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PRICING MODELLING IN THE AIR TRANSPORT MARKET

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МОДЕЛЮВАННЯ ЦІНОУТВОРЕННЯ НА РИНКУ АВІАПЕРЕВЕЗЕНЬ

One of the main conditions for a rational organization of transport activity and its profitability is the competent, qualitative and systematic formation of prices for transport services. In addition, where it is impossible to create a competitive environment, conduct a balanced tariff policy of the state. Transport fare is a fee for moving services. Its role in the activity of this or that type of transport company is difficult to overestimate, since the level of tariffs depends on the profitability, and hence the financial stability of competitiveness. The article proposes a series of mathematical models for forecasting average annual tariffs for passenger air transportation on the domestic USA market. Descriptive statistics and simulation modelling tools were used in constructing models. Since the basis of the simulation model is the discrete law of distribution of the average annual prices for airline tickets, the prospect of further research will be finding and justifying the continuous law of price distribution and the construction of mathematical models on this basis.

Одним з головних умов раціональної організації діяльності транспорту та його прибутковості є грамотне, якісне і планомірне формування цін на транспортні послуги, а там, де неможливе створення конкурентного середовища, проведення виваженої тарифної політики держави. Транспортний тариф - це плата за послуги з переміщення. Його роль у діяльності того чи іншого виду транспорту транспортного підприємства важко переоцінити, оскільки від рівня тарифів залежить прибутковість, а значить, і фінансова стабільність конкурентоспроможність. В статті запропоновано ряд математичних моделей прогнозування середньорічних тарифів на пасажирські авіаперевезення на внутрішньому ринку США. При побудові моделей використовувались інструментарії описової статистики та імітаційного моделювання. Так як основою імітаційної моделі є дискретний закон розподілу середньорічних цін на авіаквитки, то перспективою подальших досліджень буде знаходження та обґрунтування неперервного закону розподілу ціни та побудова математичних моделей на цій основі.

Keywords: *pricing, passenger air transportation, descriptive statistics, simulation.*

Ключові слова: *ціноутворення, пасажирські авіаперевезення, описова статистика, імітаційне моделювання.*

Formulation of the problem. Passenger transportation from one point to another is a kind of commodity. As with any other product, the price of the carriage is affected by demand, supply and costs. The peculiarity of air transport, which distinguishes it from terrestrial species, is the speed of passenger transportation, taking into account all the time that the passenger should spend on a passenger from the moment of departure from the place of departure to the destination. For short distances (up to 500 km), rail and road transport have an advantage over air transport, with much less time spent on ground handling. However, with increasing travel distances, passengers prefer air transport. Moreover, the price for tickets is also influenced by the use of passengers by air.

The purpose of the paper is to study the field of passenger air transportation, analyze the pricing of passenger transportation and analyze the general trends in airfare prices on an example of American airlines, starting from 1995 to 2016.

The analysis of recent research and publications. The subject of the pricing modeling in the air transport market was studied by such scientists as, G. Samoilenko, U. Kuidich, N.I. Kabushkin, and others. Analysis of research papers and gives reason to believe that this area is not explored to this day.

The object of research is the domestic market of American air travel.

The presentation of main material and results of the research. After analyzing a number of literary sources [1-6], we conclude that the demand for airfare depends on such factors:

- seasonality – there is a high season when many people want to fly: New Year, May holidays, summer holidays, but there is a low season when people fly less. In winter, on the contrary, in many areas prices are lower;
- days of the week: usually on weekdays the demand is lower than during the day off and the ticket price may be lower;
- time of day: there are more and less popular flights;
- reservation dates: airlines are seeking to sell their flight tickets as early as possible, so they encourage passengers to buy them in advance.

Airlines plan how many seats and at what price to sell. For example, for sale at a minimum cost is allocated 20 seats. Once they are booked, you will be offered a bigger price and so on. In turn, the offer for airline tickets depends on:

- quantity and quality of competitive offers from airlines in a specific direction: the more carriers operate from point A to point B, the higher the competition - and now more cheap offers - special tariffs, sales, promotions;
- the presence or absence of communication with alternative modes of transport, for example, by rail.

Airlines are, in essence, manufacturers of complex and integrated services, "air transportation", and in this case, to "production costs" can be credited: the type of aircraft, the number of seats, predictable loading by passengers; the cost of air navigation services; cost of airport services; flight range, fuel consumption per kilometer; personnel costs, crew training, staff placement in the host country; other expenses. In addition, the ticket price can be influenced by the marketing strategy of the company.

Airfare is the price at which the airline transports passengers from airport A to airport B under certain conditions.

There are several classifications of passenger air transport tariffs known by carriers. Distinguish tariffs published and confidential. The published airline tariffs are controlled by the International Air Transport Association. They are used mainly for the calculation of complex routes

with the involvement of several carriers. Tickets for published airline tariffs can be purchased anywhere in the world, but the price is usually high.

Confidential tariffs are formed by airlines on their own, taking into account the demand, competition and strategy of the company in a separate direction. Such tariffs are a commercial secret for competitors. They are operated on the airline itself and its agents.

Such tariffs are a commercial secret for competitors, they operate on the airline itself and its agents. Confidential tariffs apply, for example, when a person buys a round trip at one airline.

Separately, it is necessary to consider this kind of air transportation as low cost and their ways of setting prices for tickets. Air low-cost carriers, as well as Low-cost airlines - airlines that provide air transportation services for passengers at prices lower than the traditional airlines. The native land of the concept of low-cost - the USA, namely the company Southwest Airlines, from which it spread to Europe in the early 1990's and further in many countries around the world.

The pricing in budget airlines is influenced by many factors. The first is the high loading of planes. One plane in Lowestoft performs a lot of flights a day, and the company is sometimes willing to sell a ticket for 1 euro, if only to run it half way.

The second factor - a plane ticket does not include any additional services. Baggage, food, drinks, even a comfortable place for the feet - all at an additional cost.

The third point is the use of airports. Cheap airlines are often based at small airports, and the main transport hubs are either bypassed or rented for half an hour. Smaller airports in smaller cities are much cheaper, and some are even willing to pay extra to the carrier, hoping that in this way a tourist will be brought to the city.

Let's turn to the analysis of the domestic market of American air travel. Based on available statistics for 1995-2016, pricing trends suggest a steady decrease in the cost of airfares, as can be seen from Fig. 1.

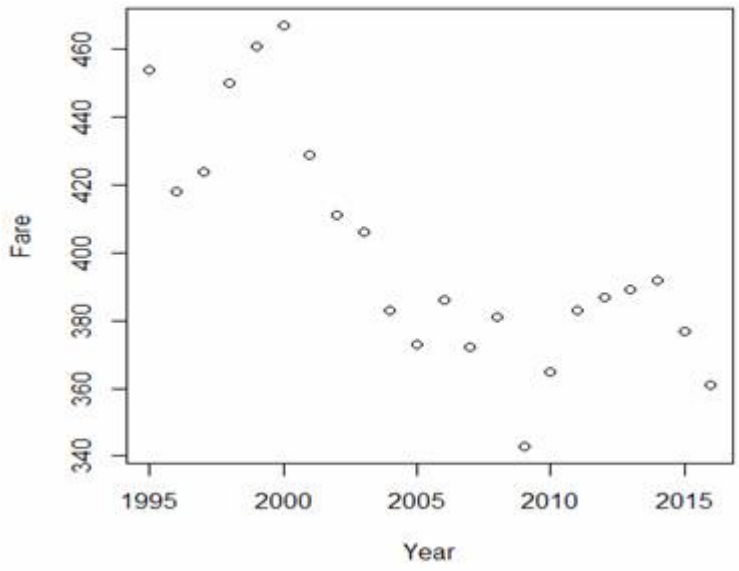

Fig. 1. Annual U.S. Domestic Average Itinerary Fare in 2016 Constant Dollars

Source: Built by authors on the basis of [1]

We will analyze the above prices using the descriptive statistics toolkit. To this end, we will construct a Box-Whisker graph in Fig. 2, and we will analyze it in detail.

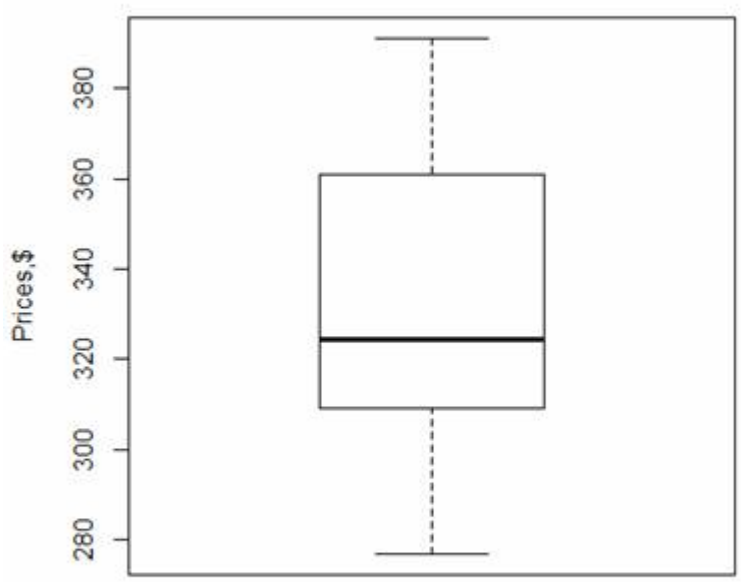

Fig. 2. Box-plot of the Annual U.S. Domestic Average Itinerary Fare in Current Dollars

Source: Built by authors on the basis of [1]

Analyze the time series of average airfare prices. Thus, according to fig. 2, for the last 10 years, the minimum ticket price was $ 277, 25% of all tickets cost less than $ 309.2. 50% have a price lower than $ 324.5, and the other half is more than this number. On average, 1 domestic ticket costs 331.1 dollars, and the maximum cost is 391.0, while 75% of tickets are cheaper than 357.2 dollars.

Based on the conducted statistical analysis, it is advisable to analyze the trend line and determine the general tendency of prices for domestic flights.

After analyzing Fig. 1, assume that this trend is linear, so let's express the dependence of the price of the ticket on the period of the linear function $Fare = b + Year \times x$.

Using the tool pair linear regression [7-10] we obtain the trend equation

$$Fare = 8637{,}704 - 4{,}107x \quad (1)$$

This equation is a prediction equation that can be used to predict future prices. It's enough to just put the desired year into formula ($Year$).

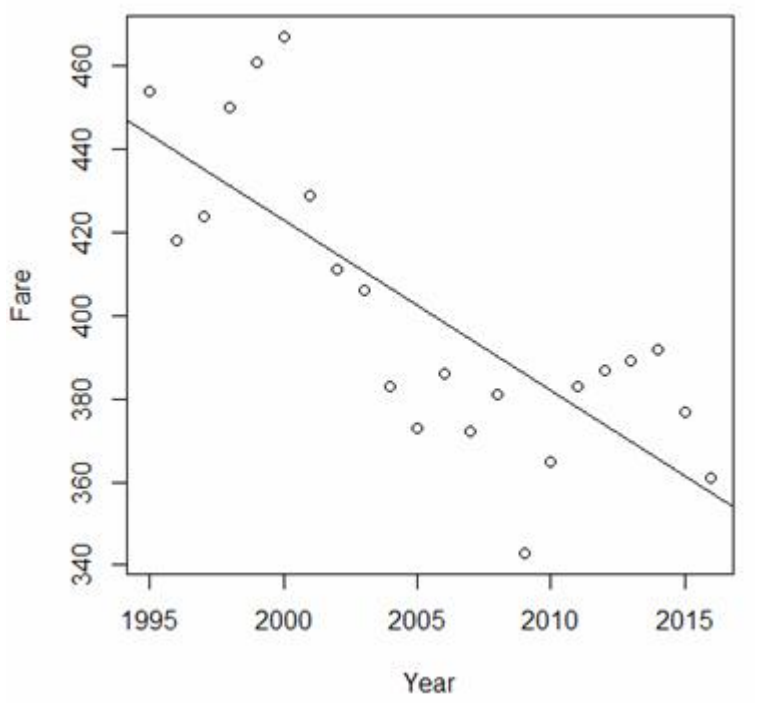

Fig. 3. Annual U.S. Domestic Average Itinerary Fare and trend line in 2016 Constant Dollars

Source: built by authors on [1]

Then, we will try to construct a forecast for the average annual price for airfares for 2017-2025, using the equation (1):

Table 1.

The forecast for the average annual price for airline tickets for 2017-2025 on the basis of the trend line

Year	Fare
2017	353.885
2018	349.778
2019	345.671
2020	341.564
2021	337.457
2022	333.350
2023	329.243
2024	325.136
2025	321.029

Source: calculated by the authors independently by the formula (1) and data [1]

However, the disadvantage of this approach is that the price will always fall, while global fuel price trends, in turn, indicate a return. So, we will try to predict the average prices for air tickets on the basis of a discrete law of distribution of historical prices for airline tickets.

Using the toolkit of descriptive statistics, we define the discrete law of the distribution of the random value of the price of the ticket. To do this, we build a histogram of frequency distribution for airfares.

To determine the number of histogram intervals, use the Sturges' rule [7]:

$$n = 1 + 3.332 \lg N \approx 5 \qquad (2)$$

Where n is the number of intervals, N is the volume of choice.

To determine the size of the intervals (step) h, set the maximum and minimum prices for the ticket. Then we get:

$$h = \frac{x_{max} - x_{min}}{n} \approx 25 \ .$$

Determine the likelihood of the price of a particular interval, which is calculated in Table 2.

Table 2.

Interval number	Lower limit prices	The top price limit	Average price	The frequency of falling prices in the interval	The probability of a price in the interval	Cumulative
1	343	368	355	3	0,136364	0
2	368	392	380	10	0,454545	0,136
3	392	417	405	2	0,090909	0,59
4	417	442	429	3	0,136364	0,682
5	442	467	454	4	0,181818	0,818
The sum				22	1	

Source: calculated by the authors independently according to [1]

Then the density function of the distribution of average prices for airfares will look like in Fig. 4.

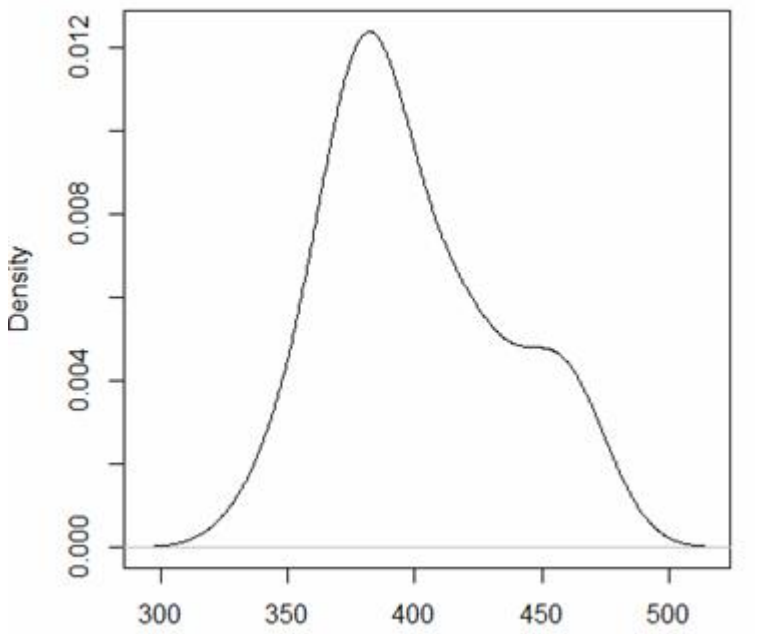

Fig. 4. The function of density distribution of average airfare prices

Source: calculated by the authors independently according to [1]

Consequently, taking for x the random value of the price of the ticket, we obtain the function of density distribution of prices:

$$f(x)=\begin{cases}0{,}136, & x \le 368\\ 0{,}455, & 368 < x \le 392\\ 0{,}091, & 392 < x \le 417\\ 0{,}136, & 417 < x \le 442\\ 0{,}182, & x > 442\end{cases} \quad (3)$$

Then the integral function of the price distribution density will look

(4)

$$F(x)=\begin{cases}0, & x \le 368\\ 0{,}136, & 368 < x \le 392\\ 0{,}591, & 392 < x \le 417\\ 0{,}682, & 417 < x \le 442\\ 0{,}818, & x > 442\end{cases}$$

Next we will determine the price forecast for the next month. For this purpose, we will apply the simulation modeling tool based on the discrete probability distribution (3) - (4) found.

Let the probability of occurrence of a price in one or another interval for 1 day can be randomly distributed in the range from 0 to 1. In particular, to develop the first simulation model, we will conduct 22 experiments on the appearance of the indicated probability, which are given in Table. 3.

Table 3.

The predicted price is found on the basis of the simulation modeling

Experiment No.	Probability appearance of the price on the interval	Average price
1	0,880	454
2	0,252	380
3	0,598	405
4	0,593	405
…	…	…
21	0,968	454
22	0,889	454

Source: calculated by the authors themselves

In table the 3 field of the average price corresponds to the integral probability distribution function *F(x).* For example, for the first experiment, the probability 0.88 falls in the interval from 0.818 to 1, then the price for the ticket corresponds to the lower limit of the interval and will equal 454. Similarly, the rest of the experiments were carried out.

According to the results of simulation of the prices for air tickets table 3, in the first forecast period, it can be either 454 days, or 380, or 405, etc. Then on average in one day the price $E(x)$ will be

$$E(x)=\frac{\sum_{i=1}^{22} x_i}{22} \approx 380 \$. \quad (5)$$

The root mean square deviation, in this case, will be σ(x)=37 $.

Similarly, we will simulate new probabilities of the emergence of a new price for the second forecast period, which are presented in Table 4.

Table 4.

Estimated prices based on simulation modeling

Experiment No.	Probability the appearance of prices on the interval	Price
1	0,280912	380,0
2	0,22536	380,0
3	0,732077	454,2

4	0,400446	429
…	…	
21	0,9497	380,0
22	0,995383	380,0

Source: calculated by the authors themselves

That is, the price in the second forecast day can be either 380, or 454, or 429, etc. Then, on average for the second day, the price will be 385 with a mean-square deviation of 3.38.

Similarly, using the simulation model with the "tightening" of the random variable x the price of the airline ticket to the discrete law of probability distribution, we obtain a forecast for the next 9 years.

Table 5.

Year of the forecast	Price for the ticket
2017	429,5
2018	404,7
2019	355,2
2020	380,0
2021	
2022	
2023	
2024	
2025	

Source: calculated by the authors independently on the basis of (5)

Compare the results:

Table 6.

Year of the forecast	Forecast by the regression model	Forecast by the simulation model
2017	353.885	404,7
2018	349.778	429,5
2019	345.671	355,2
2020	341.564	380,0
2021	337.457	396,7
2022	333.350	360,25
2023	329.243	374,8
2024	325.136	418,04
2025	321.029	355,22

Conclusions and perspectives of further research. One of the main conditions for rational organization of transport activity and its profitability is the competent, qualitative and systematic formation of prices for transport services, where it is impossible to create a competitive environment, conduct a balanced tariff policy of the state. Transport fare is a transfer fee. Its role in the activities of this or that type of transport company can not be overestimated, since the level of tariffs depends on the profitability, and hence, financial stability, survival in the competition. The article proposes a series of mathematical models for forecasting average annual tariffs for passenger air transportation on the domestic US market. When constructing models, tools used for descriptive statistics and simulation modeling were used. Since the basis of the simulation model is the discrete law of distribution of average annual prices for airline tickets, the prospect of further research will be finding and justifying the continuous law of price distribution and the construction of mathematical models on this basis.

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