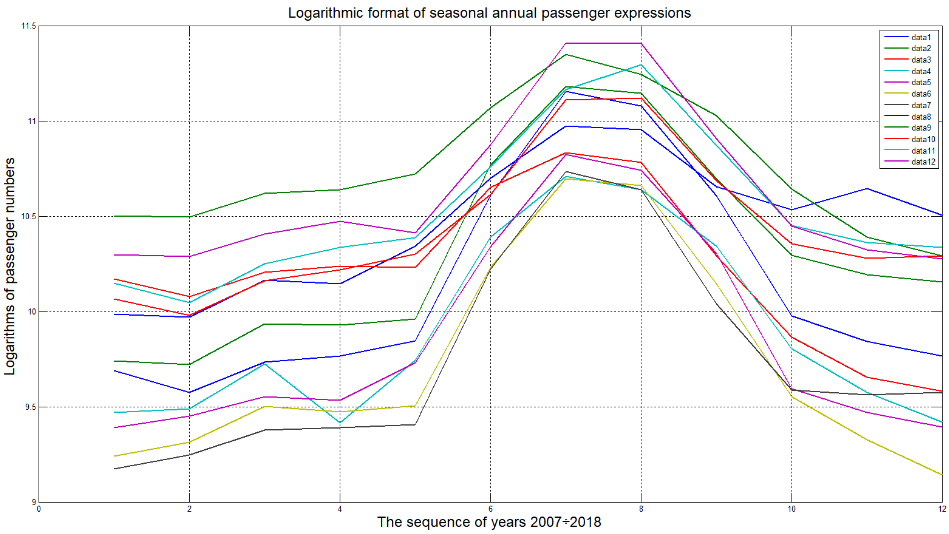

Fig. 4. The intensity and seasonality of passengers at Košice Airport

The presented matrix is with two inputs, which declare why to search correlation in the same line and in the same column is so important:

ts.TimeInfo.Format = 'dd-mmm-yyyy',is a solved problem

The task of the two-inputs collection is solved by the command:

tscol = tscollection(ts),

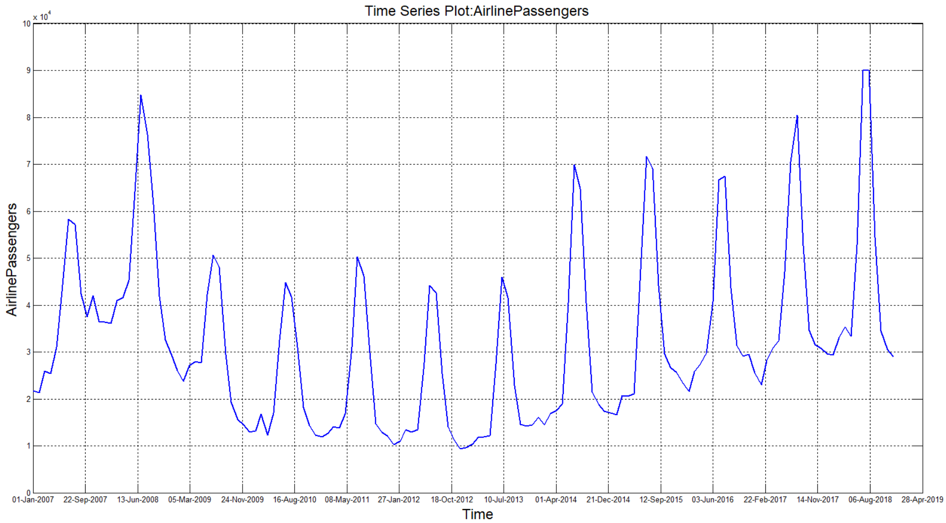

Fig. 5. Calendar Years' Time Series

The econometric analysis of passenger transport can be performed according to the rules used in the descriptive statistics. According to tab. 1 and using the Matlab program, it is possible to deduce quantitative information that qualifies (and quantifies) internal mechanisms. Regularly organized passenger numbers in calendar months and years in the reference period are a prediction for estimating the company's performance as a measurable magnitude of the economy. The area graph in fig. 4 demonstrates the amplitude shown in the traffic intensity and it has a highly seasonal character. Area graph with individual scales allows for a company to perform "filtering" of economic variables through organizational measures which shall alternate form of estimated transport activities. Figure 5 shows Calendar Years' time series and confirm the seasonality, which is highlight in logarithmic format (fig. 4) and for airport is important the knowledge of the trend.

4. Air transport trends at the Kosice Airport

The development of transport in each selected month in any selected year must be monitored with the development of transport of the same month in the previous year. The volume of calculations in such a file that presents tab. 1 is large and inconvenient for the airport's practical needs. The monthly passenger flow value is variable and varies considerably, and so the value distribution should be displayed using a logarithmic scale. We have assigned the file to the time series as their constants so that the collection accepts in the established logarithms:

tscol = addts(tscol, log(ts.data), 'logAirlinePassengers'),

logts = tscol.logAirlinePassengers

Calendar time is dated back command:

t = reshape(datenum(time),12,12)

logy = log(y)

The graph of trend whose difference values are determined by logarithms of matrix y and calculated mean values (ymean).

ymean = repmat(mean(logy),12,1)

ydiff=(logy-ymean)- the difference between the logarithm of a matrix and its mean value.

The difference between log y and y mean is:

ydiff = logy - ymean,

The value of the difference in the monthly coordinates x is (fig. 6):

tr = yr + (mo-1)/12

The model values are in fig. 3.

figure(3);plot(x,ymean,'b-',x,ymean+ydiff,'r-')

As a result of our research, we can identify the decreasing trends in the three years period of 12 monitored years.

According to the position of the mean values shown in fig. 3:

set(gca,'Position',[10.46   9.893   10.14   10.63]

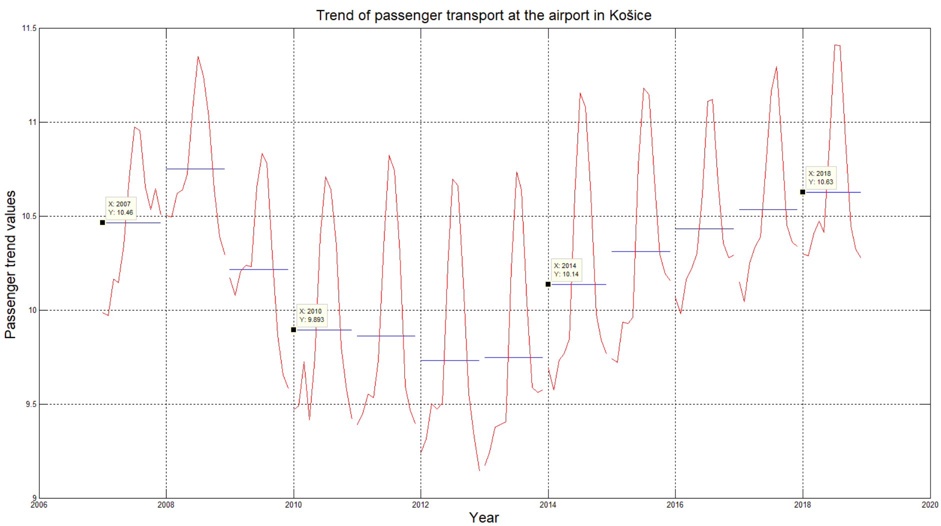

Fig. 6. Trend of passenger transport at the Košice airport

Variants of monthly mean values of the collections in 2007, ..., 2018, at the Košice airport (in the following text: mr = 0: 1: 11) are:

Vmk=[10.46 10.72 10.29 9.893 9.879 9.755 9.733 10.14 10.26 10.39 10.54 10.64 10.63];

tr=0:1:12;

[tr;Vmk]

Figure 4 is: plot(tr,Vmk,’b’,’LineWidth’,3),grid on

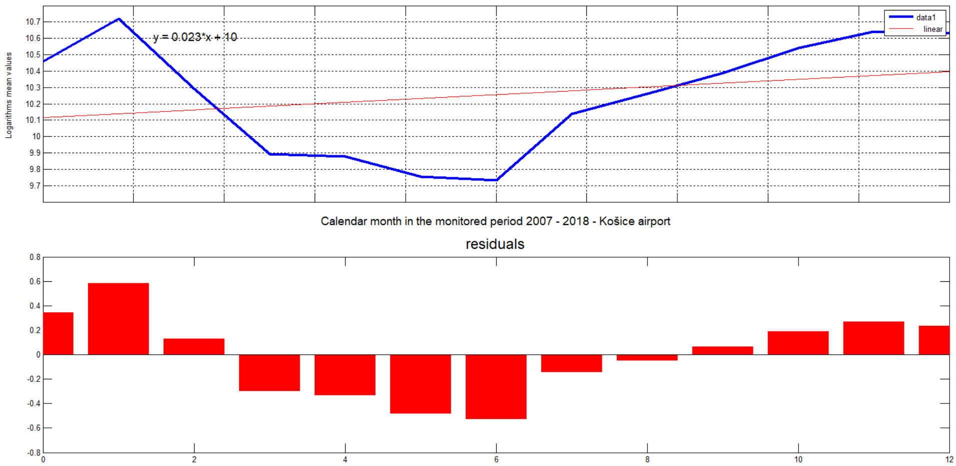

Fig. 7. Mean values of monthly collections in passenger air transport in the reporting period

As one of the results of the research, we can conclude in accordance with fig. 7 that the trend of passenger transport at the Košice airport has been increasing in the reporting period. The new comparative model of passengers in air transport was created after comparison of the “ydiff” and the trend.

figure(8a,b);subplot(2,1,1),plot(x,ymean,'b-',x,ymean+ydiff,'r-')

Figure 8a shows the difference between the annual sums of mean y mean and the difference ydiff.. Figure 8b is the monthly difference between the mean and difference mean. Meaning of display - identification of annual and monthly trends of transported passengers.

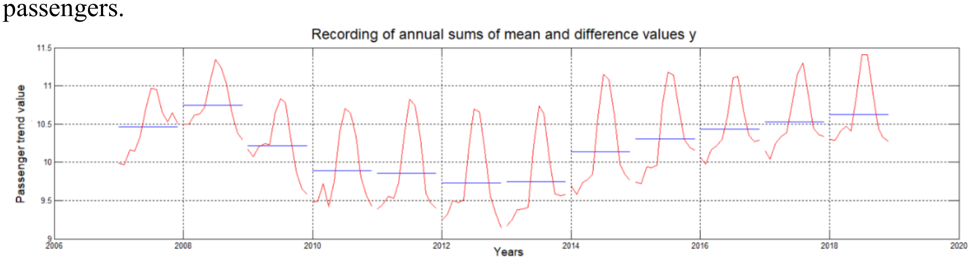

Fig. 8a. The graph of annual sums of mean and difference values *y*

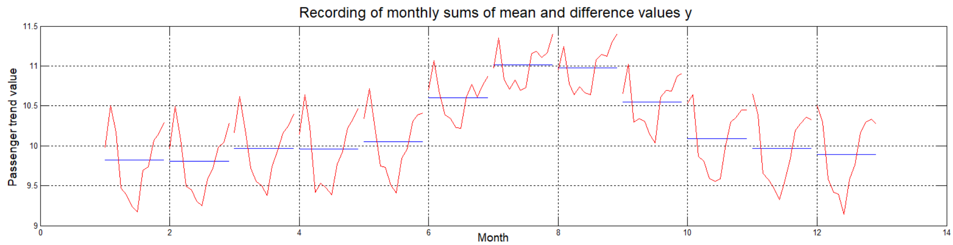

Fig. 8b. The graph of monthly totals of mean logarithmic and difference values *y*

Compare the logarithmic time series of logts to the sum of the mean and differential values of the collection: figure(8b);plot(logts),grid on.

To illustrate the trend we should apply the regression model (fig. 7), when variable shift of the months in the time of year with unchanged layout of the passenger collection by the calculation of regression gradually determine: X = [dummyvar(mo(:)), logts.time]; arise (artificial) differential complement (residium). Link regression of complement (missed bint): [b,bint,resid] = regress(logts.data, X) with time tscol: tscol = addts(tscol,X*b,'Fit1'), hold on, research of attribute (Fit) the sum of time series collection and complement X. plot(tscol.Fit1,'Color','r'),hold off, grid on (fig. 9).

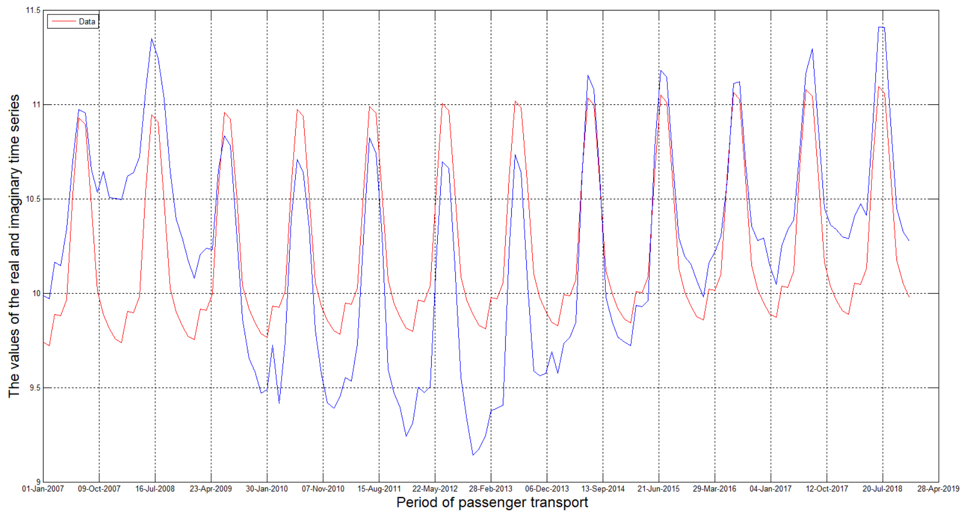

Fig. 9. The graph of the time difference of the intended displacement and the time of the logarithmic time series

Legend: red-thought time series, blue- real time series

The difference between Fit and the logarithmic time series shows the trend of transported passengers at monitored airport. The value of the trend is determined by the add-on resp. residue (residue). For detailed desciption we used command: Tools a Basic fitting in Matlab and we can identify it as: tscol = addts(tscol,resid,'Resid1') figure(10);plot(tscol.Resid1),grid on

The variability of the adjacent residue to the time series may or may not be correlated. Positive correlation is at large values on the x-axis, which also corresponds to large values on the y-axis (residual data). For our next research we used Durbin Watson method of test statistic, where „p" indicates rejection of the hypothesis of the existence of correlation at the 5% significance level:

[p,dw] = dwtest(tscol.Resid1.data,X), Durbin Watson test means the artificial displacement of the variable months in logarithmic time series: [p,dw] = dwtest(tscol.Resid1.data, X) and the calculated value is: p = 7.1429e-77, dw = 0.0820.

The existence of other test methods makes it possible to objectify the applicability of the Durbin Watson method in prediction of number passengers.

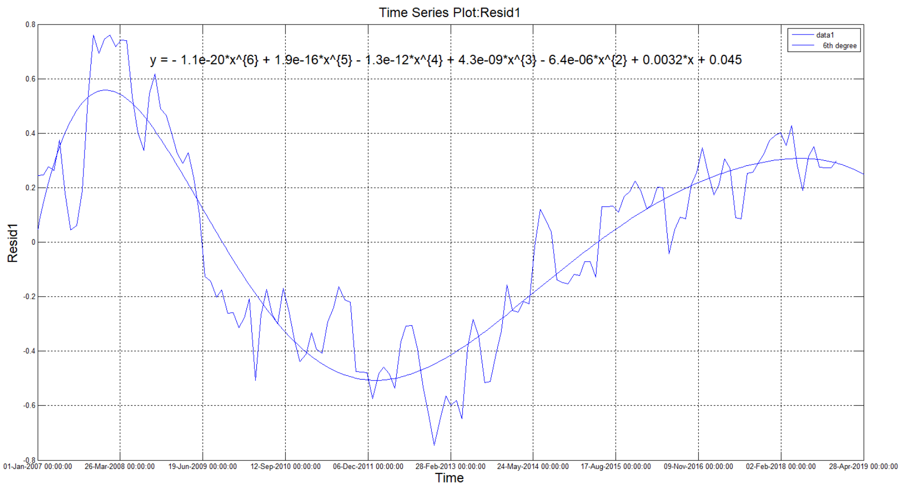

Fig. 10. Mean values of monthly collection of passenger number in the reporting period

5. Conclusions

The results of the research are very important for prediction of number of passengers. We used data of reporting period (2006–2018) and mathematical models of time series, which showed specific increases or decreases in passenger numbers at the airport. The analyzed results can used by the airport operator in the moment of creation the strategy of the development of the airport or planning the business plan.

The results of the analysis are a regressive mathematical model, which in the form of the function of fig. 5 will show the trend in passengers number development at the airport. It means that the described method has relative and conditional character of use depending on the activities of the airport operator and its strategy. This method can be very useful for other regional airports in Slovak republic during creation of their development strategies and business plan. The Slovak Ministry of Transport and Construction for creation the national schema for financing the Slovak airports can used this method for prediction the number of passengers at Slovak regional airports. With these data they can decide if the investment and operational aid is justified and allowed of the notification of EC will be necessary.

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