

## **Ticket sales optimization in the conditions of the independent and crossover demand on the basis of economic and mathematical modeling**

**Mihail Nikolaevich Dudin and Nikolaj Vasilevich Lyasnikov**

*Russian academy of Entrepreneurship,  
Radio str., 14, Moscow, 105005, Russian Federation.*

**Vladimir Dmitriyevich Sekerin and Anna Evgenevna Gorohova**

*Moscow state university of mechanical engineering,  
BolshayaSemenovskayaSt.,  
38, Moscow, 107023, RussianFederation*

**Natalia Victorovna Gayduk**

*Kuban State Agrarian University,  
Kalinina Str., 13, Krasnodar, 350044,  
Russian Federation.*

### **Abstract**

This article aims at developing the methods of economic and mathematical modeling of the ticket sales process using an intermediary network in the conditions of the independent and crossover demand on the part of intermediaries. The economic and mathematical models proposed in the article are a special case of solving optimization problems. As part of the study the following fundamental conclusions have been obtained:

1. air transport in the medium term will be one of the main means of transport, which will provide fast and comfortable spatial movement of people;
2. the market of commercial passenger air travel is developing rapidly, showing a doubling of passenger traffic over the past 15 years, and this tendency is forecast for the coming 15 years;
3. one of the key problems of development of the commercial air passenger market is the problem of reducing the profitability of airline operations due to insufficiently high flight occupancy;

4. the development of the intermediary network selling flight tickets can become a possible solution to this problem, which leads to the need for economic and mathematical modeling of benefits of cooperation between airlines and their intermediaries;
5. validation of the results obtained through developed economic and mathematical models showed that the activity of intermediaries will be characterized by a certain opportunism in cooperation with the airlines. But at the same time even in these conditions airlines may gain additional or direct income in circumstances when the potential losses could be made;
6. practical application of economic and mathematical models proposed in the article will allow to solve a wide range of airlines marketing management tasks.

The novelty of this article is to develop methods of economic and mathematical modeling for solution of particular tasks to optimize the ticket sales process using an intermediary network.

**AMS subject classification:**

**Keywords:** air travel, airlines, flight tickets, income, intermediary, market demand, losses, economic and mathematical modeling.

## 1. Introduction

The modern development of the society and economy is characterized by an acceleration of evolutionary processes, including through the emergence of ideas and solutions, which provide the world's scientific and technological progress. And along with accelerating the development processes, forming a new quality of social life, as well as a new quality of economic life, social reality is getting complicated –new types of services and products emerge; the interaction of government, business and science is not hierarchical, it is becoming a network interaction; the boundaries between physical and virtual space are erased [1–2].

Such circumstances cause the occurrence of new needs both in private and corporate segments of the market. Along with the occurrence of new needs, the behavior of market agents (both consumers and economic entities of the supply industry) gets changed. This makes it necessary to review the methods and forms of organization between consumers, manufacturers, service organizations and other agents to ensure that the existing market demand has been satisfied as much as possible or to the fullest extent [3–4]. In general, the state and changes in market demand depend on a number of factors; in particular, they are as follows [5]:

1. the quality and structure of the offer on the market of products, different types of services or any services;

2. the quality and level of competition between manufacturers in the market, the market monopolization by individual manufacturers;
3. specifics of consumer perception of certain goods, works, services and companies;
4. creditworthiness of consumers, their openness to new offers of goods, works and services.

This is not a complete list of factors that influence the state of the market demand, and these factors relate primarily to the consumer aspect. From the point of view of manufacturers of goods and services the following aspects are also important [6]:

1. the quality and effectiveness of intercompany cooperation;
2. legal regulation of certain types of economic activity;
3. potential profitability and riskiness of business in different economic areas.

It is rather difficult to combine all above-mentioned aspects for prediction of market demand changes, as well as for prediction of the benefits that goods and services producers can gain, using traditional financial, economic or marketing approaches [7-9]. In recent years economic-mathematical modeling methods are becoming increasingly popular [10-11].

This article will consider special cases of application of economic-mathematical modeling methods in terms of solving optimization tasks associated with the sales of air tickets by airlines to customers (passengers). The segment of commercial passenger air travel has not been chosen by chance:

1. Firstly, the world's regions are becoming increasingly open to tourism and the establishment of business relations;
2. Secondly, an increase in the pace of life requires rational decisions on the spatial movement of people;
3. Thirdly, air transportation connects remote regions, even in the case when there are difficulties with the use of land transport.

In turn, it is important for the airlines that their activities do not just bring economic benefits, but also have a high degree of cost-effectiveness, since receipt of a sufficient profit is the basis of sustainable development of some airlines, as well as a whole segment of the commercial passenger air travel [12].

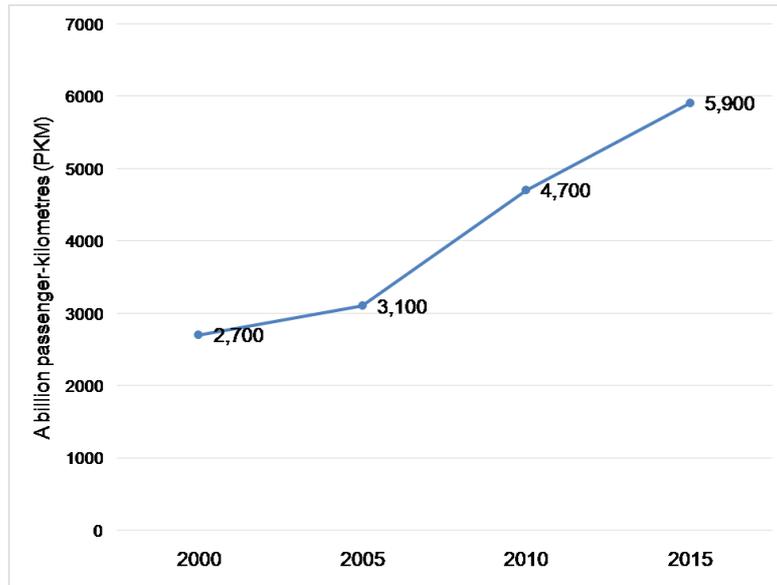


Figure 1: The dynamics of growth of the world's commercial passenger air travel [14-15].

## 2. Results

The commercial air passenger market has steadily increased in scope [13-14]. Thus, for example, over the last 15 years passenger traffic flow has increased more than 2 times (see Figure 1). It is worth noting that within the next 15-20 years (approximately till 2030-2035) the volume of commercial passenger air travel will increase approximately 2.5 times.

At the same time about 78% of the world's commercial passenger air travel is carried out by network companies, which have their own aircraft fleet, a developed route network and maintenance services (see Figure 2).

A modern aircraft fleet is represented by various types of aircrafts, in particular, air transportation is performed on turbo-prop and jet planes (the capacity of jet planes can be no more than 60 seats, as well as from 60 to 120 seats, turbo-prop planes are characterized by a maximum capacity of not more than 60 seats).

In addition, air transportation is performed on narrow-body and wide-body planes (the capacity of such planes ranges from 120 to 240 or more seats).

The bulk of the commercial passenger flights are performed on narrow-body and wide-body planes over the last five years (more than 75% of total passenger traffic flow, while 52% of passenger flights are performed on narrow-body planes). It is also important to take into account a proportion of flights, which are performed on jet planes, the capacity of which ranges from 60 to 120 seats (see below Figure 3).

Prospects for the development of commercial passenger air travel are very extensive, and the experts agree that the future of air transport belongs to the network airlines and the modern narrow-body and wide-body aircraft. However, the key problem of

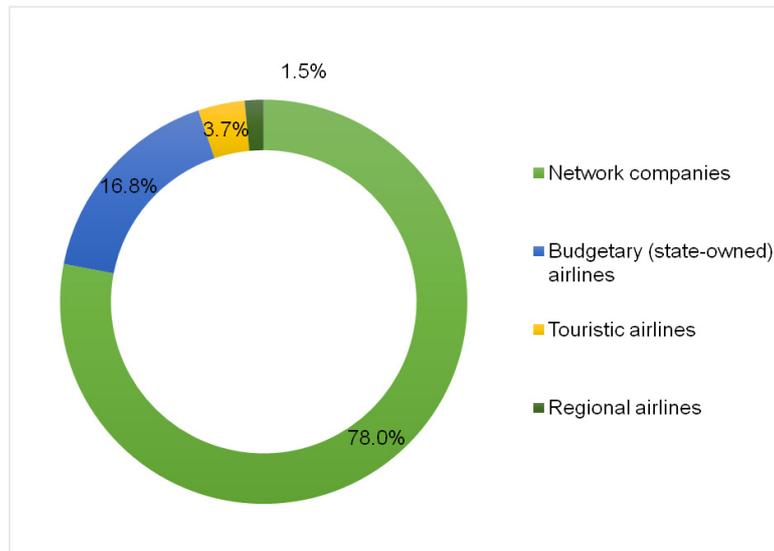


Figure 2: The structure of the commercial passenger air travel in the context of airline business models (based on 2015) [14-15].

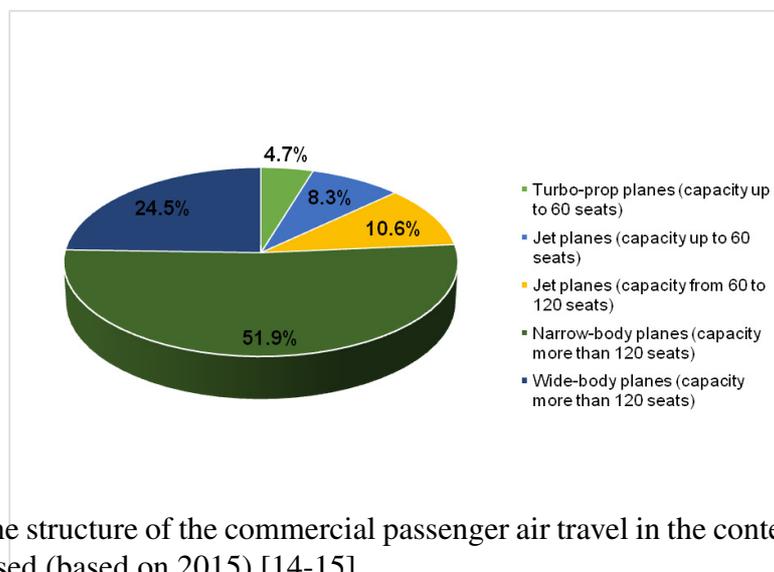


Figure 3: The structure of the commercial passenger air travel in the context of the types of aircraft used (based on 2015) [14-15].

air transportation in general and, above all, the commercial passenger air travel, is the reduction of profitability [12].

In particular, the standard ticket booking package in the network airlines varies from 50% to 70%, the companies operating exclusively on tourist destinations or as regional business structures, having a limited number of routes at disposal, have the average annual level of the standard ticket booking package that varies from 40% to 60% of all the passenger capacity [13-15]. Obviously, the unused potential of the airlines is rather high. At the same time, the industry of commercial passenger air travel is most sensitive to changes in the macroeconomic situation.

As a rule, in times of systemic financial-economic and political crises the volume of passenger air traffic flow is reduced by 10-15% and in some cases it can be reduced up to 20-25% [13-15]. The decline in passenger traffic flow does not allow the airlines to maximize their income and profits, respectively, it has a negative impact on their development, the ability to upgrade the aircraft fleet, the ability to create additional services to improve passenger comfort. On the other hand, the industry of commercial passenger air travel was one of the first that moved from the traditional competition to co-competition.

In other words, many airlines actively cooperate with each other for the most complete use of traffic potential capacity, reduction of lost profits, as well as to improve the income and profitability. In addition, many airlines actively cooperate with wide agency networks that allow to cover the most mass consumer audience with services.

Taking into account that the prospects and potential of development of commercial passenger air travel industry are rather high, including in the light of the expansion of intercompany cooperation between the airlines and their counterparts, it seems appropriate to develop standard economic and mathematical models, which will characterize the different situations of supply and demand of airline tickets, the sale of which provides financial and economic incentives for expansion of air traffic.

### 3. Methods

#### 3.1. General methodical provisions

Almost all airlines are faced with the fact that many flights have to be performed in conditions of low or average occupancy of seats in the cabin.

There are several objective and subjective reasons: the low season, the reduction in effective demand due to macroeconomic instability, consumers' refusal off lights due to the news of disasters, hostilities, acts of terrorism, etc. Therefore, the airlines, predicting their losses, are forced to seek solutions aimed at increasing demand. In this situation, as a rule, one of the key decisions is the need to engage intermediaries in the sales processes. In turn, intermediaries will cooperate with a certain number of airlines.

The methods of economic and mathematical modeling will be used in this article [16-20] as a special case of solving optimization tasks for two conditions of demand for flights (independent and crossover demand). In general, the demand is distributed by a Poisson distribution [19]:

$$p(k) \equiv P(Y = k) = \frac{\lambda^k}{k!} * e^{-\lambda}. \quad (1)$$

Where:

$p(k)$  probability function;

$Y$  random value;

$k!$  factorial for  $k$  ( $k \in \{0, 1, 2, \dots\}$ );

$\lambda$  expectation function;

$e$  base of the natural logarithm.

An independent demand means the demand of an intermediary for tickets, which does not take customers away from the airline; in other words, the intermediary attracts new customers to purchase unsold tickets, which allows to reduce losses of the airline and ensure its income by obtaining favorable terms of cooperation with the airline.

A crossover demand means the demand of an intermediary for tickets, when the intermediary can divert customers from purchasing airline tickets. But at the same time the intermediary brings the airline an additional income (profit) by selling those tickets that the airline included in the category of potential losses.

### 3.2. Development of methods of modeling the independent and crossover demand for tickets on the part of intermediaries

Two types of demand (independent and crossover demand) have been reviewed for the development of the economic and mathematical model. Moreover, for modeling of independent demand the following variables should be taken into account:

$\xi_i$  demand for the tickets for the  $i$ -th flight;

$T_i$  passenger capacity of the  $i$ -th flight;

$\alpha$  the value determining the number of purchased tickets;

$k_i$  a number of repurchased tickets for the  $i$ -th flight;

$c_i$  the ticket price set by the airline;

$c_{i1}$  the ticket price including the cost of intermediary services;

$R_A$  income or profits of the airline;

$E$  potential benefits from cooperation.

In order to simulate the independent demand it is primarily necessary to calculate a number of repurchased tickets for the  $i$ -th flight on the basis of the following set of equations:

$$\begin{cases} P(\xi_i > T_i - k_i) \leq \alpha \\ P(\xi_i > T_i - k_i) > \alpha \end{cases} \quad (2)$$

To simplify further calculations without causing the airline losses, an above-mentioned set of equations can be simplified:

$$P(\xi_i > T_i - k_i) = \alpha. \quad (3)$$

To simulate the income or profits of the airline prior to reselling tickets to an intermediary, the following calculation formula is used:

$$R_A = c_i * \xi_i + c_i * \min(\xi_i, T_i - k_i) - c_i * \min(\xi_i, T_i - k_i). \quad (4)$$

To simulate the income or profits after reselling tickets to an intermediary, the following calculation formula is used:

$$R_{A1} = c_i * \min(\xi_i, T_i - k_i) + c_i * k_i. \quad (5)$$

The potential benefits of the airline from cooperation with an intermediary will be formed only when the difference between the income derived from the cooperation with the intermediary ( $R_{A1}$ ) and the income gained before involving the intermediary ( $R_A$ ) will be more than zero:

$$E(R_{A1} - R_A) > 0. \quad (6)$$

Then, taking into account the fact that not only the airline but also the intermediary should have their own economic benefits from cooperation, these benefits are calculated as follows:

$$\sum c_{i1} * k_i - c_i * \alpha * k_i > 0. \quad (7)$$

In turn, as for the crossover demand for air tickets on the part of the intermediary, the following variables must be taken into account:

$\xi$  demand for air tickets;

$T$  passenger capacity;

$\alpha$  the value that determines the number of purchased tickets;

$k$  the number of repurchased tickets

$c$  the ticket price set by the airline;

$c_1$  the ticket price including the cost of intermediary services;

$c_2$  the ticket sale price of the intermediary;

$\eta$  a number of tickets distributed by the airline (a random variable);

$R_A$  income or profits of the airline;

$E$  potential benefits from cooperation.

Then the income or profits of the airline without the involvement of an intermediary in distributing tickets are defined as follows:

$$R_A = c * \min(\xi_0 * T). \quad (8)$$

If an intermediary is involved in distributing air tickets, and thus its demand for tickets can be regarded as crossover, then the profits or return on ticket sales of the airline are calculated as follows:

$$R_{A1} = c * \min (\xi_0 * T - k) + c_1 * k. \quad (9)$$

To determine the ticket price which will include the cost of services provided by an intermediary, the following formula can be used:

$$c_1 * k \geq c * [T * \alpha + E (\Delta\xi \div \xi < T - k)]. \quad (10)$$

The ability of an intermediary to maximize revenues from the sale of tickets at the crossover demand is determined by the following equation:

$$E (c_2 * \eta - c_1 * k) > 0 \text{ or} \\ c_2 * E\eta \geq c_1 * k > c * [T * \alpha + E (\Delta\xi \div \xi < T - k)] \quad (11)$$

It is also worth noting a few significant aspects in modeling the crossover demand for air tickets on the part of an intermediary. Firstly, for the intermediary the possibility of cooperation is definitely determined by the following economic and mathematical ratio:

$$c * [T * \alpha + E (\Delta\xi \div \xi < T - k)] \leq c * k \text{ or} \\ E (\Delta\xi \div \xi < T - k) \leq k - T * \alpha \quad (12)$$

Secondly, in order to substantially maximize the income, an intermediary must get the lowest ticket prices from the airline. Therefore, it is possible to tighten the inequality given in Formula (12), setting the condition that the purchase price of tickets for the intermediary shall not exceed a half of their sales price in the airline:

$$E (\Delta\xi \div \xi < T - k) \leq \frac{k}{2} - T * \alpha \quad (13)$$

Next let us consider the proposed economic and mathematical models on practical examples for the conditions of the independent and crossover demand.

#### 4. Discussion

Thus, we have developed the economic and mathematical models for two types of demand for air tickets of the airlines on the part of intermediaries. First and foremost we propose to consider from a practical point of view the case of the independent demand of the intermediary for tickets of one or several airlines. To unify and simplify calculations, further in the article we shall consider passenger capacity as equal to 100 seats, respectively, the maximum sales volume will be equal to 100air tickets. The base price of one air ticket will be \$200 (without discounts or markups). The average flight occupancy will be denoted by  $\lambda$  [lambda], and a number of seats (tickets) repurchased by an intermediary will be denoted by  $\alpha$  [alpha].

Table 1: Return from the sale of the airline tickets in the case of independent demand for these air tickets on the part of the intermediary.

Flight occupancy ( $\lambda$ )	The number of seats and tickets sold by the intermediary ( $\alpha$ )						
	0.00	0.05	0.10	0.15	0.20	0.25	0.50
	US dollars	The rate of the additional return from the sale of unsold tickets by the intermediary, in%					
50 seats	10,256	3.26	7.10	11.13	15.41	19.73	42.22
65 seats	12,844	1.60	3.75	6.00	8.28	10.64	23.44
75 seats	15,292	0.31	0.99	1.90	2.88	4.02	10.65
80 seats	16,130	0.10	0.57	1.00	1.61	2.39	7.19
85 seats	17,054	-0.01	0.04	0.16	0.45	0.80	4.26
90 seats	17,704	0.00	0.00	0.02	0.16	0.42	2.85
$\geq 95$ seats	18,540	0.00	0.00	0.00	0.00	0.00	0.92

Prior to further consideration of the results of testing of the developed economic and mathematical models, it is first necessary to clarify that both the airline and the intermediary seek to maximize their income or economic benefits/profits (or to increase the amount of income received due to the exclusion of the part of damages and losses). Accordingly, the airline increases its revenues in the case when it sells air tickets to an intermediary at a price that is not below than the prime cost. The income of the airline is maximized when the selling price of tickets (which can form a potential loss) sold to the intermediary includes a certain rate of return or profitability of the airline.

The intermediary increases its income in case of acquisition of air tickets at a price which will include a certain rate of return of the airline with the inclusion of the cost of services provided by the intermediary. Restrictions for the intermediary are obvious – the intermediary cannot sell tickets at a price that is higher than the price for similar air tickets sold by the airline. If the airline sells unsold tickets to the intermediary at a prime cost, not taking into account its own rate of return in order to avoid losses, then the intermediary will maximize its income if it sells all tickets to consumers (clients) in a given situation.

The results of cooperation of the airline and intermediary in the case of independent demand are presented in Table 1.

Calculations have shown that the mutual benefits of the parties will be in case when the airline sells at least 50% of the total number of air tickets to the intermediary. This is beneficial for those airlines whose activities are characterized by a constant low flight occupancy. The same situation of cooperation with the intermediary will be beneficial for the airlines, whose flight occupancy is very high in the season, but it significantly reduces during the off-season.

Table 2: Revenues from the sale of the airline tickets in the case of crossover demand for these tickets on the part of the intermediary (good faith cooperation).

Flight occupancy ( $\lambda$ )	The number of places (tickets) repurchased by the intermediary ( $\alpha$ )						
	0.00	0.05	0.10	0.15	0.20	0.25	0.50
	The rate of the additional return from the sale of unsold tickets by the intermediary, in US dollars						
50 seats	0	2,730	3,360	3,960	4,500	5,060	8,160
65 seats	0	1,540	2,080	2,520	2,900	3,410	5,760
75 seats	0	770	1,200	1,530	1,900	2,200	4,160
80 seats	0	420	720	1,080	1,400	1,650	3,360
85 seats	0	70	320	540	800	1,100	2,560
90 seats	0	0	0	90	300	550	1,760
$\geq 95$ seats	0	0	0	0	0	0	960

For deriving mutual benefits the airlines, whose activities are characterized by high flight occupancy in the seasonal demand, should optimally sell tickets to the intermediary at half price or at prime cost. In this case, the airline does not have any lost profits during the off-season, in turn, the intermediary maximizes its income.

Considering the case of crossover demand, it is worth noting that recognition of the existence of dependence or intercrossing of the demand is not always beneficial for the intermediary. Therefore, the intermediary may make a good faith cooperation with the airlines (i.e. the demand for tickets will be independent or crossover, but in the latter case, the intermediary recognizes the dependence of demand). Either the intermediary may slightly lower the dependence of demand (subsequent calculations will take into account the lowering of dependence of the demand by 15-30%). An extremely negative situation can happen when an intermediary is unfair and completely denies the dependence of demand, i.e. for the airlines – these are potentially non-recoverable losses, for the intermediary – this maximizes revenues through misconduct.

Let us consider in detail a good faith and unscrupulous cooperation of the intermediary with the airlines in case of crossover demand. In this case we shall also take into account that the base price of the tickets will be \$200, flight capacity will be 100 seats (or 100 tickets respectively). The average flight occupancy will be denoted by  $\lambda$  [lambda], and the number of places (tickets) repurchased by the intermediary will be denoted by  $\alpha$  [alpha].

Table 2 shows the calculations that demonstrate a good faith cooperation of the intermediary with the airline, while Table 3 shows the results of cooperation of the intermediary with the airline, when the intermediary lowers the dependence of demand.

Table 3: Revenues from the sale of the airline tickets in the case of crossover demand for these tickets on the part of the intermediary (lowering the dependence of demand by 15%).

Flight occupancy ( $\lambda$ )	The number of places (tickets) repurchased by the intermediary ( $\alpha$ )						
	0.00	0.05	0.10	0.15	0.20	0.25	0.50
	The rate of the additional return from the sale of unsold tickets by the intermediary, in US dollars						
50 seats	0	1,560	2,100	2,640	3,150	3,680	6,630
65 seats	0	880	1,300	1,680	2,030	2,480	4,680
75 seats	0	440	750	1,020	1,330	1,600	3,380
80 seats	0	240	450	720	980	1,200	2,730
85 seats	0	40	200	360	560	800	2,080
90 seats	0	0	0	60	210	400	1,430
$\geq 95$ seats	0	0	0	0	0	0	780

Obviously, greatest mutual benefits are derived incase when the airline sells at least half of all tickets to the intermediary even with low average flight occupancy.

In this case, if the intermediary lowers the dependence of demand, the direct loss of the airline income makes up about 23%; at the same time, the direct loss of the airline income is directly beneficial for the intermediary. Therefore, the opportunism in the intermediary's behavior will always takes place in conditions of crossover demand. The same conclusion is demonstrated by the data presented in Table 4, which shows the results of the unscrupulous cooperation of the intermediary with the airline.

Obviously, in the case of unscrupulous cooperation of the intermediary, the airline loses more than a third of its income if it sells at least half of the tickets at relatively low average flight occupancy. At relatively high average flight occupancy the airline does not lose its direct income even it sells at least half of the tickets to the intermediary.

Thus, the airlines may suffer losses (direct losses or additional lost revenues) in case when the intermediary lowers the dependence of demand, or acts in bad faith. On the other hand, even in case when the intermediary acts entirely in bad faith, the airline gains a certain income rate where there could be a direct loss.

## 5. Conclusions

In the present article the economic and mathematical model for solving the optimization tasks of cooperation of the airlines with their intermediaries in terms of independent and crossover demand has been developed. During the study it was found that, on the

Table 4: Revenues from the sale of the airline tickets in the case of crossover demand for these tickets on the part of the intermediary (unscrupulous cooperation).

Flight occupancy ( $\lambda$ )	The number of places (tickets) repurchased by the intermediary ( $\alpha$ )						
	0.00	0.05	0.10	0.15	0.20	0.25	0.50
	US dollars	The rate of the additional return from the sale of unsold tickets by the intermediary, in %					
50 seats	9,910	15.74	21.19	26.64	31.79	37.13	66.90
65 seats	12,776	6.89	10.18	13.15	15.89	19.41	36.63
75 seats	14,976	2.94	5.01	6.81	8.88	10.68	22.57
80 seats	15,690	1.53	2.87	4.59	6.25	7.65	17.40
85 seats	16,936	0.24	1.18	2.13	3.31	4.72	12.28
90 seats	17,886	0.00	0.00	0.34	1.17	2.24	8.00
$\geq 95$ seats	18,786	0.00	0.00	0.00	0.00	0.00	4.15

one hand, the market of commercial passenger air travel shows a consistently upward tendency of development (over the last 15 years a more than twofold increase in passenger traffic rate has been observed; according to the estimates for the next 15 years, this tendency will persist). But, on the other hand, some problems hinder the sustainable economic growth of the market: insufficient occupancy rate of flights, reduced profitability of airlines, reduction of their ability to invest in their own development. Therefore, it is important for the airlines to find solutions to attract customers. Hence a promising tendency can be considered the development of co-competition forms and attraction of a wide intermediary network to cooperation.

The proposed economic and mathematical models used for prediction of benefits of the airlines and their intermediaries provide various options for cooperation and take into account the fact that the activities of intermediaries can be characterized by opportunistic behavior. The practical use of the developed economic and mathematical models allows the airlines:

1. to simulate the rate of return from activities, depending on the forms of organization of cooperation with intermediaries and depending on the type of demand of intermediaries for air tickets. This allows the airlines to find the best alternate solutions and schemes for distribution of air tickets for the greatest (maximum) flight occupancy;
2. to predict their cash flows for business planning and strategy development, taking into account the potential benefits and possible losses. This provides a balance of strategic action plans and promotes the greater financial and economic stability of the airlines;

3. to find new solutions in the sphere of marketing and promotion of passenger air travel services (including the use of various forms of intercompany cooperation, co-competition, co-branding). This makes it possible not only to better meet customer demand, which, in turn, promotes the growth of loyalty of the airline customers. Moreover, the use of economic and mathematical models makes it possible to determine the potential benefits and possible risks of new services provision in the sphere of commercial passenger air travel.

In this article some special cases of economic and mathematical modeling of the ticket sales process have been examined, taking into account the activities of intermediaries in the commercial air passenger market, but without taking into account the changes in consumer behavior. The aspect of economic and mathematical modeling of consumer behavior in purchasing services in the commercial air passenger market will be discussed in the next articles dedicated to this topic.

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