Modelling for determining the adaptive potential of air carriers as participants in the process of creating a tourist product

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Abstract. The study is devoted to the adaptation capacity management of enterprises in the service sector. To determine the adaptation capacity of the air carrier, as an actor with a significant impact on the global tourism market, a mathematical model was proposed, which is characterized by constant variables. The model is based on the criterion of optimality of the discounted financial result of the air carrier for the entire period of modeling with restrictions on financial capabilities, demand on air lines, including the tourism, the number of flights and flight hours of planes, as well as general balance restrictions. Keywords: service sector, model, air carrier, tourism, airline, air transport market.

1 Introduction

A special service sector feature in servicing population transport mobility is its link to the global tourism market. In many cases, international tourism is closely linked to air transport, as long-distance transportation is usually performed by air.

Air transportation service plays a crucial role in the tourist product offered to international tourists, which means that travel market operators have to hire specialists dealing with a purely aviation product.

Moreover, international tourist flows form the basis for the majority of international flights of air carriers, which also requires them to cooperate more actively with travel agencies. All this implies a search for new approaches to managing the adaptation capacity of global tourism market players.

2 Literature Review and hypothesis development

The influence of air carriers on the creation of the tourist product is quite significant.

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Various aspects of this problem have been actively researched in previous scientific studies. In particular, the segmented regression model of interaction of budget carriers and tourism was proposed by Vergori and Arima in [1]. The work [2] is devoted to the study of the influence of air transportation on tourist demand. The study of He, Shen, Wong et al [3] is focused on the estimation of the capacity of tourism resources. The influence of international air routes on tourism was studied by Tang, Wu, Ramos and Sriboonchitta in [4]. Researchers Kumar and Patel in [5] examined the nonlinear effect of air travel demand in tourism on economic growth. The dynamic relationship between air transport, economic growth and inbound tourism were studied in depth in [6]. Various aspects of tourism have been investigated in [7-12]. The aviation product was studied in [13-15].

As noted in [16], the largest travel service providers now have huge opportunities to develop from out-of-the-box thinking and can find new ways to be more relevant to their customers around the world, thereby increasing their own competitiveness. At the same time, air carriers have the opportunity to generate additional revenue from the appropriate marketing policies focused on sophisticated personalization for different categories of travelers. An example of such a through-personalized service would be providing personal preferences that the traveler, both on board and in the hotel, as well as at other segments of the journey.

The spheres of tourism and air transportation overlap strongly in the global online travel market. As noted in Research and markets [17], this global market is expected to be about $1.5 trillion by 2027. It is clear that most travelers shifted away from traditional travel agencies in favor of online travel booking options. Dynamic growth of online tourism will be primarily due to the increasing penetration of international flights. The online travel agency model is a combination of a travel agency and an e-commerce platform, while the international air carrier will evolve into a combination of an e-commerce platform and a traditional airline.

As far back as 2015, Hess et al [18] concluded that tourists and transnational tourism corporations have the highest adaptive capabilities and this hypothesis was confirmed by the conducted study. The tourism product in the global dimension, as noted earlier, includes services, and since international tourism involves overcoming significant distances, it usually has an air component. Air carriers' adaptation is necessary to many markets in which they operate and interact with. The global travel market is among the important markets for the majority of scheduled passenger air carriers.

3 Metodology

In order to better understand the socio-economic opportunities associated with growth, climate changes, environmental, technical and cultural risks, Dawson et al [19] conducted an empirical study using the Delphi method, which allowed to identify and evaluate potential adaptation strategies for decision-making in cruise tourism development. 65 potential options of adaptation were implemented, the evaluation of which was carried out including tour operators, which determine the special study relevance within the scope of the issue addressed.

The methods of quantitative analysis to improve the tourist destination competitiveness can be used to create a complex adaptive socio-economic system [20]. The practical orientation of this study in providing recommendations for streamlining the information flow by employees of travel companies should also be noted, which, seemingly, is the main contribution of this work to science.

Within the study of Núñez-Ríos et al [21] a model focused on organizational sustainability in the tourism sector was proposed. Herewith, the authors offered a very theoretically valuable multi-methodological approach, with the help of which the application of the model to other types of organizations can be carried out. The successful interconnection of methodological tools for structuring the problem, analyzing social networks, assessing and confirming the relevance of relationships in them should be noted.

The development of augmented reality business models using a multi-method approach, taking into account stakeholder interests, interviewing tools and analytical hierarchy process modeling based on the principles of consistency, inclusivity, suitability, flexibility and transparency proposed by Cranmer et al [22] should be considered a new methodological approach to solve the task at hand.

The methods of system and economic-statistical analysis, economic-mathematical modeling and optimization serve as the methodological basis of the study. Based on the use of these methods, the mathematical model of adaptability of the air carrier as a participant of the tourist product creation process in the conditions of the global tourist market development is proposed. As the main parameters of the adaptability of the realized economical-mathematical model it was suggested to use: average tariff for transportation of one passenger on a particular airline in a given period; level of the tariffs set by an air carrier relatively to average tariff for passenger transportation on an airline in a given period; number of flights of a particular aircraft type in an airline in a given period.

4 Results and discussions

In order to determine the adaptation potential of air carriers as participants when developing a tourist product in the global market, a mathematical model was proposed.

When recording a mathematical model, the following conventions are used:

T – total number of periods studied;

$t \in T$ – particular single period, $t = 0, 1, ..., T$;

T_1 – common subset of contiguous periods, which are generally measured by an annual range;

ρ – discount rate adjusted to a specific period;

S_t – total set by aircraft types that may be available for use by the air carrier for a given period t;

k_{st} – total number of aircraft type $s \in S_t$ in a given period t, which are available for the air carrier;

J_t – certain set of air lines that the air carrier can use for a given period t;

d_{jt} – total demand on the air line j for a given period t;

$c_{sjt}(\gamma)$ – costs of the air carrier for performing the flight by aircraft of type s on air line j for a given period t under the condition of loading γ;

r_{jt} – level of the average tariff for the transportation of one passenger on air line j for a given period t;

σ_{jt} – general level of tariffs of the air carrier taking into account the average tariff level for transportation on the air line j for a given period t, $\sigma_{jt} > 0$;

$\delta_{jt}(\sigma_{jt})$ – certain share of demand on the air line j which can be covered by the air carrier, as a function depending on the level of tariffs;

$\gamma_{jt}(\sigma_{jt})$ – maximum level of flight load on the air line j for a given period t, as a function depending on the level of tariffs.

Conventions of airplane characteristics used in the mathematical model:

n_s – total number of passenger seats on the airplane type s;
φ_s – total maximum flight hours for the airplane type s for one period;
Φ_s – maximum annual flight hours for airplane type s.
Characteristics of the air lines:
Δt_{sj} – time to carry out flight on air line $j \in J$ on an airplane type s;
S_{jt} – set of types of airplanes that can be used on airline j for a given period t.
The variables in the model will be as follows:
χ_{sjt} – total number of flights of the airplane type s on airline j for a given period t;
N_{jt} – number of passengers carried on airline j for a given period t by all types of aircraft;
F_t – total financial result of the air carrier for a given period t;
σ_{jt} – level of tariffs set by the air carrier.
The criterion of optimality in the mathematical model is the discounted financial result of the air carrier for the entire period of modeling, which is calculated by the formula:

$$\sum_{t\in T}\frac{F_t}{(1+\rho)^{t-1}} \to \max \tag{1}$$

Determining the financial result of the air carrier for the period t:

$$F_t = \sum_{j\in J_t}\left(N_{jt}r_{jt}\sigma_{jt} - \sum_{s\in S_j}x_{sjt}c_{sjt}(\gamma_{jt}(\sigma_{jt}))\right), t \in T, \tag{2}$$

With the following restrictions:
– restrictions on general financial capabilities of the air carrier during the period t by the amount of previous accumulations:

$$\sum_{\tau=0}^{t}F_t \geq 0, \ \ t \in T, \tag{3}$$

– restrictions on total volume of transportation by the demand on air line j for a given period t:

$$N_{jt} \leq d_{jt}\delta_{jt}(\sigma_{jt}), \ j \in J_t, \ t \in T, \tag{4}$$

– restrictions on the flight hours of airplane type s for one period:

$$\sum_{j\in J_{st}}x_{sjt}\Delta t_{sj} \leq k_{st}\varphi_s, \ s \in S_t, \ t \in T, \tag{5}$$

– restrictions on the total number of flights of airplane type s on air line j for a given period t:

$$\underline{x}_{jt} \leq \sum_{j\in S_t}x_{sjt} \leq \bar{x}_{jt}, \ j \in J_t, \ t \in T, \tag{6}$$

– restrictions on volume of transportation on air line j for a given period t by available aircraft fleet:

$$N_{jt} \le \sum_{s \in S_{jt}} x_{sjt} n_s \gamma_{jt}(\sigma_{jt}),\ j \in J_t,\ t \in T, \tag{7}$$

– restrictions on the range of values of model variables:

$$x_{sjt} \ge 0,\ \ s \in S_{jt},\ \ j \in J_t,\ \ t \in T, \tag{8}$$

$$\underline{\sigma}_j \le \sigma_{jt} \le \overline{\sigma}_j,\ \ \ j \in J_t,\ \ t \in T. \tag{9}$$

$$N_{jt} \ge 0,\qquad F_t \text{ – random.} \tag{10}$$

The proposed mathematical model of air carrier adaptability allows, primarily, the determination of optimal parameters for carrier's air line network changes, including tourist routes. The application of the adaptive principle of air carrier network development should be considered as a key factor for successful development in the passenger air transport and global tourism markets. The economic-mathematical model calculations were performed on a set of flights that Ukraine International Airlines (UIA) was going to perform with its own aircraft, including on tourist destinations in 2021. Since flights are currently suspended due to the war, it is proposed to use 2021 as the basis for calculations. Most of the flights are operated from Kyiv. The proposed model was used to calculate three options for the optimization of the UIA carrier's airline network to ensure effective adaptation to new market conditions. Each option optimized the distribution of the airline's allocation of aircraft fleet by flights, under the condition of limiting flight hours for each aircraft type during the week and the mandatory implementation of the list of flights for each week of the year on the criteria of maximizing the financial performance of the given flights.

The options generally differed in terms of the list of flights to be operated by the airline during a year. All options restricted the use of the Boeing 737-900 aircraft, namely it was not used on flights of less than 1,000 km. The basic (first) option included the airline's entire current list of flights per year. Flights to Athens, Dubai, Larnaca, Munich and Tbilisi were excluded from the second option. In the third option, flights to Astana, Warsaw, Vilnius and Prague were additionally excluded. For all three variants, the weekly income and costs of the flights have been calculated as the weekly totals of all flights, and the financial result as the difference between income and costs. The total weekly flying hours of the aircraft and total number of flights per week have also been calculated.

Based on the data obtained, recommended that in order to maximise profits from the core business UIA should exclude insufficiently profitable flights (to Athens, Dubai, Larnaca, Munich and Tbilisi) (Table 1).

Table 1. Results of the optional network optimisation of UIA according to the economic-mathematical model

Option	Number of flights	Flight hours		Income, € mln.		Costs, € mln.		Profit, € mln.	
		Total	1 paired flight	Total	1 paired flight	Total	1 paired flight	Total	1 paired flight
1	15167	73465	4.84	1065.8	71.82	1013.5	68.34	52.3	3.53
2	11983	57546	4.8	901.22	78.72	786.02	68.71	115.2	10.07
3	9973	47184	4.73	752.3	75.45	660.9	66.29	91.4	9.17

Consequently, under the most favourable option of airline network optimization and its symmetrical development, UIA can generate operating profit of €115.2 million, taking into account the network effect. In addition, using the proposed model, it is possible to define the principles of mutually beneficial cooperation between air carrier and travel company in the formation of the tourist product of the latter. Thus, it provides synergies not only for the air carrier but also for the joint work with the tour operator. In addition, network air carriers using the proposed toolkit are able to successfully develop the cargo component of their own business as an additional opportunity. The effective organization of additional cargo loading for passenger aircraft becomes a significant competitive advantage in the market, as it allows for additional revenue, with a minimal increase in costs for the air carrier on each of the flights.

5 Conclusions and implications

The mathematical model was proposed to determine the adaptation potential of air carriers. The practical value of this model, in particular, lies in the ability to determine the balance of traditional and tourist routes for the air carrier in dynamic development conditions. The practical significance and extreme relevance of the proposed model is determined by the possibility of its effective use in the current unstable situation of air transport markets, as well as in interaction with the global tourism market.

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