Analysis on the relationship between ticket price and competitiveness of high speed railway under the market environment

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Abstract

This paper uses the decision analysis method to study the relationship between the fare and the competitive ability of different modes of transportation. We mainly take transportation time, cost and safety as decision-making factors of decision-making level, quantitatively compare the advantages and disadvantages between some existing railways, highways and civil aviation, and give some suggestions for high-speed rail to increase competitiveness and how to adjust transport price. Through a case study, it is proved that decision analysis is consistent with fact in quantitative analysis of ticket price and competitiveness. Meanwhile, managers or passengers can use this method to select their most suitable transportation and travel mode by combining qualitative and quantitative analysis.

Keywords

passenger transport; high-speed railway; competitiveness; fares.

1. Introduction

In recent years, China's high-speed railway construction developing rapidly, which has formed a high-speed railway passenger network connecting the major and middle cities based on the passenger dedicated line and regional high speed intercity track line. This will certainly have a significant impact on the pattern of transportation industry and the choice of long distance travel mode. At the same time, the number of motor vehicles, especially cars in China is also increasing rapidly. The trip proportion between middle distance and long-distance expressways has been steadily improving, and has become the main competitor of high-speed railway. The development of aviation also makes the choice of passengers' travel more diverse. The characteristics of its safety and high speed have great competitiveness in long distance and middle-distance transportation, especially in recent years, since the cost of air transportation has been reduced, its competitive ability is more prominent.

Both domestic and foreign studies have shown that travel costs are one of the key factors that determine the way of passengers.

High price of high-speed railway will lose the competitive advantage of highway and aviation, and will reduce transport demand and the occupancy rate of high-speed railway, resulting in idle equipment and waste of resources; if the price of transportation is too low, it may lead to excessive transportation demand, tight transportation capacity, cause all kinds of unreasonable transportation, and even cause the vicious competition of the transportation industry. Obviously, it is important to establish the basis of reasonable price. The research results of competition between different modes of transportation at home and abroad are mainly included in the following.

Wang B discussed the economic distance of highway and railway passenger transport, analyzed the advantages of both, put forward relevant strategies and suggestions, to improve overall competitiveness of highway passenger traffic, obtain the probability of passenger selection of various modes of transportation by ant colony algorithm [1]. In contrast, high speed railway and civil aviation have more researches. Li Z H, Lu W W, Zhang X, Wu B, He T, etc. have studied the technical and economic characteristics and network layout of high speed railway and civil aviation transportation.

According to the analysis system of airline database, High speed railway occupies the absolute superiority in 600km following distance range, high-speed railway and civil aviation will form a fierce competition in the distance range of 600km-1200km. Civil aviation has obvious advantages in the distance range of more than 1200km [2-6]. Wei L X constructed a bi-level programming model of passenger and rail operations unit of the 2 contradictory dual interests, the penalty function algorithm is developed to solve the flow path Frank Wolfe Algorithm based on the rationality of the model and algorithm. The rationality and superiority of the designed model and algorithm is verified by Beijing-Shanghai high-speed railway [7]. Zhang Jing set up a planning model for passenger transport hub network coexisting with high speed rail and aviation, studied the optimization of high speed rail and air fare in hub network, and concluded that hub capacity should first satisfy the demand of the market [8].

The above research lays a theoretical foundation for the pricing of high speed railway. The high-speed railway has increased the share of the railway market to a certain extent, and has a certain impact on the transportation of civil aviation. However, some high-speed rail lines have few attendance rate, and the market share is low. Some of them are due to inconveniences or inconveniences, but more for the cost of the high-speed railway. On the basis of previous studies, this paper analyzes the competition of different modes of transportation to make reasonable fees for railway design, and better increase competitive ability. By the decision analysis method, we use the transportation time, cost and safety as the target vectors of the decision, and analyze the ticket price and competitiveness of the high-speed railway.

2. Decision analysis method

2.1 Principles and basic ideas

Decision analysis is the idea of classifying different kinds of factors and summarizing. The specific factors or abstract factors are classified and set up, each group is made up of similar factors. Finally, the process of analysis, computation and comparison for each “class” is analyzed. The decision analysis method humanizes and systematizes the thinking process, so that the decision basis is easily accepted. The method is widely used, and can be combined with many other modern algorithms. However, decision-makers need to have a thorough understanding of the nature of the problem, the factors involved and the logical relationship between the various factors. Moreover, the decision analysis method is more suitable for the non dimensional system evaluation or the multi-objective decision problem.

The basic idea of the decision analysis method is to classify the similar decision-making factors of the system. In each “class” of comparison set, we set up a range of values between each decision factor group and a calculated value corresponding to the factor value in this range. According to a judgment of a certain objective reality, we determined the specific values of each group of "class". Then, a mathematical method is used to determine the weight of each factor, and the decision analysis is used to determine the advantages and disadvantages of various alternatives

The decision analysis method can give full play to the subjective analysis and judgment ability of the decision-maker, and decompose the complex problem into a number of "classes". A corresponding factor model in each "class", through the comparison of factors and optimal vector of each decision, then combine the factors by a certain combination method, we obtain the correlation degree of the decision scheme, after sorting by association degree, we can get an excellent scheme of high correlation degree.

2.2 Steps of decision analysis

Generally, the following steps are needed when the decision analysis method is used to evaluate or make a decision on a problem.

Step1: data preprocessing

Based on actual situation, we analyze all factors that are involved in the target class, and select the scale, type and characteristic scale of each class. The feature selection is used to select important features, and the feature extraction is used to transform the input features into new significant features. If some values that are not in the range of "class", these are the data that do not depend on general data behavior or models, viz., the isolated point, and need to be removed.

Step2: scheme situation set

A situation set is made for the programs that need to be compared and analyzed. Let $B=\{b_1,b_2,\cdots,b_m,\}$, of which b_j is a transportation mode. There are $A=\{a_1,a_2,\cdots,a_n,\}$, where a_i is the cost or benefit of b_j. We obtain a final conclusion of the situation set $S=A\otimes B=\{(a_i,b_j)|a_i\in A,b_j\in B\}$.

Step3: decision target quantification

The effect of the transport mode b_j corresponding to the a_i is denote by u_{ij}, and the effect vector $u_{ij}=\left(u_{ij}^{(1)},u_{ij}^{(2)},\cdots,u_{ij}^{(k)}\right)$, $i=1,2,\cdots,n$, $j=1,2,\cdots,m$. Since the units of decision making the target difficult to be unified, some decision goals cannot be directly quantified, so we often need to divide the "classes" after dimensionless treatment, and use the same standard to quantify all the factors in a same class. At the same time, in order to reduce the decision errors caused by the subjective factors of decision makers in dimensionless process, we use intervening range transformation to reduce errors caused by human factors in dimensionless process.

Step4: the effect vector of the decision goal

After determining the expression form of the effect vector, we suppose that S_0 is the ideal situation. In the ideal scheme, there is an ideal scheme effect vector $u_0=\left(u_0^{(1)},u_0^{(2)},\cdots,u_0^{(k)}\right)$, which is the best vector in all the effect vectors. Comparing the correlation degree between the set of "class" obtained by each other transportation mode S_i and S_0, if $S_0\in S$, then S_0 is the best solution; if $S_0\notin S$, the closer the A is to the B, the better the scheme is.

3. Design of indexes

Competitiveness can be represented by the number of passengers choosing the way of transportation, similar to the attendance rate, but different from the calculation. Train attendance refers to the number of passengers and train staff ratio of the ticket on the train, the train seat utilization rate reflects. The high-speed rail train stops in the middle of the way, the passenger has the up and down, the seat is reusable, so the attendance rate is difficult to truly reflect the competition ability of the high speed railway. The competitive situation is more likely to count the real time average attendance rate, which can reasonably show the competitive ability of high-speed railway transportation.

3.1 Decision analysis index and optimal effect vector

In the process of decision analysis, the decision index is: time cost (including operation time and operation time change rate), operation cost (including maintenance depreciation, dynamic energy consumption, labor cost, management cost) and safety benefit. etc. A game set of countermeasures for four modes of transportation is set up for high speed railway, ordinary railway, air transportation and road transportation. The four modes correspond to b_1, b_2, b_3, b_4, respectively, then we get the game set $B=\{b_1,b_2,b_3,b_4\}$. The corresponding cost decision index of all transportation modes is $(\mu_{i1},\mu_{i2},\mu_{i3}\cdots)$, $i=1,2,3,4$.

Vector optimal effect: optimal vector is an ideal existence, but in general it is not possible in reality. The optimal results of the decision goal are as follows: (1) the shortest operation time, considered to be the 0 best; operation time change rate unchanged, the transportation time stable every constant, ideal value 0; (2) no unit maintenance depreciation expense, energy consumption costs, labor costs, management costs and sales service costs, the ideal value of 0; (3) there will not be any accident, the ideal value of 0. So the ideal optimal effect vector can be established:

$$\mu_0 = (\mu_{01}, \mu_{02}, \mu_{03}, \cdots) = (0, 0, 0, \cdots). \tag{1}$$

3.2 Correlation degree

In order to eliminate dimension and increase comparability, the lower and upper limit values are as follows:

$$\mu_{ij}^{-} = \frac{\underline{\mu}_{ij} - \underline{\mu}_j^{\nabla}}{\overline{\mu}_j^{*} - \underline{\mu}_j^{\nabla}}, \tag{2}$$

$$\mu_{ij}^{+} = \frac{\overline{\mu}_{ij} - \underline{\mu}_j^{\nabla}}{\overline{\mu}_j^{*} - \underline{\mu}_j^{\nabla}}. \tag{3}$$

Where $\overline{\mu}_j^{*} = \max_{1 \le i \le n} \{\overline{\mu}_{ij}\}$ and $\underline{\mu}_j^{\nabla} = \min_{1 \le i \le n} \{\underline{\mu}_{ij}\}$, A is standardized, and the correlation degree between the evaluation vectors and the best ideal scheme of each scheme is established. The correlation degree of each factor is:

$$r_{ij} = 1 - \frac{1}{2}\left(\left|\mu_{ij}^{-}\right| + \left|\mu_{ij}^{+}\right|\right). \tag{4}$$

Where μ_{ij}^{-} is the lower limit of μ_{ij}, and μ_{ij}^{+} is the upper limit of the value of μ_{ij}, that is, $\mu_{ij} \in \left[\mu_{ij}^{-}, \mu_{ij}^{+}\right]$. The correlation degree of b_i is:

$$\varepsilon_i = \sum_{j=1} \omega_j r_{ij}. \tag{5}$$

Where ω_j is the resolution factor, also called the environmental regulation factor, $\omega_j \in [0,1]$. If the specific values of the coefficients are not taken into account, all the resolution coefficients are $\omega_{ij} = \frac{1}{j}$, and j is the number of the decision indexes.

4. Numerical Example

4.1 Beijing-Shanghai transport line

Taking the transport line between Beijing and Shanghai as an example, the above theoretical model is verified and analyzed. The alternative travel plan between two nodes along Beijing Shanghai high-speed railway is: (1) Beijing Shanghai high speed railway, G101 high-speed train, running distance 1268 kilometers, running time 5 hours, 54 minutes, ticket price two and other seats 553 yuan, first class 935 yuan. (2) 1461 for ordinary railway, 20 hours and 9 minutes for operation time and 156.5 yuan for ticket price. (3) Expressway, operating distance of about 1300 kilometers, running time of about 14 hours, the ticket price of about 341 to 404 yuan. (4) civil aviation, the operation time is about 1 hours and 55 points, and the ticket price is about 500 to 1200 yuan. Build the game sets of four transportation methods including high speed railway, ordinary railway, air transportation and highway transportation. The four modes of transportation correspond to b_1, b_2, …. And then we get the game set $B = \{b_1, b_2, b_3, b_4\}$.

The specific information about the four modes of transport transported between Beijing and Shanghai is shown in Tab 1. In order to get closer to the actual situation, the running time of aviation needs to consider the flight time and the ground travel time, about 5 hours. Similarly, the high-speed railway operation time also includes the transfer time with the station's connection time and transportation mode, about 7 hours.

Tab 1 Decision layer information of four transportations

	High speed railway	ordinary railway	air transportation	highway transportation
Transportation time (hour)	7	15.2	5	14
Change rate of transportation time	0.5	1	1.2	5
Fares (yuan)	553~935	156.5~283.5	500~1200	341~404
Safety benefits (%)	0.1	0.1	0.05	0.2

The change rate of transportation time is a possible late time, and the safety benefit is the number of people killed on the basis of an accident of 1 billion kilometers per operation.

In the actual transportation process, transportation time, ticket price and other factors must change within a certain range. Therefore, we introduce the situation vector to indicate the change of factors. Finally, the evaluation value of the situation effect is shown in Tab 2.

Tab 2 Quantitative evaluation of four transportations

	High speed railway	ordinary railway	air transportation	highway transportation
Transportation time	[7, 7.5]	[20.2, 21.2]	[5, 6.2]	[14, 19]
Fares	[553, 935]	[156.5, 283.5]	[500, 1200]	[341, 404]
Safety benefits	[0.1, 0.1]	[0.1, 0.1]	[0.05, 0.05]	[0.2, 0.2]

The evaluation of the index quantitative standard is carried out in Table 2, as shown in Table 3.

Tab 3 Evaluation of the index quantitative standard

	High speed railway	ordinary railway	air transportation	highway transportation
Transportation time	[0.123, 0.154]	[0.938, 1]	[0, 0.074]	[0.556, 0.864]
Fares	[0.361, 0.746]	[0, 0.122]	[0.329, 1]	[0.177, 0.237]
Safety benefits	[0.1, 0.1]	[0.1, 0.1]	[0.05, 0.05]	[0.2, 0.2]

According to the formula (4) and formula (5), the correlation degree vectors of four types of transportation are obtained. In the example, we can define the coefficient ω_j as 1/3 here. The ideal optimal effect vector is shown by (1), that is, the smaller the correlation degree is, the more competitive the transport is.

$r_{i1} = (0.139, 0.553, 0.1)$, $\varepsilon_1 = 0.264$; $r_{i2} = (0.969, 0.061, 0.1)$, $\varepsilon_2 = 0.377$; $r_{i3} = (0.037, 0.665, 0.05)$, $\varepsilon_3 = 0.251$; $r_{i4} = (0.710, 0.207, 0.2)$, $\varepsilon_4 = 0.372$.

For air transport, the flight time of Beijing Shanghai civil aviation is about 2 hours. The time to go to the airport and the waiting time at the airport is about 3 hours, which amounts to 5 hours. The actual time of the high-speed railway is about 6 hours, couples with the journey time, it takes about 7 hours, and 2 hours more than air transportation. Compared with high-speed rail and air transport, road transport and general rail transportation costs only less than 50% of it, but because of more than 15 hours in transit time, the highways and railway transportation competitive ability are limited. Only in the passenger peak season of Spring Festival, it is difficult to buy high-speed rail and air tickets, we will choose highway transportation.

4.2 Comparison of other transport lines

Taking the Beijing Shanghai line as an example, it can not represent the competitiveness of all high-speed railway lines. Refer to the method of the example, choose Chengdu-Chongqing (short distance), Beijing-Taiyuan (halfway), Wuhan-Guangzhou (long distance) to make a comparison.

Tab 4 Scheme correlation degree

	Distance (km)	High speed railway	Ordinary railway	air transportation	highway transportation
Chengdu - Chongqing	308	0.312	0.36	/	0.355
Beijing - Taiyuan	508	0.125	0.361	0.320	0.233
Wuhan - Guangzhou	1069	0.283	0.399	0.181	0.555

As shown in above table, during the transportation between Chengdu and Chongqing, the competitiveness of Chengdu-Chongqing high-speed railway is generally higher, and the attendance rate is more dependent on a more suitable departure time. In the course of transportation in Beijing-Taiyuan, the high-speed railway has a strong competitive ability. The competition ability of Wuhan-Guangzhou high speed railway is low, especially the high discounts of civil aviation fare between Wuhan and Guangzhou, which has a great influence on the transport of high speed railway. In fact, the Chengdu-Chongqing and Beijing-Taiyuan's attendance rate is higher, the real-time attendance at the rate of 70% and 80%. But most of the time the Wuhan-Guangzhou is not high, the main reason is the fares are too high, even more than the civil aviation fare, a great extent decreases the high-speed railway competition ability.

5. Conclusion

Generally speaking, there are many factors that influence the competitiveness, such as time, service level, environmental weather, passengers' income level and age. But in fact, the most important thing is transportation cost, including ticket price and time value. Although the price of high speed railway is fixed in China, local and enterprises can adjust the fare of high speed railway in a certain range. In order to enhance its competitive ability, the high-speed railway can make more reasonable fare to increase the attendance rate through a similar method of decision analysis. In this paper, the different modes of transportation are compared quantitatively by the method of decision analysis. By a number of examples, it is shown that the real-time attendance rate and competitive ability of the high speed railway are largely influenced by the fare. Setting a reasonable ticket price and competing with other modes of transport reasonably and orderly can alleviate the tension of transport capacity, but also promote different transportation modes to reduce costs, improve service quality and optimize transportation resource allocation.

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