Research on Regional Multi-Airport Passenger Source Competition Based on Hotelling Model

Yangyang Qi[1]; Wei Wei[2]; and Rui Han[3]

[1]Shanghai Univ. of Engineering Science. E-mail: 824638117@qq.com
[2]Shanghai Univ. of Engineering Science. E-mail: 13675184065@163.com
[3]Shanghai Univ. of Engineering Science. E-mail: 15951265945@163.com

ABSTRACT

The passenger travel behavior in multi-airport areas has the characteristics of "preference for different flight attributes and strong attraction of the hub airport", leading to the polarization of air passengers' distribution in the region and the Matthew effect in airport development. This paper uses Hotelling model to analyze the internal mechanism of passenger competition among multiple airports in a region, and the purpose is to propose an airport operation optimization plan to alleviate contradictions in the development process of regional air transport industry, and finally follow the coordinated development strategy of the national airport group. According to the research: (1) the increase in passenger price sensitivity coefficient and passenger travel cost will cause an decrease to the airport market share; (2) the core factor of airport passenger source competition is flight price; (3) differentiation strategy is an effective way to enhance the market competition advantage, form a competitive and cooperative mode, and promote the coordinated development for airports in a region.

INTRODUCTION

With the steady growth of China's social economy and the continuous development of air transportation business, the total passengers traffic in the region show the rapid growth trend, but there are many problems in the development process : passengers choose regional hub airports for travel, causing the hub airports are operating in the state of over-saturation, while small & medium - sized airports are short of tourists, the development of airports are in the "Matthew effect". Taking the Beijing, Tianjin and Hebei Airport Group as an example, the ratio of passenger throughput between Beijing capital international airport and six small& medium-sized airports in the region was 7:3 in 2018, showing a significant gap in passenger throughput. Therefore, it is an effective way to solve the problem that alleviate the transportation pressure of hub airports and meet the demand of transportation capacity of small &medium-sized airports.

Considering the hub airport and within the different geographical position and the area of small and medium-sized airport hubs of monopoly on affected passengers' choice behavior, this article uses the Hotelling model depicting regional hub airports and small &medium-sized airport customers competitive behavior, analyzing the airport passengers' competition process, finally thinking development opinions and measures to ease polarization patterns in airports.

The application of Hotelling model by domestic and foreign scholars has been widely developed: From the pure position game to the position price game, and then to the position price and strategic price game. Main research direction includes: product differentiation research, price differentiation research, and two-dimensional Hotelling model study. Among them, domestic and foreign scholars have made abundant achievements in product differentiation research. Feng (2013) re-derived the equilibrium results of the Hotelling model, and concluded that product differentiation development is an important way of competition to maintain a monopoly position in the market and obtain high profits. Klemperer (1987) extended the product differences to brand differences in the Hotelling model and explained the importance of taking market share as the strategic goal of enterprises. Ye and Halpitim (2019) used the Hotelling model to construct a strategic choice model of capital-intensive and labor-intensive enterprises, and discussed the development mechanism of the market strategies of the two types of enterprises under the change of productivity differences between the two enterprises. Li (2013) used the Hotelling model to demonstrate the significance and necessity of the differentiation strategy for the development of online banking business in the banking industry.

For the research on the competition of airports, domestic and foreign scholars also have rich research achievements. Lian and Rønnevik (2011) found that the market share of airports in Norway shifted to the nearby major airports, the passengers' turnover of feeder airports was high, leading to fierce airport competition. Pels et al. (2000) established an airport and airline selection model based on the nested polynomial logit model, and studied the competition of metropolitan airports and airlines with multiple take-off and landing airports. Barbot (2009) established a three-stage game model of airport and airline competition with static and dynamic game methods, and analyzed the motivation and results of vertical cooperation between one airport and another airport and another airline.

Domestic scholars tend to study airport competition and passenger volume forecast from the perspective of airport competition. WANG et al. (2013) comprehensively considered the layout and competitiveness of hub airports in the region, and established the prediction model of airport aviation market share, which was used for the prediction of air passenger volume of airports in hinterland cities; Bai (2018) used Lotka-Volterra model to analyze the competition and cooperation relationship between adjacent airports in a regional multi - airport system, so as to predict the passenger flow of feeder airports; Huang quantitatively analyzed the changes of direct passenger flow competition and possible equilibrium results of adjacent airports through Lotka - Volterra model, and solved the stable state of the competition system and the conditions it met; Zhang (2017) considered the congestion cost of airports in the Hotelling model, and constructed the "two-airport-two-airline" airport source competition game model, and analyzed the airport source competition strategies under symmetric and asymmetric conditions in the market.

Through the review of relevant literature at home and abroad, it can be seen that Hotelling model is widely used to analyze the impact of product differentiation on enterprise development, and there are few studies on airport passenger source competition under regional airport group model. Therefore, based on small & medium -sized airport and hub airports and their market development strategy, this paper uses Hotelling model to analyze the internal mechanism of passenger competition among multiple airports in a region, and the purpose is to built an airport operation optimization plan to alleviate contradictions in the development process of regional air transport industry, and finally follow the coordinated development strategy of the national airport group.

MATHEMATICAL MODEL

Model specification

The classic Hotelling model means that there is no difference in costs and products between two enterprises at both ends of the city, and travel costs lead to changes in benefits due to location differences. The model has the following characteristics:

Supposing that there is a linear city of length 1, and consumers are evenly distributed in the interval of [0, 1], with distribution density of 1.

Assuming that there are two vendors located at opposite ends of the city, vendor 1 at $x = 0$ and vendor 2 at $x = 1$.

Assuming that two manufacturers sell homogeneous products, the marginal cost provided by each manufacturer is c, and the travel cost of each purchase is directly proportional to the distance from the manufacturer, and the additional cost per unit distance is t.

Based on the classic Hotelling model, this paper adds factors such as passenger travel cost, airport congestion coefficient and other factors, studies the internal mechanism of airport passenger source competition, and makes the following assumptions:

Supposing there are two adjacent airports, one of which is a large hub airport and the other is a medium and small airport, as shown in figure 1.

The two airports are located at both ends of the hinterland and the length of the hinterland market is 1. Passengers are evenly distributed in the hinterland of the airport. The distribution density is 1, and the position is $x(1 < x < 2)$.

The rate of passengers which choose airports i is $X_i (i = 1, 2)$, $X_1 + X_2 = 1$.

Considering the effect of airport congestion on passenger utility. Since the congestion of the airport is inversely proportional to the capacity of the airport [11], it is assumed that the congestion cost per unit airport is β / I_i, and β is the unit time cost, then the congestion cost of the airport is $\frac{X_i \cdot \beta}{I_i}$.

The research object of this paper is leisure travelers, and the key consideration is the influence of choice behavior of leisure travel airport on airport passenger source. It is assumed that the fare sensitivity of leisure travelers is b.

Airport price refers to the price that a flight is required to pay when operating in the airports i, defined as p_i.

The marginal cost of the airport is c_i and the fixed cost is zero.

The degree of conformity between airport development status and airport positioning is defined as airport parity degree, which is expressed as θ_i $(0 < \theta_i < 1)$. The increase of airport parity degree depends on the implementation of differentiated development strategy by the airport. The definition of airport coordinate degree is related to the number of airport routes a. The more routes that conform to the airport positioning a_i, the greater the value of airport coordinate degree, which is $\theta_i = \frac{a_i}{a}$. At the same time, the market location of airport depends on the change of airport route. The number of passengers attracted by the route in line with the airport location is higher than the number of passengers attracted by simply increasing the route. At the same time, after the increase of route density, the operating cost of unit route allocation decreases. Both of these effects bring the increase of airport revenue, which calls as the scale effect. Supposing that the unit revenue brought by the change of route category to the airport is ∂. The more in line with the positioning of airport development will bring profit to the airport, defined as $\partial \cdot \theta_i$.

The travel cost of passengers is related to the straight-line distance between the destination airports, and they show a quadratic function relationship. The travel cost per passenger is assumed to t, and the travel cost of passenger is $t \cdot x^2$ and $t \cdot (1-x)^2$ respectively.

The u_i represents the utility function when passengers choose to travel at the airports i , u_0 represents the inherent benefits before passengers choose to travel at the airports i , and u_0 is large enough, π_i represents the profit of the airports i .

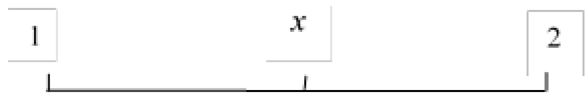

Figure 1. Linear location of airports and passengers

Model building

Passengers choose airports according to their own utility maximization principle, assuming passengers who with position x between [1,2] have the same value of utility function when they choose airports.

$$U_1 = U_0 - \frac{\beta x}{I_1} - t \cdot x^2 - b \cdot p_1 + \theta_1 \cdot \partial \tag{1}$$

$$U_2 = U_0 - \frac{\beta(1-x)}{I_2} - t(1-x)^2 - b \cdot p_2 + \theta_2 \cdot \partial \tag{2}$$

The expressions of X_1 and X_2 can be obtained through equations (1) and (2).

$$X_1 = x = \frac{\frac{\beta}{I_2} + t + b(p_2 - p_1) + \partial(\theta_1 - \theta_2)}{2t + \frac{\beta}{I_1} + \frac{\beta}{I_2}} \tag{3}$$

$$X_2 = 1 - x = \frac{\frac{\beta}{I_1} + t + b(p_1 - p_2) + \partial(\theta_2 - \theta_1)}{2t + \frac{\beta}{I_1} + \frac{\beta}{I_2}} \tag{4}$$

Thus, obtaining airports' profit value of passenger transportation business π_i .

$$\pi_1 = (p_1 - c_1) \cdot x = (p_1 - c_1) \cdot X_1 \tag{5}$$

$$\pi_2 = (p_2 - c_2) \cdot (1-x) = (p_2 - c_2) \cdot X_2 \tag{6}$$

Airports i take profit maximization as the target of market competition, making formula (5) and formula (6) are respectively equal to 0, calculating the equilibrium price of the airports:

$$p_1 = \frac{\frac{\beta}{I_1} + \frac{2\beta}{I_2} + 3t + \partial(\theta_1 - \theta_2) + b(2c_1 + c_2)}{3b} = \frac{Y_1}{3b} \tag{7}$$

$$p_2 = \frac{\frac{2\beta}{I_1} + \frac{\beta}{I_2} + 3t + \partial(\theta_2 - \theta_1) + b(c_1 + 2c_2)}{3b} = \frac{Y_2}{3b} \tag{8}$$

Model analysis

Analyzing the influence mechanism of passenger price sensitivity coefficient, unit passenger travel cost and differentiation coefficient on airport equilibrium price and market share value.

The influence of passenger price sensitivity coefficient on airport market share value

Calculating the derivative to b in equations (3), (4), (7) and (8), and the results are as follows:

$$\frac{\partial X_1}{\partial b}=\frac{p_2-p_1}{\frac{\beta}{I_1}+\frac{\beta}{I_2}+2t} \tag{9}$$

$$\frac{\partial X_2}{\partial b}=\frac{p_1-p_2}{\frac{\beta}{I_1}+\frac{\beta}{I_2}+2t} \tag{10}$$

$$\frac{\partial p_1}{\partial b}=\frac{2c_1+c_2+3Y_1}{9b^2} \tag{11}$$

$$\frac{\partial p_2}{\partial b}=\frac{(c_1+2c_2)+3Y_2}{9b^2} \tag{12}$$

According to formulas (9) and (10), the symbols of the formula are related to the equilibrium price difference p_1-p_2 of airports. According to equations (11) and (12), both equations are positive, b has same effects on p_i .so the change of market share value X_i depends on the change degree of p_i as the increase of b. when $p_1 \ge p_2$, formula 9 is less than 0 and formula 10 is greater than 0, showing $X_1 \le X_2$; when $p_1 \le p_2$, formula 9 is greater than 0 and formula 10 is less than 0, showing $X_1 \ge X_2$. Therefore, in the airport's passenger source competition model, the change trend of the airport's market share value is determined by the airports' equilibrium price difference p_1-p_2, and the change trend is opposite.

The influence of airport parity on airport market share

Calculating the partial derivatives of equations (3) (4) (7) and (8) to θ_1 respectively, and the results are as follows:

$$\frac{\partial X_1}{\partial \theta_1}=\frac{\partial}{6t+\frac{3\beta}{I_1}+\frac{3\beta}{I_2}} \tag{13}$$

$$\frac{\partial X_2}{\partial \theta_1}=\frac{-\partial}{6t+\frac{3\beta}{I_1}+\frac{3\beta}{I_2}} \tag{14}$$

$$\frac{\partial p_1}{\partial \theta_1}=\frac{\partial}{3\mathrm{b}} \tag{15}$$

$$\frac{\partial p_2}{\partial \theta_1}=\frac{-\partial}{3b} \tag{16}$$

Formula (13) and (14) show that θ_1 has opposite effect on the airports' market share value, with the increase of θ_1, X_1 increases and X_2 decreases. Formula (15) and (16) show that with the increase of θ_1, p_1 increases, p_2 decreases. It can be seen from the analysis that the increase of θ_1 represents that the route opened by airport 1 conforms to the positioning of the airport itself, causing X_1 increases.

Determining the influence of θ_2 on the airport market share value, and calculating the partial derivatives of equations (3) (4) (7) and (8) to θ_2 respectively, the results are as follows:

$$\frac{\partial X_1}{\partial \theta_2} = \frac{-\partial}{6t + \frac{3\beta}{I_1} + \frac{3\beta}{I_2}} \tag{17}$$

$$\frac{\partial X_2}{\partial \theta_2} = \frac{\partial}{6t + \frac{3\beta}{I_1} + \frac{3\beta}{I_2}} \tag{18}$$

$$\frac{\partial p_1}{\partial \theta_2} = \frac{-\partial}{3b} \tag{19}$$

$$\frac{\partial p_2}{\partial \theta_2} = \frac{\partial}{3b} \tag{20}$$

Judging from the symbols of formula (17) - (20), it can be known that with the increases of θ_2, p_1 and X_1 decreases; p_2 and X_2 increases, which is the opposite to that of θ_1 increases. It can be seen that changes of θ_i have opposite effects on the airports' market shares, which is related to p_i.The influencing mechanism is $\theta_i \to p_i \to X_i$. The flow chart takes θ_1 as an example, as shown in Figure 2:

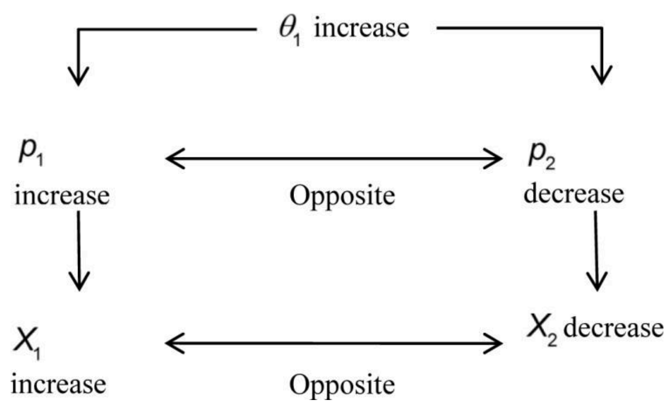

Figure 2. The flowchart of the change of $p_i(i=1,2)$ and $X_i(i=1,2)$ with the Increase of θ_1

CASE ANALYSIS

This paper assumes the relevant data of Beijing Capital International Airport and Shijiazhuang Zheng - ding International Airport, and combines the equilibrium solution of the airport Passenger Source Competition model to simulate the customer competition process of the two major airports, analyses the impact of the airport parity on the airports' market share. Supposing the unit passenger travel cost is 0.75, unit profit is assumed as 1, the passenger price sensitivity coefficient is 1, the average freight rate is 0.7 RMB / km, so the cost of transporting passengers at the airport is 0.7, the capacity of Beijing Capital International Airport is 9, and the capacity of Shijiazhuang Zheng - ding International Airport is 1. Thus, I_1=9, I_2=1. t=0.75, b=1, $c_1 = c_2$=0.7, ∂=1.

The influence of the differentiated development of Beijing Capital International Airport on the airports' market shares

Analysis the condition of θ_2 =0.2, θ_1 ={0, 0.2,0.4,0.6,0.8,1} and θ_2 =0.8, θ_1 = {0,0.2,0.4,0.6,0.8,1}, the change of airports' equilibrium price and the market value. The results are as shown in Figure 3.

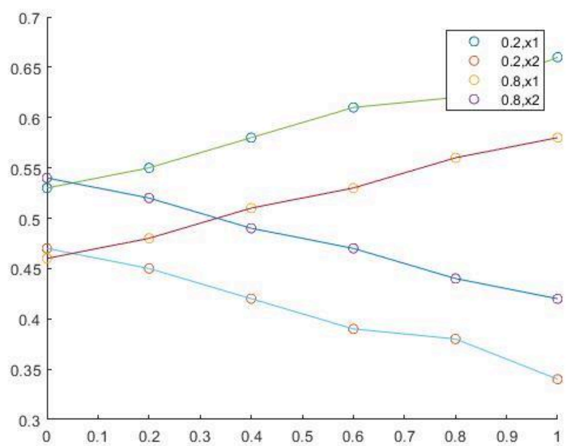

Figure 3. The trend chart of the X_i that θ_2 = 0.2, 0.8

As it can be seen from Figure 3, when $\theta_2 = 0.8$, the rate of increase or decrease of airport market share is slower than that of $\theta_2 = 0.2$, indicating that with the increase of airport isometric degree, the gap between the two airports' market share values gradually decreases and the development of the two airports tends to be stable. When $\theta_2 = 0.8$, with the continuous increase of θ_1, the market shares of the two airports tend to be the same, avoiding the state of polarization, indicating that the differentiated development of airports has a great impact on the change of airport market shares.

In the actual airport operation process, Shijiazhuang Zheng - ding international airport should start from the airport itself and build the airport around the positioning of "regional aviation hub, international logistics hub", so as to reduce the business overlap with Beijing capital international airport, so as to promote the continuous development of the airport.

The influence of the differentiated development of Shijiazhuang Zheng - ding International Airport on the airports' market shares

Analyzing the condition of θ_1 = 0.2, θ_2 = {0,0.2,0.4,0.6,0.8,1} and θ_1 = 0.8, θ_2 ={0,0.2,0.4,0.6,0.8,1},the change of airports' equilibrium price and the market value. The results are as shown in Figure 4.

As it can be seen from Figure 4, when θ_1 values are different, the two curves show the same trend of change and the difference is small. By comparing figure 3 and figure 4, it can be seen that under the curve of figure 4, the airport tends to develop in a more balanced way, which indicates that in the process of passenger source competition between the two airports, the differential development of Shijiazhuang Zheng - ding international airport makes the market share gap between airports smaller and the development tends to be stable.

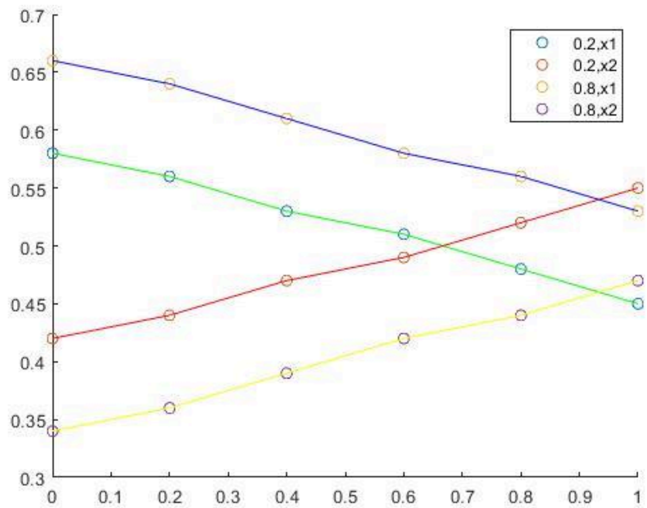

Figure 4. The trend chart of the X_i that $\theta_1 = 0.2, 0.8$

The above simulation results show that the differentiation strategy is conducive to promoting the balanced development of the two airports. The greater the degree of differentiation between airports, the more likely the airport development is to achieve the equilibrium state, and the change of the degree of differentiation of hub airports makes the difference of airport market share relatively small. which indicating the main driving force to realize the balanced development of regional airports is hub airports rather than small & medium - sized airports. The differentiated development of hub airports promotes the balanced distribution of passengers in regional airports.

This paper only analyzes the impact of airport differentiation development on passengers' choice of airports from the perspective of leisure travelers. In the future, it will broaden the scope of research and further analyze the internal mechanism of regional Passenger Source Competition.

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Passenger Behavior Characteristics-Based Research on Beijing "One City, Two Airports" Air Traffic Assignment under the Beijing-Tianjin-Hebei Coordination Strategy

Wei Wei[1] and Huihui Xiao[2]

[1]Shanghai Univ. of Engineering Science. E-mail: wwnjnh@163.com
[2]Shanghai Univ. of Engineering Science. E-mail: huelaxiao@163.com

ABSTRACT

After the construction completion of the Beijing new airport, based on the increasingly mature and integrated ground transportation, the research on the aviation market demand distribution of the regional airport system based on passenger behavior characteristics has been significant for Beijing to explore the cooperation mode of "one city, two airports". Based on the background of Beijing-Tianjin-Hebei coordination strategy, this thesis firstly analyzes air passenger behavior attribute characteristics in Beijing-Tianjin-Hebei region from three aspects including passenger personal characteristics, passenger travel characteristics, and aviation activity selection behavior characteristics. Secondly, the passenger group is divided into business travelers and leisure travelers, and then this thesis constructs a two-layer nested Logit model of the selected airports, and finally predicts the radiation area and air traffic assignment of "one city, two airports" of Beijing. The results show that: (1) in terms of passenger behavior characteristics, the top preference of business travelers is flight frequency, while it is flight fare for leisure passengers, and the on-time rate is a common concern factor for both business and leisure travelers. (2) Both airports in Beijing radiate cities including Beijing, Tianjin, Tangshan, Langfang, Baoding, and Cangzhou. (3) After the operation of the new airport, passenger flow of PEK will be diverted to ease its operational pressure on one hand, and it will also expand the aviation radiation area of Beijing and promote the competitiveness of Beijing as an international aviation hub.

INTRODUCTION

In order to comply with the national strategy of coordinated development in the Beijing-Tianjin-Hebei region, the Beijing-Tianjin-Hebei regional civil aviation industry has started their first step ahead. In December 2015, the CAAC issued gradually built the most influential Beijing-Tianjin-Hebei airport system in China. After completion of PKX, the move of air passengers among airports is more convenient and frequent based on the increasingly mature and integrated ground traffic. An in-depth analysis of air passengers' behavior characteristics can help explore the factors affecting the distribution of air passengers in the region and realize the adjustment of air passenger throughput allocation among airports in the Beijing-Tianjin-Hebei region by relying on work division of regional airports.

Many existing studies focused on the analysis of the travel behavior characteristics of air passengers initially. With the emergence of regional multiple airport systems, numerous scholars used the Logit model to analyze the airport choice behavior of air passengers in many multiple airport regions, attempting to explain which are the sensitive factors affecting the airport choice of air passengers; airlines are also paying increasing attention to the characteristics of air passengers' behavior, and applying the travel choices of air passengers to research areas such as airline marketing and revenue management dynamic pricing [11-12]. Chinese scholars' studies on travel behavior characteristics of air passengers mainly lie in two aspects. One is to analyze