Study on the Pricing of Passenger Products of Beijing-Shanghai High Speed Railway under the Influence of Civil Aviation Competition

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Abstract: At present, China's single railroad fare mechanism restricts its own healthy development to a certain extent, and it is in a disadvantageous position to compete with the passenger traffic of civil aviation in the high-speed passenger transportation market. In order to better cope with the competition from civil aviation, this paper takes Beijing-Shanghai corridor as an example and solves the optimized fares of high-speed railway passenger products under the influence of civil aviation competition based on game theory, and the results show that the optimized fares can effectively improve the revenue of high-speed railway operating enterprises.

Keywords: potential category model; two-level planning; game pricing; differential pricing

1 Introduction

The two high-speed passenger transportation modes, high-speed rail and civil aviation, have many common advantages, such as high speed, high safety and high comfort, so the market competition between the two transportation modes is very fierce.Civil aviation fares in China are relatively perfect, occupying a favorable position in the high-speed passenger transportation market.[1] How to formulate the high-speed railroad passenger fares under the influence of civil aviation competition, and improve the competitiveness of high-speed railroad in the high-speed passenger transport market, has become an urgent problem for the railroad sector to solve.

2 High-speed passenger transportation market segmentation

Carlos Martin J, Roman C .[2] A questionnaire survey of travelers obtained that high-speed rail and civil air travelers are more concerned about the connection time when traveling, and that travel choice behavior of travelers is also influenced by travel time.Segmentation of the high-speed passenger transportation market is conducive to high-speed rail and civil aviation operators to grasp the travel choice behavior of passengers and their demand for passenger transportation services.

The data of this paper mainly comes from the questionnaires issued.In this paper, the potential

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category model (LCM) is used[3] to segment the high-speed passenger market, which divides the Beijing-Shanghai high-speed passenger market into three categories (budget passengers, business passengers, and mixed passengers).

3 High-speed passenger transportation market segmentation based on high-speed rail and civil aviation game pricing

3.1 Game pricing model construction

1.Modeling the game between high-speed rail and civil aviation companies

The objective function for maximizing profit returns of high-speed rail and civil aviation enterprises is as follows:[4]

$$\max Z_{ni} = q_{ni}(p_{ni} - c_n) \tag{1}$$

In equation (1),Z_{ni} denotes the profit of mode n when transporting passenger type i,q_{ni} denotes the volume of passengers transported by mode n for passenger type i, p_{ni} denotes the fare of the passenger product offered by mode n to passenger type i, and c_n denotes the unit transportation cost of mode n.

2.Traveler travel choice game modeling

The generalized cost function of the traveler when traveling[5] can be expressed by the following equation:

$$G_n = p_n + s_n + b_n + k_n + z_n \tag{2}$$

In equation (2),G_n passenger travel represents the broad cost, p_n represents the economic cost, i.e., the fare,s_n represents the comfort cost,b_n represents the convenience cost,k_n represents the speedy cost, and z_n represents the on-time cost.

The generalized cost function of passenger travel mainly has two forms, logarithmic function and power function[6] , this paper uses the power function to represent the generalized cost function, whose generalized cost function can be expressed as follows:

$$G_i(q_{ni}) = aq_{ni}^{\beta} + V_{ni}, \quad n \in N \tag{3}$$

In equation(3), $G_i(q_{ni})$ denotes the generalized cost of class i travelers, V_{ni} denotes the observable portion of the generalized cost, and α and β are parameters, usually taken as 1.25 and 0.4, respectively.[5] .

The observable part of the generalized cost function is obtained as follows:

$$V_{ni} = \frac{\lambda_{1i}p_{ni} + \lambda_{2i}s_{ni} + \lambda_{3i}b_{ni} + \lambda_{4i}k_{ni} + \lambda_{5i}z_{ni}}{a}, \quad n \in N \tag{4}$$

In equation (4), s_{ni} denotes the comfort cost of the nth transportation mode chosen by the i-th category of passengers, b_{ni} denotes the convenience cost of the nth transportation mode chosen by the i-th category of passengers, k_{ni} denotes the expeditiousness cost of the nth transportation mode chosen by the i-th category of passengers, z_{ni} denotes the punctuality cost of the nth transportation mode chosen by the i-th category of passengers, λ_{1i} - λ_{5i} denotes the weighting coefficients of the i-th category of passengers for the economy cost, comfort cost, convenience cost, expeditiousness cost and punctuality cost, respectively, and a denotes the security.

3.Construction of a game pricing model for high-speed passenger transportation between high-speed rail and civil aviation based on market segmentation

The game pricing model to be constructed in this paper is mainly about the relationship between maximizing the profit of the operating company and minimizing the generalized cost of passengers[7] Therefore, this paper constructs the corresponding game pricing model based on the two-layer programming model.

(1) The two-tier planning model for HSR fare setting is as follows:

$$\max Z_1 = q_{1i}(p_{1i} - c_1) \tag{5}$$

$$c_1 \le p_{1i} \le p_{1i}^{\max} \tag{6}$$

$$\min G = \Sigma_{n \in N+1} \int_0^{q_{ni}} \left(\alpha w^{\beta} + \frac{\lambda_{1i}p_{ni} + \lambda_{2i}s_{ni} + \lambda_{3i}b_{ni} + \lambda_{4i}k_{ni} + \lambda_{51}z_{ni}}{a_n} \right) dw \tag{7}$$

$$\text{s.t.} \quad \begin{aligned} &\Sigma_{n \in N} q_{ni} = Q_i \\ &q_{ni} \ge 0, \forall n \in N+1 \end{aligned} \tag{8}$$

(2)The two-tier planning model for civil airline fare setting is consistent with the above.

3.2 Empirical analysis of game pricing in the Beijing-Shanghai passenger corridor

1.Beijing-Xuzhou section game pricing

After several rounds of gaming, the final game fares of high-speed rail and civil aviation for each type of passenger are shown in Table 1:

Table 1. High-speed rail and civil aviation game fares for three types of passengers

	High-speed rail gaming fares/yuan	Civil aviation gaming fares/yuan
Mixed travelers	380	417
Business travelers	391	441
Budget travelers	357	393

2.Beijing-Shanghai segment game pricing

The final calculated fares of the Beijing-Shanghai section for each type of passenger for the high-speed rail and civil aviation game are shown in Table 2:

Table 2. High-speed rail and civil aviation game fares for three types of passengers

	High-speed rail gaming fares/yuan	Civil aviation gaming fares/yuan
Business travelers	756	945
Mixed travelers	570	640
Budget travelers	542	618

4 Empirical analysis of differential pricing of passenger products of Beijing-Shanghai high-speed rail based on game fares

This chapter only classifies passenger transport products for Beijing-Shanghai section where the competition between high-speed railroad and civil aviation is relatively intense, and conducts differential pricing research on passenger transport products.

4.1 High-speed railway passenger products division of Beijing-Shanghai section

The classification of products in this paper is based on the passenger product classification method of civil aviation, and different classes of passenger products are classified based on travel time and departure time period. In terms of travel time, there are roughly two types of travel time from Beijing to Shanghai: 6h and 4.5h; in terms of departure time periods, there are four time periods: 6:00-8:00, 8:00-12:00, 12:00-16:00 and 16:00-18:00, and the specific classification is shown in Table 3 shows:

Table 3. Passenger product division of Beijing-Shanghai section

Product Grade	Product Serial Number	Travel time/h	Departure time period
Level I (1)	I_1	4.5	8-12
	I_2	4.5	12-16
Level II (II)	II_1	6	8-12
	II_2	6	12-16
Level III (III)	III_1	4.5	6-8 or 16-18
	III_2	6	6-8 or 16-18

The research in this paper assumes that the primary product is for business travelers, the secondary product is for mixed travelers, and the tertiary product is for economy travelers.

4.2 Differential pricing model construction

1.Profit function construction for high-speed rail operating companies

The profit maximization objective function of a high-speed railroad operating company is as follows:

$$\max Z_m = q_{mk}(p_{mk} - c) \tag{9}$$

$$c \leq p_{\mathrm{mk}} \leq p_m^{\max} \tag{10}$$

In the above equation, Z_m denotes the total profit of passenger product of class m, q_{mk} denotes the passenger traffic of the kth passenger product of class m selected, p_{mk} denotes the fare of the kth passenger product of class m, c denotes the unit transportation cost of HSR, and $p_m^{\max}$ denotes the fare cap of passenger product of class m.

2.Passenger travel generalized cost function construction

Based on Chapter 3, the observable part of the generalized cost function in this chapter does not take into account the convenience cost and on-time cost, but adds the departure time period cost, so the observable part of the generalized cost function for passenger travel is as follows:

$$V_{mk} = \frac{\lambda_{1i} p_{mk} + \lambda_{2i} s_{mk} + \lambda_{3i} k_{mk} + \lambda_{4i} T_{mk}}{a} \tag{11}$$

In equation(11), V_{mk} denotes the generalized cost observable component for selecting the kth passenger product of class m, s_{mk} denotes the comfort cost of the kth passenger product of class m, k_{mk} denotes the speedy cost of the kth passenger product of class m, T_{mk} denotes the departure time segment cost of the kth passenger product of class m, and $\lambda_{1\mathrm{i}}$ - λ_{4i} denote the weighting coefficients for economy cost, comfort cost, and departure time segment cost for class i passengers, respectively. a denote the weighting coefficients of economy, comfort, speed and departure time for passenger class i, respectively, and denotes security.

3.Differential pricing model construction

A two-tier planning model for differential pricing of high-speed rail passenger products based on game fares is as follows:

1) Upper level planning:

$$\max Z_m = \Sigma_{k\in K} q_{mk}(p_{mk} - c) \tag{12}$$

$$c \leq p_{\mathrm{mk}} \leq p_m^{\max} \tag{13}$$

$$\sum\nolimits_{k\in K} \frac{q_{mk}}{\Sigma_{k\in K} q_{mk}} p_{mk} = p_m \tag{14}$$

$$\max(p_{11}, p_{12}) \geq \max(p_{21}, p_{22}) \geq \max(p_{31}, p_{32}) \tag{15}$$

2）Lower level planning:

$$\min G = \sum\nolimits_{k\in K} \int_0^{q_{mk}} (\alpha w^{\beta} + V_{mk})\ dw \tag{16}$$

$$\sum\nolimits_{k\in K} q_{mk} = Q_m,\ \ q_{mk} \geq 0, \forall k \in K \tag{17}$$

4.3 Differential pricing of high-speed rail passenger products in the Beijing-Shanghai section

1.Passenger broad-based costing

From Chapter 3, the value of travel time for business passengers in the Beijing-Shanghai segment is RMB 45.25/h, for mixed passengers is RMB 23.34/h, and for economy passengers is RMB 18.38/h. The broad cost observable component costs for various passenger products can be calculated as shown in Table 4:

Table 4. Broad Cost Observable Components for Various Passenger Transportation Products

Product Grade	Product Serial Number	Travel time/h	Observable cost/yuan
Grade I (I)	I_1	4.5	$0.12p_{11}$ +52.38
	I_2	4.5	$0.12p_{12}$ +61.20
Level II (II)	II_1	6	$0.35p_{21}$ +36.99
	II_2	6	$0.35p_{22}$ +40.50
Grade III (III)	III_1	4.5	$0.48p_{31}$ +18.17
	III_2	6	$0.48p_{32}$ +21.96

2.Calculation of differential pricing for high-speed passenger rail products

From the calculation results in Chapter 4, we know that there are 12,604 business-type passengers, 14,423 mixed-type passengers and 25,895 economy-type passengers who choose to travel by high-speed rail in the Beijing-Shanghai section. The final calculation results of the bring-in data according to the differential pricing model are shown in Table 5:

Table 5. Differential Pricing Results for Various Passenger Transportation Products

Product Grade	Product Serial Number	Differential pricing/$	Passenger flow/trip	Profit/$
Grade I (I)	I_1	763	6131	4677953
	I_2	745	6473	4822385
Level II (II)	II_1	578	7034	4065652
	II_2	567	7389	4189563
Grade III (III)	III_1	545	12434	6776530
	III_2	538	13461	7242018

Combining the above differential pricing results, when the number of passengers choosing high-speed rail travel is 52922, combined with the current Beijing-Shanghai high-speed rail fares and passenger flow, we can get the profit of high-speed rail operating enterprises when the fares are both 553 yuan is 29265866 yuan, while the profit of high-speed rail operating enterprises after differential pricing is 31774101 yuan, after differential pricing The increase of profit of HSR operators is 8.57%.

5 Conclusion and outlook

Based on game theory, differential pricing theory and two-layer planning theory, this paper studies the pricing of high-speed railways in the Beijing-Shanghai high-speed passenger corridor under the influence of competition from civil aviation, and obtains the game pricing results of high-speed railways and civil aviation, as well as the differential pricing of various passenger products of high-speed railways based on game fares, which shows that differential pricing of high-speed railways passenger products can effectively improve the revenue of enterprises.

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