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Modelling the Assessment of the Potential Changes in Air Transportation Rates Based on Cost Components

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ABSTRACT

The price of transportation (rate) is one of the key factors in the development of the air transportation system (ATS) of any country, in particular of the Russian Federation. In turn, the formation of the rate directly depends on the cost price of transportation and its components. Forecasting and modelling the cost prices considering the influence of external factors allows us to obtain an assessment of the potential of changing the rate, which can be used as an indicator of the direction of ATS development and adjustments to improve its efficiency.

The objective of the study is to develop a model for assessment of the potential of changes in air transportation rates in the Russian Federation in the 2030–2040 period for the fleet of foreign-made mainline aircraft. The assessment of the potential for rate changes is based on changes in the most significant external components of the cost price of transportation, such as fuel cost, annual flight time, cost of maintenance and repair. The choice of components is due to their greatest exposure to the influence of long-term factors.

Using mathematical modelling and economic and mathematical methods, based on statistical and forecast data, the model has been tested for an assessment of the potential change in the value and structure of direct operating costs of mainline aircraft regarding aggregated expense items. Using scenario assumptions, intervals of variation of factors affecting cost price were determined. The result of modelling the potential for change in cost and rates is demonstrated for two groups of mainline commercial aircraft: narrow-body and wide-body.

Keywords: *air transportation, cost price, rate, operating costs, mathematical modelling.*

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BACKGROUND

Price (rate) is a key factor influencing demand for air travel. At the same time, the rate is directly related to the cost price of air travel, i.e. it depends on the direct and indirect costs required to perform flights and operate the company. The main expense items that form the airfare include servicing passengers, baggage and aircraft at the airport, costs of aviation fuel, aircraft maintenance and repair, insurance and leasing, payroll, advertising and administrative costs, commissions and fees, air navigation and meteorological support, and aircraft depreciation [1–4].

At the same time, the airfare is also affected by the degree of competition and changes in the solvent demand of the population. Thus, on lines with many carriers, air tickets can often be sold below cost price to maintain the company's position in the market. The commercial policy of the company also has a significant impact on the airfare. In this case, the significant impact is provided by periods of flight operations (seasonality) [5] during which airlines vary a schedule and set different rate levels. At the same time, airlines often use the principle of price discrimination of passengers [6], when consumers can pay different fares for the same air travel since airlines, as a rule, have many rates for each destination, which differ in terms and conditions of booking. The main «limitations» include [7] early booking (minimum time before departure, calculated in days), spending Saturday evening at the destination, accrual of miles (bonuses) to frequent flyers, the possibility of returning/exchanging a ticket, the airline's schedule.

The airfare can also be affected by the consumer's appurtenance to a certain social group, e.g. special rates for youth, children, students, retirees. Some of these social groups are included in air travel subsidy programs[1].

However, it should be noted that most of the above factors are elements of the airline's operations management (revenue operations management) [8; 9] and are practically not related to the fleet in operation. Therefore, the only factor that has a significant impact on the rate level in the long term and is related to fleet is the cost price of air transportation. It is its change that largely determines the potential volume of air transportation [3; 10], revenue and profit of the company.

Currently, several problems can be identified in the field of operation and maintenance of aircraft [11], which in turn can potentially have a significant impact on the structure and amount of operating costs and, therefore, can entail an increase in the level of air transportation rates. Thus, the *purpose* of determining the potential rate changes is relevant for planning the airlines strategy and forecasting the demand for air transportation and development of the air transportation system (ATS) as a whole.

To determine the potential change in air transportation rates, the study using *mathematical modelling* [1; 12–14] and *statistical and forecast input data*, available at open sources at the moment of the research, developed an assessment model of the change in the value and structure of aircraft direct operating costs (DOC), including the following consolidated items: aviation fuel and lubricants, maintenance and repair, flight and cabin crew wages, airport costs, ownership. Among the most significant external conditions affecting the assessment of the cost of transportation under the influence of long-term factors, three are highlighted: cost of fuel and of maintenance and repair as well as annual flight time.

A scenario analysis of the change and sensitivity of the structure and total value of the cost price of air transportation was carried out for the identified factors. To test the application of the model for each of the factors, scenario variation intervals were considered. Based on the results of the change in the cost price and its components, obtained during testing, the scenario intervals of rate change were considered in the long term for 2030–2040. The result of the assessment of the potential rate changes is presented for mainline aircraft of foreign manufacture.

RESULTS

Determination of variation intervals of factors, influencing cost price

The cost and type of fuel are key conditions for determining the fuel efficiency requirements of advanced engines. Since the cost of aviation fuel has historically been strongly correlated with the oil prices[2], it can be expected that the average cost of fuel for the period 2030–2040 will change

[1] Resolution of the Government of the Russian Federation dated 02.03.2018, № 215. [Electronic resource]: http://static.government.ru/media/files/oY69DJH21BsDYTYg9wGksgA7AbEN8AVi.pdf. Last accessed 29.01.2024.

[2] Jet Fuel Price Monitor. [Electronic resource]: https://www.iata.org/en/publications/economics/fuel-monitor/. Last accessed 29.01.2024.

significantly under the influence of changes in the oil prices. At the same time, an additional impact will be exerted by the expansion of the use of synthetic aviation fuel and the introduction of various types of fees for extra greenhouse emissions into the atmosphere – the so-called «carbon tax» [15–17].

To assess the cost of jet fuel (aviation kerosene), the values of 85–105 US dollars per barrel, were used as forecast values for the cost of oil in 2030–2040, those values are also present as assumptions in the FAA [3] and EU [4] forecast. At this oil price, the cost of jet fuel will be from 730 to 930 US dollars per ton.

With the overall tightening of environmental requirements in the period 2030–2050, conventional and hybrid engines may largely switch to the use of bio- or synthetic fuel, SAF (Sustainable Aviation Fuel). The transition to SAF may significantly increase the actual cost of fuel relative to the projected oil price. Considering the forecasted increase in the share of such fuel in the total volume of aviation fuel by the International Energy Agency from 10 % in 2030 to 19 % in 2040, the real cost of aviation fuel can amount to from 864 US dollars per ton to 1020 US dollars per ton [5].

The spread of the practices of introducing a carbon tax may also result in the future in an additional increase in the cost of fossil fuel. As an assumption for calculating the increase in the cost of jet fuel, the carbon tax value can be taken as 50 US dollars per ton of CO_2e in 2030 and 200 US dollars per ton of CO_2e in 2040 [6], which, when converted to a ton of jet fuel burned, would correspond to a cost of 157 US dollars to 630 US dollars per a ton. In this case, the cost of a mixture of fossil and synthetic fuels in 2035 would be 1100–1500 US dollars for a ton.

In Russia, the prospects for introducing a carbon tax and biofuel production are currently unclear. At the same time, a complete rejection of fossil fuels seems unlikely. The average cost of fuel in Russia generally reflects the dynamics of world prices but is less susceptible to fluctuations. The most realistic range of average cost of aviation fuel for the conditions of the Russian Federation in terms of traditional engines in 2030–2040 seems to be from 730 US dollars to 1100 US dollars per ton. Since the price of aviation fuel on the world market has recently demonstrated high volatility, the value of 1500 US dollars per ton was additionally considered. The base value of the cost of aviation fuel is taken as 850 US dollars per ton [7] (in 2021 prices).

Maintenance and repair costs are an important component of the cost price. Since most modern aircraft analysed in the study use many foreign-made components and technologies, assumptions in forming the scenarios comprise an increase in expenses under this item, including due to exchange rate changes in cost, complication and increased cost of spare parts delivery logistics. Since it is currently impossible to predict the exact balanced value of the relative change in the cost of maintenance and repair, the coefficients of change in the cost of maintenance and repair per flight hour were taken as scenario assumptions for model calculations equal to 1 (without increase in the cost), 1,3 (slight increase in the cost) and 1,7 (high increase in the cost).

The annual flight time is closely related to the possibility of carrying out maintenance and repair and has a direct impact on the volume of operations performed per year. A decrease in the indicator of maintenance and repair leads to a proportional decrease in the annual volume of operations and, accordingly, to the same increase in the specific cost of ownership of an aircraft.

When carrying out model calculations, the annual flight time relatively characteristic of different aircraft was assumed for three scenarios at the level of 1 (flight time is the same), 0,85 (slight decrease in flight time), 0,7 (high decrease in flight time).

Flight and cabin crew labour costs for the calculations were fixed at current levels typical for aircraft classes.

Airport charges were estimated for aircraft classes by obtaining weighted average airport

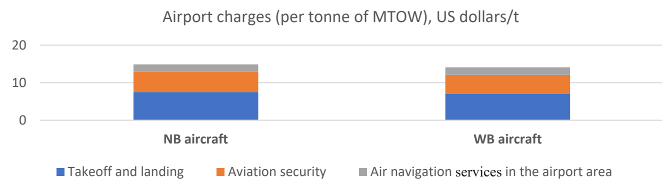
[3] FAA Aerospace Forecast Fiscal Years 2023–2043. [Electronic resource]: https://www.faa.gov/sites/faa.gov/files/2023-FAA%20Aerospace%20Forecasts.pdf. Last accessed 29.01.2024.

[4] Hydrogen-powered aviation. A fact-based study of hydrogen technology, economics, and climate impact by 2050. [Electronic resource]: https://op.europa.eu/en/publication-detail/-/publication/55fe3eb1-cc8a-11ea-adf7–01aa75ed71a1 Last accessed 29.01.2024.

[5] Aviation fuel consumption in the Sustainable Development Scenario, 2025–2040. [Electronic resource]: https://www.iea.org/data-and-statistics/charts/aviation-fuel-consumption-in-the-sustainable-development-scenario-2025–2040 Last accessed 29.01.2024.

[6] Hydrogen Insight 2021. [Electronic resource]: https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021.pdf Last accessed 29.01.2024.

[7] Federal Air Transport Agency. [Electronic resource]: https://favt.gov.ru/dejatelnost-ajeroporty-i-ajerodromy-ceny-na-aviagsm/ Last accessed 05.03.2022.



Pic. 1. Airport charges [performed by the authors].

charges based on the volume of operations for aircraft of different classes at airports within the air transport system of the Russian Federation (Pic. 1). The charges were assumed at approximately 15 US dollars for narrow-body (NB) aircraft and approximately 14 US dollars for wide-body (WB) aircraft per ton of maximum take-off weight (MTOW).

Based on the data on the flight performance characteristics (FPC), the levels of direct operating costs were estimated for modern foreign-made aircraft for which data on the technical features is available.

Since the seat layout and nature of the use of aircraft may differ significantly from company to company, the following assumptions were made for comparability of the results of estimation of the level of specific costs: (1) for all aircraft within the same class, the same value of average flight time corresponding to the aircraft class was assumed; (2) for all aircraft, for calculations single-class cabin layouts with the same seat pitch were assumed.

The scenario cost estimates were grouped for two classes of commercial mainline aircraft under consideration: narrow-body aircraft, wide-body aircraft.

To determine potential changes in the cost of transportation, calculations were performed based on the basic scenario values of counting of the change intervals for the three factors under consideration: (1) fuel cost – 850 US dollars; (2) – change in the cost of maintenance and repair – 0 %; (3) decrease in flight hours – 0 %. Since these factors separately affect independent cost items, their impact can be considered separately.

To determine the cost, based on open data[8],[9] on the transportation of passengers and goods, the average journey distances were estimated for the aircraft classes under consideration.

[8] FlightRadar24 [Electronic resource] https://www.flightradar24.com/ Last accessed 29.01.2024.

[9] Federal State Statistics Service [Electronic resource] https://fedstat.ru/ Last accessed 29.01.2024.

Estimation of direct operating costs regarding mainline aircraft

Estimation of direct operating costs (DOC) were obtained using mathematical modelling and economic-mathematical methods, based on available statistical data and dependencies [1; 14]. These calculations are largely conditional in nature, are not related to the operational performance of individual companies, do not consider changes that have occurred in the period since the preparation of the research materials, and are used exclusively to test the proposed calculation model within the framework of the specified scenarios.

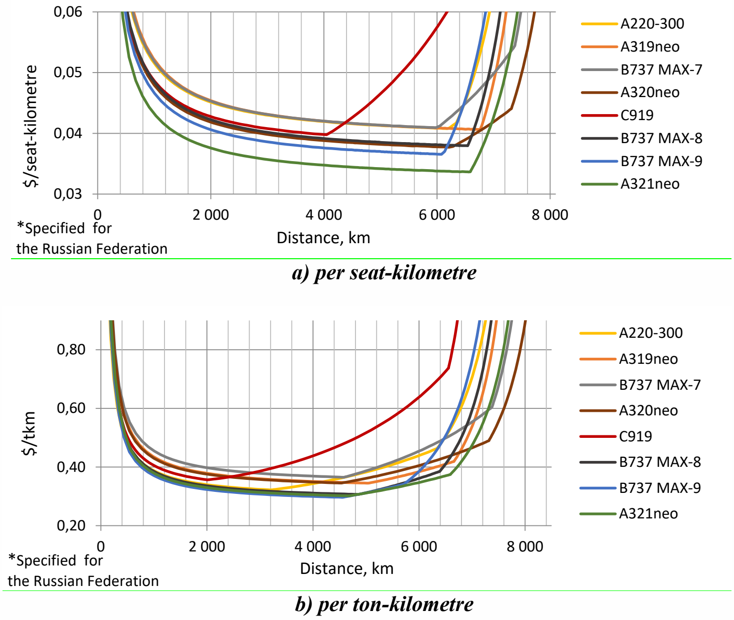
Mainline narrow-body aircraft

Pic. 2 shows diagrams of specific DOC regarding NB aircraft calculated per seat-kilometre and per ton-kilometre depending on the flight distance. Optimal specific costs for passenger transportation are achieved within the ranges of 1900–7000 km and amount, depending on the aircraft, to 3,5 to 4,5 US cents per seat-kilometre. The range of optimal distances for cargo transportation are shifted to the left and are within the range of 1000–6500 km. The cost of transportation depending on the aircraft model is 0,3–0,4 US dollars per ton-kilometre.

Specific direct costs on medium distances (Pic. 3) for passenger transportation average about 4,6 US cents per seat-kilometre, and for cargo transportation – 34,3 US cents per ton-kilometre.

Mainline wide-body aircraft

Pic. 4 shows the specific DOC of WB aircraft per seat-kilometre and per ton-kilometre depending on the flight distance. Optimal specific costs for passenger transportation are achieved within distances of 4000–14000 km and, depending on the aircraft, range from 3,1 to 4 US cents per seat-kilometre. The range of optimal distances for cargo transportation is shifted to the left and is within 2000–13000 km. WB aircraft have a minimum cost of transportation per ton-



Pic. 2. Specific direct operating costs of NB aircraft as calculated per a) seat-kilometre and b) ton-kilometre [calculated by the authors].

kilometre, which, depending on the aircraft model, is 22–30 US cents per ton-kilometre.

Specific direct costs for medium distances (Pic. 5) average about 3,9 US cents per kilometre for passenger transportation and 26,2 US cents per ton-kilometre for cargo transportation.

Variation of cost factors

Based on the cost structure obtained for each class of aircraft, the change in the total cost was estimated when varying within the above-assumed ranges of three factors relative to the basic value. For building a model the following values were considered as the scenario examples:

– Fuel cost of 730, 1100 and 1500 US dollars per ton (–14 %, +29 % and +76 % relative to the basic value under the conditions of high volatility).

– Increase in the cost of maintenance and repair by 30 % and 70 %.

– Decrease in flight hours by 15 % and 30 %.

Pic. 6 shows the results of modelling the change in direct operating costs of passenger and cargo transportation depending on the changes in factors for NB aircraft and WB aircraft. The results show that the values of the average change in tariff for a given change in the factor for cargo and passenger transportation are very close. At the same time, with an increase in the average range of aircraft use, an increase in the influence of the fuel component on the level of costs is observed.

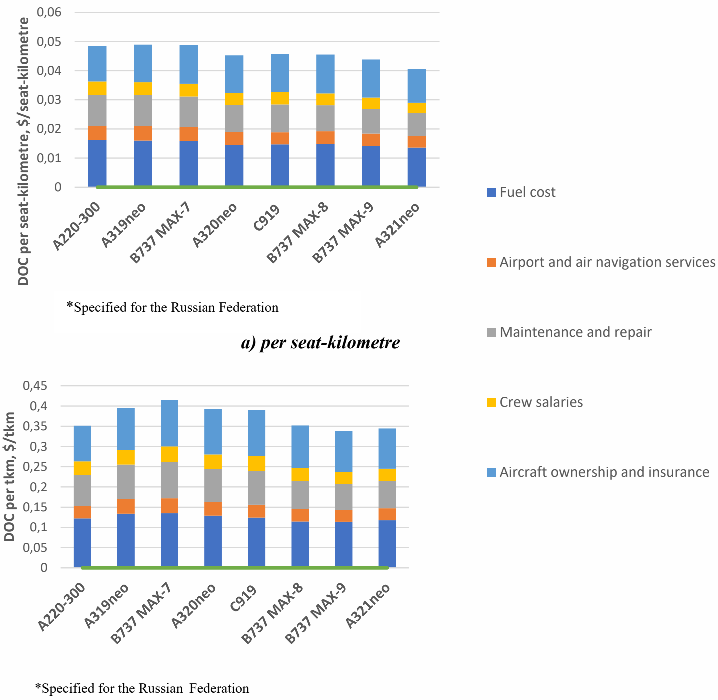
Rate change assessment

If we proceed from the rather low level of operating profit margin of air transportation (for example, the operating profit margin of passenger air transportation in Russia, according to National Credit Ratings LLC estimate was at that time of 1–4 %[10]), it need scarcely be said about the accelerated growth of the rate compared to the cost. Assuming that the level of profitability will be around zero, the change in the rate will occur synchronously with the change in the full cost price.

To shift from direct operating costs to full cost price, it is necessary to take into account other expenses that are not included in DOC. Authors' analysis of the structure and dynamics of expenses shows that their value for both passenger and cargo transportation in constant prices has changed very little since 2013 and is estimated at about 0,9 US cents per seat-kilometre and about 8,7 US cents per ton-kilometre (Pic. 7).

Considering the addition not included in DOC, the relative change in the rate is estimated (Pic. 8). The largest increase in the rate for NB aircraft and WB aircraft will be at extremely high fuel prices. At the same time, WB aircraft demonstrate a greater increase in the rate with an increase in fuel prices.

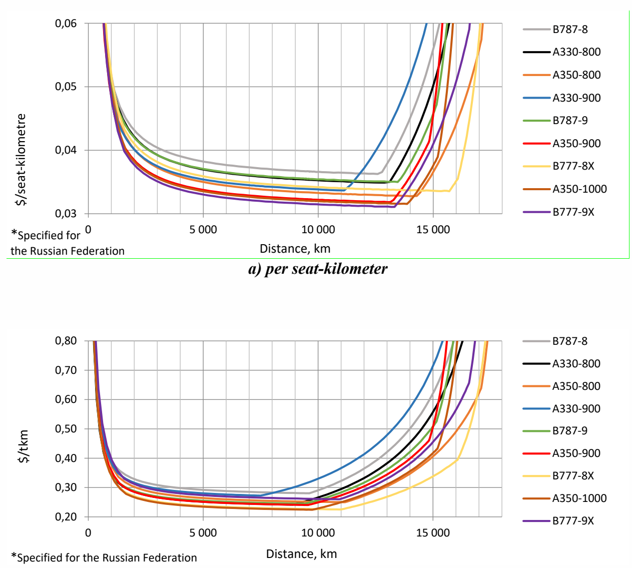
[10] Baymukhametova. L. Transport: where the margin lies? National Credit Rankings LLC, 6.12.2021, P. 10. [Electronic resource]: https://ratings.ru/files/research/corps/Transport_margin_Dec2021.pdf. Last accessed 29.01.2024.



a) per seat-kilometre

b) per ton-kilometre

Pic. 3. Distribution of specific direct operating costs by NB aircraft expense items calculated per a) seat-kilometre, b) ton-kilometre [calculated by the authors].

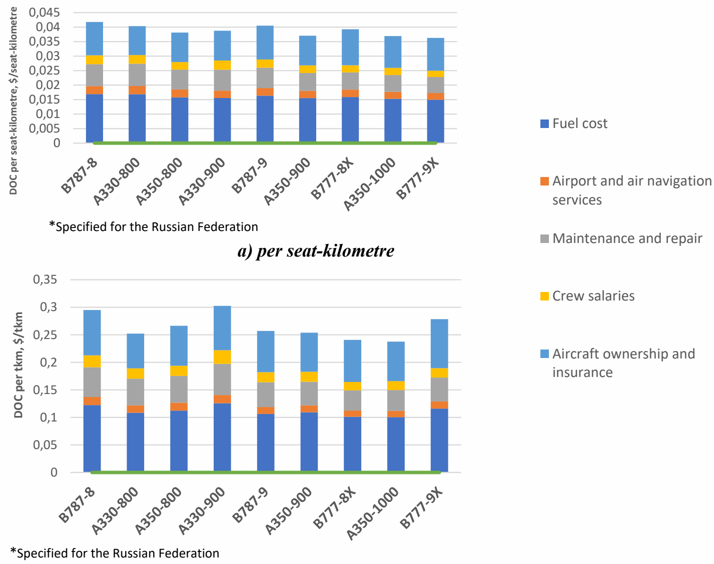


a) per seat-kilometer

b) per ton-kilometre

Pic. 4. Specific direct operating costs of WB aircraft calculated per a) seat-kilometre and b) ton-kilometre [calculated by the authors].

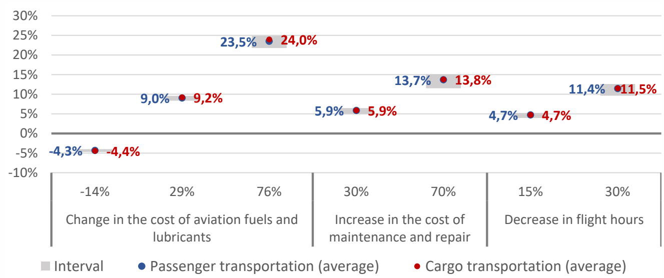
The analysis of rate sensitivity to the factors affecting the cost price showed that the rate elasticity relative to the increase in the cost of aviation fuel is from 0,26 (NB aircraft) to 0,31 (WB aircraft), relative to the increase in the cost of maintenance and repair elasticity is from 0,13 (WB aircraft) to 0,16 (NB aircraft), relative to the decrease in flight hours it is from 0,27 (WB aircraft) to 0,29 (NB aircraft). In general, it can be noted that with an increase



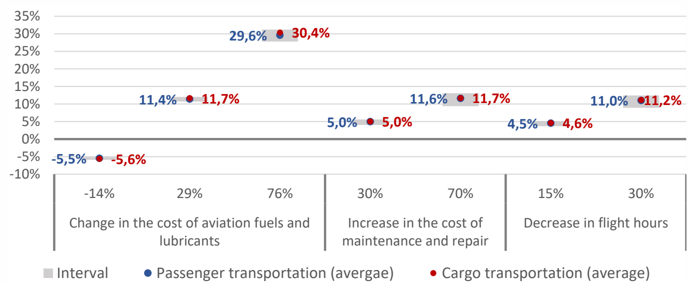
a) per seat-kilometre

b) per ton-kilometre

Pic. 5. Distribution of specific direct operating costs of WB aircraft by cost items calculated per a) seat-kilometre, b) ton-kilometre [calculated by the authors].



a) NB aircraft



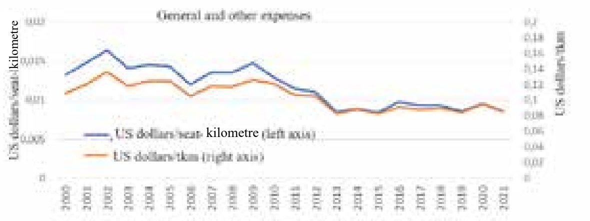
b) WB aircraft

Pic. 6. Change in direct operating costs with varying factors [performed by the authors].

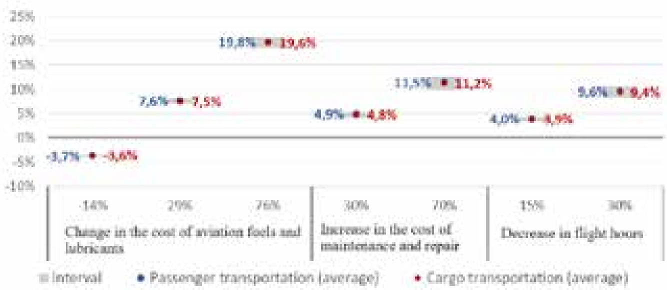
in the average transportation distance, the role of the fuel component increases. The greatest sensitivity of the transportation rate for NB aircraft is observed to a decrease in flight hours, for WB aircraft – to the cost of fuel.

Modelling shows (Pic. 9) that with the combination of high values of scenario factors (scenario 1: fuel cost of 1100 US dollars per ton, increase in maintenance and repair costs by 70 % and a decrease in flight hours by 30 %) the rate increase for NB aircraft will be about 30 %, for WB aircraft – 29 %.

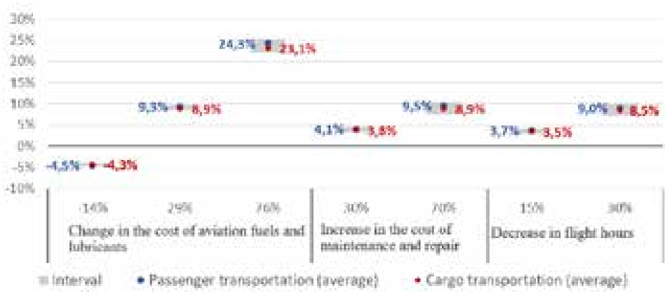
If extreme fuel prices are set (1500 US dollars per ton) together with a 70 % increase in maintenance and repair costs and a 30 % decrease in flight hours (scenario 2), then the rate increase will be 43 % for NB aircraft and 45 % for WB aircraft.



Pic. 7. Dynamics of specific costs not included in DOC [performed by the authors].



a) NB aircraft



b) WB aircraft

Pic. 8. Rate change depending on factors influencing cost price change [performed by the authors].

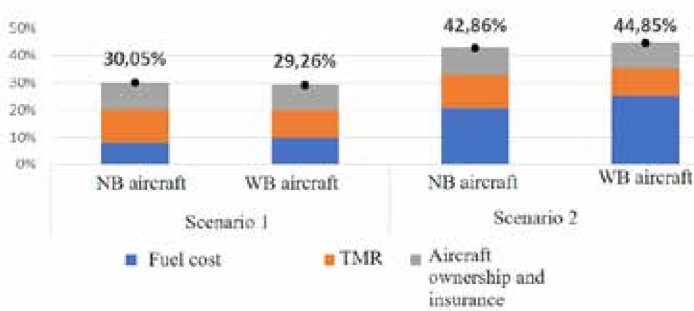


Рис. 9. Структура увеличения тарифа на перевозки в двух сценариях [выполнено авторами].

BRIEF CONCLUSIONS

The work, based on evaluations of the increments of the components of the cost price of transportation, has presented the model and, based on proposed scenarios, estimates of the average value and structure of direct operating costs for passenger and cargo transportation within the air transport system of the Russian Federation corresponding to the average weighted flight distance of narrow- and wide-body mainline aircraft. With one of scenario assumptions of the increase in the cost of fuel from 850 to 1100 US dollars/t, in the cost of maintenance and repair by 70 % and a decrease in flight time by 30 % of the basic level, it was found that the increase in direct operating costs will be about 36 %; for NB aircraft, 10 % of that increase will be induced by aviation fuel and lubricants costs, 14 % by maintenance and repair costs and 12 % by reduced flight time, and for WB aircraft 12 % will be induced by aviation fuel and lubricants costs, 12 % by maintenance and repair costs and 12 % by reduced flight time.

Considering the evaluation of factors of changes in the cost of transportation and if a near-zero values of air transportation operating profit margin is assumed for the Russian air transport system, the calculations resulted in estimates of changes in the transportation rates.

The model tested during the study and the approaches to assessing changes in air transportation rates obtained during the study of the model can be used in the future to forecast potential demand for air transportation of passengers and cargo based on the input of up-to-date real data and considering changing parameters of external factors.

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