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Dynamic Method of Seats Allocation in Airline Alliance

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***Abstract*—Slot Inventory Control holds a core position in airline revenue management. The paper attempts to propose an optimal seats allocation model in airline alliance by the continuous expansion and in-depth cooperation of airlines. Centralization and decentralization in dynamic allocation processes are established to model the dynamic pricing process. Results indicate that optimal seats allocation can be set dynamically in airline alliance which is not controlled by airlines.**

Keywords—air transportation; seats allocation and control; dynamic programming; airline alliance; revenue management

I. INTRODUCTION

Since the end of the 1990s, more and more airlines have joined the aviation alliance. The main reason is that aviation alliance members can quickly increase the number of flights and expand the route network by expanding the number of aircraft or increasing operating costs. Increase revenue and market share. According to the 2018 IATA data report, the three major airline alliances account for more than 60 percent of the market, while airlines that do not join the three major leagues are also deepening cooperation with other airlines. While airline cooperation continues to deepen and become more complex, many airlines are also aware that researching effective airline alliance revenue methods to maximize aviation alliance revenue is the key to future civil aviation industry success.

The remainder of this paper is as follows: the second section reviews the literature on seats allocation. The third section presents the dynamic allocation model. Finally, the paper is summarized and concluded with the main findings and future works.

II. STATIC SEATS ALLOCATION METHODS IN AIRLINE ALLIANCE

In the aviation alliance, air tickets are generally sold by the marketing airlines and the operating airlines. Considering the independence and operability of the system, the member companies generally adopt the following distribution methods in the alliance agreement.

A. Fixed number allocation

Fix number allocating means that the alliance members decide how many seats to allocate to the partners by setting different agreements in the code-sharing airline alliance. One is a non-refundable agreement in which the carrier "sells" some seats to another company at a certain price. Another airline sells these seats to passengers through its own marketing and sales system. The unsold tickets cannot be returned to the carrier, which is actually It is a form of partial wet rent. Another is a returnable agreement which is similar to the non-refundable agreement. The difference is that the cooperative company can return the unsold tickets to the carrier at some point time in the agreement (such as 21 days before the flight or14 days, etc.), the carrier does not charge or charge a certain amount of return fee. This approach reduces the sales pressure of the partner company and increases the opportunity for the carrier to resell the ticket within a certain period of time.

B. Unfixed number allocation

Compared with the fixed seat number allocation, the most widely used is the free seat allocation agreement. There is no special restriction on the number of tickets sold by cooperative airlines in the agreement. Each airline can sell tickets as much as possible and the fares are subject to the fare class established by the operating airlines. The operating airlines realize the expected return by closing a certain class of space and changing the fare class at different time points of the flight (such as 21 days before the flight, 14 days, etc.).

This allocation method uses the revenue management theory which increases the revenue of the carrier airline and the cooperative airline to a certain extent (at least the total revenue of the airline alliance). However, cooperative airlines are required to transmit the sold ticket data to the carrier airline every day and to use the carrier's fare class. But it's hard to realize the connecting of two companies' ticket systems, that transferring data always is delayed.

C. Static seats reallocation

In order to achieve the aviation alliance network balance and reduce the difference in shadow price between the operating airline and the marketing airline in the airline alliance, the power of selling tickets will be transferred from low-priced airlines to high-priced airlines in the static seats allocation. $\lambda_i, \Delta_i, \lambda_i^+$ represent shadow price, gradient, and changed shadow price. n indicating the number of transfers between the two airlines.

$$\lambda_1^+ = \lambda_1 + n\Delta_1 \tag{1}$$

$$\lambda_2^+ = \lambda_2 + n\Delta_2 \tag{2}$$

When $\lambda_1^+ = \lambda_2^+$, it is the optimal allocation. If $\lambda_1^+ > \lambda_2^+$, the number of n seats will be transferred from the airline 1 to airline 2, and $n = \dfrac{\lambda_1 - \lambda_2}{\Delta_1 + \Delta_2}$. (3)

This method can be used not only between two airlines, but also among a number of cooperative airlines in the aviation alliance by calculating a series of equations to calculate the number of seats added and reduced to each airline.

III. Dynamic Method of Seats Allocation in Airline Alliance

Booking time is a long and complex period. The prices sold to passengers are determined by not only the marketing airline but all so the cooperate airline in airline alliance. Basically, airlines adjust their ticket prices over time prior to the flight departure in an attempt to gain the maximum profit of itself. The sum of the maximum profit of each airline is not meant to the optimal revenue of the whole airline alliance. It often less than the maximum profit. So we establish the dynamic control model to allocate the seats in order to get the optimal revenue of the whole alliance rather than each airline.

The key to implementing dynamic seats control lies in two points. First, the marketing airline ensures that the seats sold are feasible on the alliance network route. Second, the operating airlines agree to receive the connecting leg of the marketing airlines' passengers, which mainly depends on the price of the ticket price afforded by the passengers and the price paid by the marketing airline to the operating according to the airline alliance allocation agreement.

A. Symbol description and assumptions

C represents the airlines in airline alliance $C = \{1,2\}$;

N represents the legs of itineraries; N_1 represents legs of a multi-leg itinerary operated by airline 1; N_2 represents legs of a multi-leg itinerary operated by airline 2; N_s represents legs of a multi-leg itinerary operated by together, so $N = N_1 + N_2 + N_S$; x^i represents the rest seats in leg i, so the rest seats of the whole airline alliance are $\vec{x} \equiv \left\{x^1, \dots, x^{m_1}, x^{m_1+1}, \dots, x^m\right\}$;

We assume in the booking time k the probability that airline C obtains a passenger request is

$q_k^{cj}, q_k^{cj} \ge 0$, and the probability of no passenger request is $q_k^0 = 1 - \sum_{c\in(1,2)} \sum_{j\in N} q_k^{cj} \ge 0$;

We assume that each passenger arrives independently, revenue is R_k^{cj}, and the cumulative distribution function is $F_k^{cj}(r)$, $J_k(\bar{x})$ represents the whole respect revenue of airline alliance. $\Delta J_k\left(\bar{x}, e^j\right)$ represents the opportunity cost which is the least income when marketing airline receives of a passenger, so $\Delta J_k\left(\bar{x}, e^j\right) \equiv J_k\left(\bar{x}\right) - J_k\left(\bar{x}, e^j\right)$. The decision amount $u_k^j\left(r, \bar{x}\right)$ represents the itinerary accepts or rejects a passenger, $u_k^j\left(r, \bar{x}\right) = \begin{cases} 1 & accept \\ 0 & reject \end{cases}$.

B. Dynamic control model under centralized control

$$E\left(J_k\left(\bar{x}\right)\right) = q_k^0 J_{k-1}\left(\bar{x}\right) + \sum_{j\in N} q_k^j \begin{bmatrix} R_k^j u_k^j\left(r, \bar{x}\right) + \\ J_{k-1}\left(\bar{x} - e^j u_k^j\left(r, \bar{x}\right)\right) \end{bmatrix} \tag{4}$$

$$J_0\left(\bar{x}\right) = 0 \quad \forall \bar{x} \ge 0 \tag{5}$$

$$u_k^j\left(r, \bar{x}\right) = \begin{cases} 1 & r \ge \Delta J_k\left(\bar{x}, e^j\right) \\ 0 & r < \Delta J_k\left(\bar{x}, e^j\right) \end{cases} \tag{6}$$

$$if \quad u_k^j\left(r, \bar{x}\right) = 1, \quad R_k^j = r \tag{7}$$

Equation (6) indicates that when the passenger is willing to pay a fare that is greater than or equal to the opportunity cost of the airline alliance, the airline alliance sells the ticket and vice versa;

Equation (7) shows that when the airline alliance agrees to sell a ticket, the proceeds are equal to the fare the passenger is willing to pay.

C. Dynamic control model under decentralized control

Since the aviation alliance involves anti-monopoly law, member airlines cannot share information completely, and each airline is selfish. When selling fares that benefit airline alliances are less than the proceeds from their separate sales, aviation Companies often reject such fares, but after joining the airline alliance, airlines have expanded their markets and increased passengers. Therefore, when performing dynamic seats control, the opportunity cost variation factor should be introduced to prevent the airline alliance from overflowing.

Taking into account the above conditions, the airline's decision is divided into the following steps:

1. The marketing airline receives a request from a passenger who is willing to pay the fare;

2. Marketing airline confirms and transmits the transfer price for the seat on the operating airline;

3. The operating airline confirmation and feedback of the seat and transfer price are feasible;

4. Accept or reject passengers.

In the booking time of k, the transfer price for the rest seats $\bar{x}$ in itinerary is $p_k^{cj}\left(\bar{x}\right)$, To simplify the formula, assume one airline is c, and the other is $-c$, then:

$$\Delta J_k\left(\bar{x}, e^j\right) = \Delta J_k^c\left(\bar{x}, e^j\right) + p_k^{-cj}\left(\bar{x}\right) \tag{8}$$

The dynamic control equation is

$$E\left[J_k\left(\bar{x}, \mathrm{e}^j \middle| p_k^{-cj}\left(\bar{x}\right)\right)\right] = \left\{\begin{array}{l} \sum_{j\in N_s} q_k^{cj}\left[\begin{array}{l} R_k^{cj}u_k^{cj}\left(r,\bar{x}\right)+ \\ J_{k-1}^c\left(\bar{x}-e^j u_k^{cj}\left(r,\bar{x}\right)\right)\end{array}\right] \\ +\sum_{j\in N_s} q_k^{-cj}\left[\begin{array}{l} p_k^{cj}u_k^{-cj}\left(r,\bar{x}\right)+ \\ J_{k-1}^c\left(\bar{x}-e^j u_k^{-cj}\left(r,\bar{x}\right)\right)\end{array}\right] \\ +\sum_{j\in Nc, c\in(1,2)} q_k^{cj}\left[\begin{array}{l} R_k^{cj}\tilde{u}_k^{cj}\left(r,\bar{x}\right)+ \\ J_{k-1}^c\left(\bar{x}-e^j \tilde{u}_k^{cj}\left(r,\bar{x}\right)\right)\end{array}\right] \\ +q_k^0 J_{k-1}\left(\bar{x}\right)\end{array}\right. \tag{9}$$

$$J_0\left(\bar{x}\right) = 0 \quad \forall \bar{x} \geq 0 \tag{10}$$

$$u_k^{cj}\left(r,\bar{x}\right) = \begin{cases} 1 & \begin{array}{l} r \geq \delta\Delta J_k^c\left(\bar{x}, e^j\right) + p_k^{cj} \\ u_k^{-cj}\left(r,\bar{x}\right) = 1 \end{array} \\ 0 & \quad otherwise \end{cases} \tag{11}$$

$$u_k^{-cj}\left(r,\bar{x}\right) = \begin{cases} 1 & p_k^{cj} \geq \delta'\Delta J_k^{-c}\left(\bar{x}, e^j\right) \\ 0 & p_k^{cj} < \delta'\Delta J_k^{-c}\left(\bar{x}, e^j\right) \end{cases} \tag{12}$$

$$\tilde{u}_k^{cj}\left(r,\bar{x}\right) = \begin{cases} 1 & r \geq \Delta J_k^c\left(\bar{x}, e^j\right) \\ 0 & r < \Delta J_k^c\left(\bar{x}, e^j\right) \end{cases} \tag{13}$$

Equation (9) represents the decision of three parts, the first part indicates whether the marketing airlines sell the fare r for the ticket and get revenue $r - p_k^{cj}$. The second part indicates whether the operating airline accepts the transfer price p_k^{cj}. And the third part dynamic control separately by marketing airline and operating airline.

D. Dynamic control coefficient

The two airlines have an opportunity cost of 800 yuan and 700 yuan for their respective segments. When airline 1 receives a 1360 yuan request as the marketing airline, airline 1 pays airline 2 for the transfer price p, if no opportunity cost coefficient δ are used. See as TABLE I

TABLE I. INTERLINE BENEFIT OF REVENUE SHARING

Airlines	e^j	Opportunity Cost	Passenger Arrival Probability
Airline 1 Airline 2	(1, 0) (0, 1)	800 700	0.5 0.5
Airline 1	(1, 1)	1300	1.0

The two airlines want to get the income of $1360 - p \geq 800$ and $p \geq 700$, then $p \leq 560$ and $p \geq 800$, obviously not established, so airline 1 rejected the ticket request. But $1360 \geq 1300$, this ticket is greater than the entire alliance opportunity cost, the marketing airline should be accepted, so global optimization cannot be achieved.

Using the opportunity cost variation factor δ, assume that the two airlines have an opportunity cost variation factor of 0.9, and the revenues are $1360 - p \geq 720$, $p \geq 630$, then $630 \leq p \leq 640$, it is respective. The airline accepts the ticket request and the airline alliance receives the proceeds. The above shows that the introduction of the opportunity cost factor can prevent the aviation alliance from overflowing, and the adjustment can be infinitely close to the global optimum.

IV. CONCLUSIONS AND PROSPECTS

In the context of the deepening of the aviation alliance's revenue and the mature income management methods, domestic and foreign airlines have begun to pay attention to the revenue management of airlines in the alliance environment in the past two years. On the one hand, airlines are most concerned about the issue of income, that is, how to ensure that in the case of code sharing, they will not suffer losses due to the acceptance of intermodal transportation. On the other hand, from the perspective of the alliance, it is necessary to ensure that passengers who benefit from the alliance's revenue should not be rejected.

This paper establishes the dynamic capacity allocation model of the airline alliance and theoretically establishes how the airline manages the revenue after joining the alliance. However, if it is applied to the actual operation, there are still many realistic factors to consider. The future will be from algorithms and systems. Research and development in other aspects, the airline alliance revenue management theory model is transformed into application technology, contributing to the aviation alliance revenue management.

REFERENCE

[1] Vinod, B. Alliance Revenue Management. Journal of Revenue and Pricing[J].Management Science. 2005, 4(1), pp. 66-82.

[2] Richard Ratliff and Larry R .Weatherford Codeshare and alliance revenue management best practices[C]. AGIFORS roundtable review.2014.

[3] M. Graf and A. Kimms. Transfer price optimization for option-based airline alliance revenue management[J]. International Journal of Production Economics.2013(9), pp.281-293.

[4] Waldemar G and Alf Kimms. Revenue management under horizontal and vertical competition within airline alliances[J]. Omega, 2015(6), pp.1-28.

[5] D. Çetinerand A. Kimms.Assessing fairness of selfish revenue sharing mechanisms for airline alliances[J]. Omega. 2013(8), pp.641-652.

[6] LIU W. Capacity control strategy research of airline alliance[D]. Beijing: Beijing Institute of Technology,2015. (In Chinese)

[7] Waldemar G and Alf Kimms.Revenue management under horizontal and vertical competition within airline alliances[J]. Omega,2015(6), pp.1-28.

[8] M. Graf and A. Kimms.Transfer price optimization for option-based airline alliance revenue management[J]. International Journal of Production Economics.2013(9), pp.281-293.