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Analysis of Beijing-Guangzhou High-Speed Railway Competitiveness Based on Generalized Travel Cost Model

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Abstract—After the completion of the Beijing-Guangzhou high-speed railway, this paper studies the market sharing rate of the normal-speed railway, high-speed railway and civil aviation aircraft in the Beijing-Guangzhou line, and the broad travel cost of passengers. Ticket price, speediness, safety, comfort, convenience and punctuality are selected as evaluation indexes. Combined with the improved Logit model, a multiple discrete choice model of passenger travel is established. Then this paper investigates the travel intention of passengers and the actual data needed for model indicators. At last, the share rate of various modes of transportation in the Beijing-Guangzhou under the circumstances of different distances and different time values is predicted, as well as the impact of air fares on the competitiveness of high-speed rail products.

1. INTRODUCTION

The large-scale construction and implementation of high-speed railway have a certain impact on the traditional transportation pattern. While the diversified travel demands of passengers have been further met, the competition between vehicles has become increasingly fierce. With the continuous development of China's economy and the improvement of people's living standards, passengers not only concerning about ticket prices or whether they can reach their destination safely, but also have demands for timing, comfort, punctuality and convenience ^[1-2].

Given that all consumers are rational as they will maximize their utility. The "utility" here can be understood as "the degree of satisfaction people obtained in a certain dimension". According to the theory proposed by Kenneth, utility theory and the idea of utility maximization can reflect the essence of choice behavior ^[3-4]. At present, some scholars at home and abroad have used generalized travel costs to allocate the way of passenger travel. For example, Jia Junfang made a fuzzy evaluation of generalized travel costs to predict the passenger intensity among cities ^[9]. Based on generalized costs, Jing Yun uses a two-tier planning model to describe the passenger allocation of various vehicles ^[11]. However, these models are often based on certain conditions and differ from the physical truth. Marschark proved the consistency between Logit model and maximum utility theory, which initiated the idea of generalized cost model. Li Zhenghao combined travel cost and Logit model to study the market competition between civil aviation and high-speed railway ^[6]. However, he only considered the influence of distance in this binary model. Insufficient data made it less worth trusting. By analyzing travel fees and passengers' utility, this paper improves Logit model. Besides, this paper settles parameter calibration by big data survey about various factors that influence passengers' multiple discrete choice model of passenger travel can be utilized to predict the passenger's preferences.



In order to describe the competitiveness of different vehicles more specifically, this paper takes Beijing-Guangzhou line as the object. Due to the long-distance economic characteristics of this line, the road transportation is not taken into consideration. The multiple discrete choice model implied here is the combination of generalized cost model and improved Logit model, which is used to analyze competitiveness of railway transportation and civil aviation aircraft. This paper also predicts advantageous distance, value of time, and the influence of air ticket prices, so as to formulate the corresponding marketing strategy.

2. TRANSPORTATION CHOICE MODEL

Travelers care about the cost they paid and benefit they gained during the journey. And the cost here can be a broad concept. Transportation enterprises take the competitiveness under different circumstances of great importance.

2.1. Improved Logit Model

The Logit model assumes that utility maximization is the basis for passengers' choices. In other words, passengers choose a certain mode of transportation for more utility can be obtained by doing so^[5]. When making choices, the utilities passengers gained are determined by fare, time and so on; The random utility refers to the part that is difficult to measure or quantify. For passengers, the random utility part includes convenience, comfort and safety, etc.^[6-8]

The generalized cost function can quantify the uncertain part of the utility function^[9]. Therefore, this paper utilizes generalized cost function of passenger travel to replace the utility function in the improved Logit model, so as to calculate the passenger sharing rate of each mode of transportation, which can be expressed as follows:

$$P_i = \frac{\exp(Y_i - Z_i)}{\sum_i \exp(Y_i - Z_i)} \quad (1)$$

P_i --The probability of choosing i

Z_i -- The utility of i

Y_i -- The cost of i

2.2. Generalized Cost Model

The generalized cost of a passenger's journey refers to the difference between the total cost paid and the total utility gained during the whole journey, including not only the actual fare paid, but also the extra cost and utility brought by the journey.

2.2.1. Ticket Fares

It refers to the transportation cost paid by passengers to accept the service of a certain mode of transportation, so the calculation formula can be expressed as:

$$E_i = L_i \times M_i \quad (2)$$

E_i -- Fare for Transportation (Yuan)

L_i -- Distance (km)

M_i -- Rate of Transportation (Yuan/ person·km)

This paper gathers information from the app named "12306" about the railway line from Beijing to Guangzhou train information, including the table level, departure time, operation frequency, ticket price and travel time. Meanwhile, by analyzing Beijing-Guangzhou railway, distance between Beijing-Guangzhou high-speed rail, and the distance of aviation, this paper calculates the rate of high-speed rail (second class) is 0.41 yuan/person·km, and that of regular trains (hard seat) railway is 0.11 yuan/person·km. Due to the existence of a considerable number of discount tickets, it is difficult to determine the rate of Beijing-Guangzhou aviation. Therefore, the average rate of domestic civil aviation transportation (economy class) is taken into account in determining the rate of Beijing-Guangzhou air Express, which is 0.75 yuan/person·km^[10].

2.2.2. Rapidity

Rapidity describes the passenger's journey from start to finish. The performance of speediness in the generalized travel cost is that passengers use the travel time as the equivalent time value, and the speediness cost F can be expressed as follows:

$$F_i = T_i \times V = \left(\frac{L_i}{Sp_i} + T_x \right) \times V \quad (3)$$

T_i --The total time taken by the passenger to travel from the point of origin to the destination (h);

V --The passenger's time value (Yuan /h);

L_i --Distance traveled by means of transportation i (km)

Sp_i --Speed of Transportation i (km/h)

T_x -- connection time between departure and destination(h);

According to the data survey, the average running time and connecting time of Beijing-Guangzhou normal speed railway, high-speed railway and air aircraft are respectively 0.75h, 0.5h and 1h. Finally, the distance, average speed and travel time of different transportation modes are shown in the following table:

TABLE I. DISTANCE, AVERAGE SPEED AND TRAVEL TIME UNDER DIFFERENT MODES OF TRANSPORTATION

	Distance (km)	Time (h)	Velocity (km/h)
Normal-speed railway	2294	23.62	97.12
High-speed railway	2108	9.39	224.49
Airplane	1890	3.25	581.54

2.2.3. Fees for Safety

Safety is the primary requirement of passengers, which, to a certain extent, is reflected in the proportion of accident deaths in this mode of transportation. According to the proportion of accident deaths, a safety attribute value S can be given for each mode of transportation, and S is negatively correlated with generalized cost.

According to Wikipedia and the United Nations statistics as shown in TABLE II, railway and civil aviation deaths per 1 billion hours and 1 billion hours of the deaths, are less than motorcycles, cars, such as transportation, and close to, railways and civil aviation aircraft all can be thought of as safer travel choice, this paper take the high speed/normal-speed rail railway and civil aviation transportation safety attribute value are 0.99.

TABLE II. MORTALITY OF VARIOUS MODES OF TRANSPORTATION

The number of deaths	Every billion hours	Every billion km
Railway	30	0.1
Airplane	30.8	less than 0.1
Motorcycle	4840	96.9
Car	130	2.6
Walk	220	36.2

2.2.4. Convenience cost

Transit time and ticket purchase time directly determine the convenience of taking a certain mode of transportation. The quantitative formula is as follows:

$$B_i = (T_{ig} + T_{ih}) \times U \quad (4)$$

B_i -- Convenience cost of i ;

T_{ig} -- Waiting Time of i ;

T_{ih} -- Time for Buying Tickets;

According to the survey of travelers, the waiting time is determined as follows: 0.55h for high-speed railway, 1.47h for aviation and 1 hour for normal speed railway. At present, it is very convenient to purchase tickets on the Internet, which can be set as the purchase time is 0.1h.

2.2.5. Loss for Behind Schedule

It refers to the loss of passengers caused by delayed transportation mode. Its quantitative formula is as follows:

$$R_i = T_w \times U \quad (5)$$

R_i -- Loss for Behind Schedule in Transportation

T_w --Average delay time of transportation

According to the investigation and statistical analysis of the delay time of normal speed trains, high-speed trains and flights in the Beijing-Guangzhou passenger transport corridor, the average delay time of various modes of transportation is roughly 0.145 hours for high-speed trains, 1.5 hours for flights and 0.6 hours for normal speed trains.

2.2.6. Comfort

According to the research of relevant scholars at home and abroad, the comfort degree of a certain mode of transportation is positively correlated with the fare of that mode of transportation. In general, it is recommended that the basic value of the comfort cost should be 5%-10% of the fare of various transportation modes, and this paper USES 8% for calculation. Its formula is:

$$C_i = E_i \times \alpha = L_i M_i \times a \quad (6)$$

C_i -- Fees for Comfort

α --Percentage of ticket price (5%-10%)

$$Y_i - Z_i = \frac{\lambda_1 L_i M_i + \left(\frac{L_i}{S p_i} + T_x \right) V \lambda_2 + \lambda_3 (T_{ig} + T_{ih}) V + \lambda_4 (T_w) \times V - \lambda_5 L_i M_i a}{S_i} \quad (7)$$

Therefore, the generalized expenses of passengers choosing transportation can be expressed as:

2.3. Weight Coefficient

It is very important to determine the weight coefficients of various costs and utilities in the generalized travel cost function of passengers, because it greatly affects the accuracy of the model calculation results and whether they are in line with the reality [6]. We care about is when the passengers on the choice of way to travel is to consider in this paper, the five cost/utility parameters, using analytic hierarchy process, and designed a questionnaire to investigate the Beijing west railway station on Beijing-Guangzhou channel passenger, get 203 samples, the results after statistical standardization and standardization, it is concluded that the factors weights.

TABLE III. WEIGHT OF EACH INFLUENCING FACTOR

Factors	Prices	Speed	Punctuality	Convenience	Comfort
Weight	0.22	0.31	0.15	0.19	0.13

3. THE DETERMINATION OF TIME VALUE V

In this paper, the production method is adopted to calculate the passenger time value. It is necessary to determine the total GDP and total population of each region within the transport corridor, and also the average working time of passengers within the transport corridor. Its formula is:

$$V = \frac{GDP}{t \times P} \quad (8)$$

V -- Time Value of Passengers (Yuan/h);

GDP --Gross National Product(Yuan) ;

t --Average working time of passengers;

P -- Population of this zone;

The statistical yearbook of cities where all stations of the Beijing-Guangzhou High-speed Railway are located in 2019 is shown in the figure below:

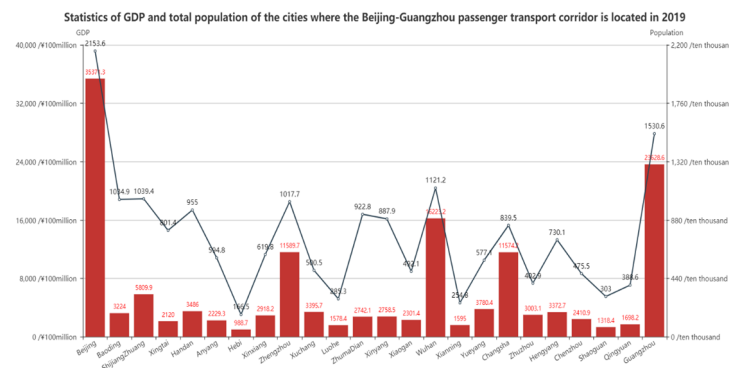


Figure 1. Statistics of GDP and total population of the cities where the Beijing-Guangzhou passenger transport corridor is located in 2019

In 2019, there is 104 rest days and 11 statutory holidays. Excluding statutory holidays, there is 250 working days. According to the standard working time of 8 hours per day in China, the total working hours in a year will be 2,000 hours. So that $V=41.2$ Yuan/h.

4. ANALYSIS

4.1. Analysis of time value V

In the model of this paper, the time value V is converted from the GDP and population of each place, so it is representative. However, the income gap of passengers is large, and the measurement of time value is different. The following figure shows the market share and time value of various transportation methods. Diagram of V .

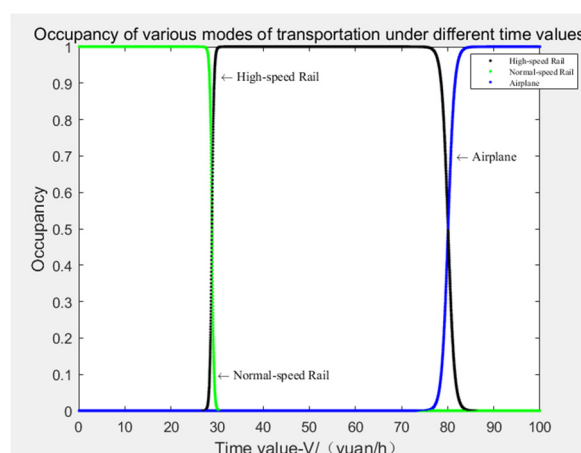


Figure 2. Occupancy of various modes of transportation under different time

1. The time value range of 0-30 is dominated by mostly ordinary speed trains, because low-income people pay more attention to economic costs.

2. The 30-75 time value segment is dominated by high-speed rail, because Beijing-Guangzhou is far away, and the high-speed rail is fast and the price is moderate, so this part is the main target of high-speed rail service.

3. The time value section other than 80 is occupied by civil aviation, which is the advantage of long-distance aviation. Compared with economic expenses, high-income people pay more attention to factors such as speed and comfort.

4.2. Analysis of Dominant Distance

This paper calculates the sharing rate of ordinary speed train, high-speed rail and aviation under different kilometers as shown in the following figure:

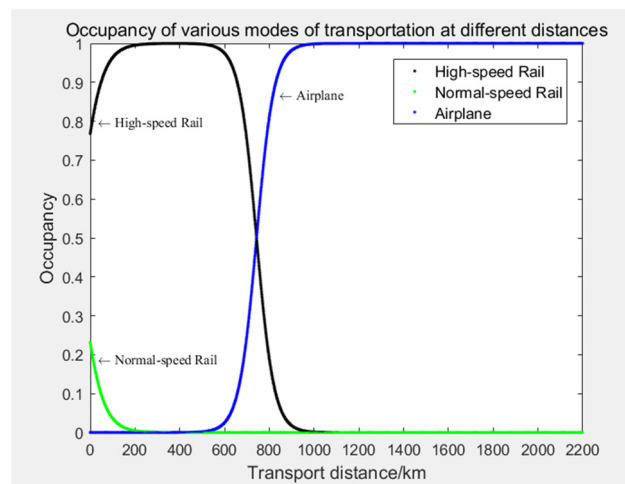


Figure 3. Occupancy of various modes of transportation at different distances

1. The market share of ordinary speed trains gradually decreases with the distance, but when the distance is small, the market share is not high. The reason may be that the Beijing-Guangzhou Channel surveys are mostly long-distance passengers, and they have higher requirements for "fastness", causing the corresponding weight to be too large.

2. The market share of high-speed rail is a process that increases first and then decreases with the distance. Its specific trend can be divided into three segments:

① 0-200 kilometers is the competitive section of high-speed rail with normal-speed rail, which is a rising section of high-speed rail

② 200-700 kilometers is the golden section of high-speed rail operation, and the market share can reach more than 50%

③ 700-1000 kilometers is a region where the share of high-speed rail has dropped.

4.3. The impact of air freight rates on the high-speed rail market

For medium and long-distance transportation, the competition between high-speed rail and civil aviation is obvious. It belongs to a typical buyer's market. The freight rate of railways is relatively fixed, and the price of civil aviation is often discounted, which is very attractive to consumers.

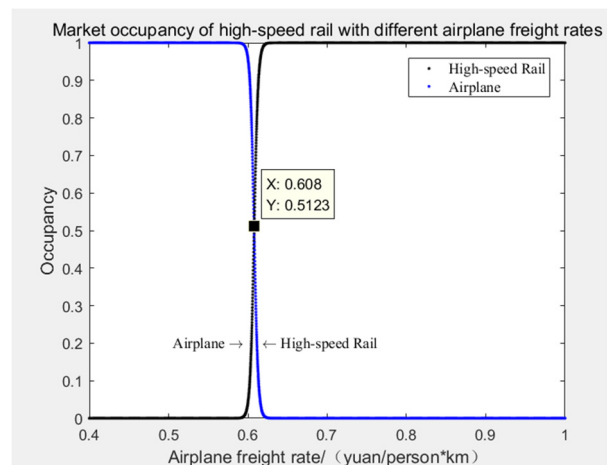


Figure 4. Market occupancy of high-speed rail with different airplane freight rates

Suggestions for Beijing-Guangzhou high-speed rail products: 1. Learn from the civil aviation company, according to the peak and low seasons of railway passenger flow, and the fare can be appropriately floated, such as lowering the fare during the off-peak season and off-peak period of railway demand, attracting passengers to choose high-speed railway travel. 2. Formulate different tariff strategies for people in different distance areas, 3. Formulate different tariff strategies for people in different cities and at different time values, such as students, subsistence allowances, farmers and retirees, etc.

5. CONCLUSIONS

Based on the traveler's demand analysis, this paper conducts a large amount of data investigation on various factors in the travel process of passengers, and establishes the sharing rate model of passenger transport products. Finally, it predicts the sharing rate of various transportation modes in different time value groups and different distances in the Beijing-Guangzhou passenger transport corridor, as well as the impact of air fares on the competitiveness of high-speed rail products. Based on the analysis results, relevant suggestions for Beijing-Guangzhou high-speed rail products are put forward. In short, this method divides the market from the traveler's own attributes, can predict the deep-level passenger flow structure, and provide technical support for the transportation department's decision-making.

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