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REVIEW ARTICLE

PASSENGER TRAVEL CHOICE OF AIR AND RAIL INTEGRATED TRANSPORTATION HUB

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ABSTRACT

Taking Hongqiao integrated transportation hub as an example, this paper studies the passenger travel choice of air and rail integrated transportation hub. Due to the difference in speed, price and time between high-speed rail and civil aviation, a radiation circle with different distances centered on Hongqiao Hub is formed. Using Binary Logit (Binary Logit) selection behavior model to determine the influencing factors, the result is that age, travel distance, travel time, travel cost, cost source, advance ticket purchase time and pre-departure waiting time are the factors that affect passengers' choice of transportation mode. According to different influencing factors, countermeasures are proposed, which can improve the services of high-speed rail and civil aviation, improve passenger satisfaction, and attract more passengers to travel through Hongqiao Hub.

KEYWORDS

Air-Rail Integrated Hub, Travel options, Hongqiao Hub

1. INTRODUCTION

High-speed rail stations and airports are important nodes of the national comprehensive transportation network and important engines for modernization. China has become one of the countries with the fastest developing high-speed transportation network in the world. With the gradual improvement of high-speed transportation network, high-speed rail has become a powerful competitor of civil aviation with time and cost advantages. Aviation and high-speed rail have different technical and economic characteristics, so they have different scope and space of application. In domestic short-distance transport, especially the journey of less than 900 km, high-speed rail has a significant diversion effect on air transport (Jixue et al., 2013). High-speed rail has begun to "invade" the original aviation market to a certain extent and to a certain extent. After the formation of China's "four vertical and four horizontal" high-speed rail network, more than 60% of the domestic civil aviation market will be affected to varying degrees (Jun, 2010). After the opening of Beijing-Shanghai high-speed Railway in July 2011, the operation of Beijing-Shanghai high-speed Railway has a certain diversion effect on the passenger flow of Hongqiao Airport (Suping, 2013).

In addition to the "fast, safe and convenient" characteristics of air transport, high-speed rail also has the characteristics of "on time, cheap, environmental protection and land saving", which makes it more competitive. The impact of high-speed rail on air transport can not be avoided, and the vicious competition between the two will lead to the waste of transport capacity, unreasonable allocation of resources and other phenomena. They should cooperate with each other according to their respective characteristics. High-speed rail can be used to replace aviation on short-range non-hub routes, and the transit hub route adopts the combined transport mode of "high-speed rail + aviation".

Hongqiao Hub integrates a variety of transportation modes such as civil aviation and high-speed railway, and adopts a variety of co-existence and complementary operation mode, which alleviates the problem of airspace tension at Hongqiao Airport and promotes the air transport market to shift to the long-range transport route market. High-speed rail can solve the

domestic problem of rapid and large-volume passenger flow, especially among cities within 900 kilometers. After arriving at the hub through urban connection transportation, passengers can choose high-speed rail to travel, and they can also arrive at the destination through civil aviation. Different modes of transportation selected by passengers are affected by different factors. Analyzing these factors is of great significance for improving the service level of high-speed rail and civil aviation passenger transport, enhancing the market competitiveness of the hub, and promoting the coordinated development of comprehensive transportation.

2. HONGQIAO HUB TRANSPORTATION CHARACTERISTICS

According to the transportation characteristics of Hongqiao integrated transportation Hub, the travel services provided by high-speed rail (bullet train) and civil aviation are analyzed from the supply side. The paper selects major cities with different miles from Shanghai, which have high-speed rail (bullet train) to Hongqiao high-speed rail station, or flights to Hongqiao airport, or both. High-speed rail (bullet train) and civil aviation service data of Hongqiao Hub will be collected and sorted out on <http://www.ctrip.com> (Ctrip) and <http://www.12306.cn> (official website of China Railway Customer Service Center) on December 21, 2022. Among them, due to different airline frequencies, flight time and ticket price are different, and different purchase times are also different. Flights between 6:00 am and 12:00 noon of the next day are uniformly selected and the average value is obtained. If there are no flights in this period or there are few flights between two cities, the average value of all flights is obtained. Compared with civil aviation, the transit time and ticket price of high-speed rail (bullet train) are relatively stable. The frequency with the least transit time is selected as the data to characterize railway service.

Within 300km of the city pairs, the high-speed rail (bullet train) between Shanghai and Nanjing, Shanghai and Hangzhou are more than 100 times, and the flight is zero, which shows that the passenger transport between the two cities is almost borne by the railway. At this stage, China's high-speed railway is in the rapid development stage, and some cities have not been able to access the high-speed rail network, such as Yancheng, due to

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the demand for high-speed passenger transport, Hongqiao Airport to Yancheng Nanyang Airport has two flights a day.

Among cities within a distance of 300-700km, Qingdao, Yantai and Wuhan have significantly more flights than high-speed trains, while Wenzhou, Jinan and Nanchang have significantly more flights than high-speed trains. There are no flights from Hongqiao Airport to Hefei Xinqiao Airport, but there are many trains, about 26 trains a day. Among cities within 700-1000km, the number of flights in Xiamen is 42, which is significantly higher than the number of railways. The number of flights in Tianjin, Changsha and Zhengzhou is slightly less than the number of railway flights.

For cities with a travel distance greater than 1000km, the number of flights in Taiyuan, Guangzhou, Shenzhen, Chongqing and Xi'an is far greater than the number of high-speed trains (bullet trains). The Hongqiao Integrated Transport Hub has 84 flights to Beijing, while 37 high-speed trains arrive daily. Beijing and Shanghai are the two largest cities in China, and there are frequent exchanges and contacts between the two economies. Before the operation of Beijing-Shanghai high-speed railway, business passengers mostly chose air transportation. After the operation of Beijing-Shanghai high-speed railway, passengers between the two cities have an additional choice, and the competition pattern is becoming increasingly fierce.

3. PASSENGER TRAVEL BEHAVIOR CHARACTERISTICS

3.1 Questionnaire survey

In the passenger transport market, there are a variety of means of transport for passengers to choose, and passengers will choose their own means of transport according to their own conditions and travel purposes. In the process of choosing the means of transportation, the factors that affect the decision-making of passengers involve all aspects. Different scholars analyze the factors affecting the choice preference of passengers from different perspectives, mainly focusing on the main characteristics of passengers and the attributes of transportation modes (Jianchuan and Zhicai, 2008; Jensen, 1999; Hagman, 2003; Verplanken et al., 2008). The following table:

Table 1: Factors influencing passengers' choice of means of transportation	
Passenger subject characteristics	Gender, age, occupation, income, personal habits, time value, travel purpose, travel distance, etc
The transportation mode itself attributes	Safety, comfort, convenience, speediness, punctuality, economy, accessibility
other	Random factors such as weather and other cognitive differences among passengers

According to the above analysis, the index system of passenger travel behavior in the questionnaire includes two parts: basic attributes of passengers and travel characteristics. The basic attributes of passengers include gender, age, education, occupation, income, travel habits, time value, etc. The basic characteristics of passengers' travel include destination, mode of external transportation, purpose of travel, source of transportation expenses, number of luggage, number of traveling companions, frequency of using Hongqiao, etc. In the process of data statistics, the distance between the passenger arriving at the city and Shanghai is identified as the travel distance, that is, the linear distance between the downtown of the two cities, and the distance value is measured by the ranging tool of Baidu map. From January 8 to 14, 2022, survey questionnaires were officially distributed in Hongqiao Comprehensive Transportation Hub, and a total of 1,000 questionnaires were distributed in Hongqiao high-speed Railway Station and Hongqiao International Airport. Questionnaires that were not completed, had obvious errors and did not meet the survey objects were eliminated, and 894 valid questionnaires were finally recovered.

3.2 Passenger travel characteristics

Through collecting questionnaire data, the travel characteristics of Hongqiao comprehensive transportation hub are obtained. According to the travel characteristics of different passengers, the paper focuses on the choice of transportation mode for passengers with different travel distances. The travel distance is less than 300km, and the high-speed rail (including the bullet train, hereinafter referred to as "high-speed rail") has the absolute advantage among the transportation modes selected by passengers from Hongqiao Hub. High speed rail has more frequency and

short waiting time, which is the best choice for passengers to travel. However, civil aviation has not had many flights within this travel distance, and under the impact of high-speed rail, it has gradually canceled some flight services, making civil aviation passengers change to high-speed rail passengers.

Within a travel distance of 300-700km, passengers who travel from Hongqiao Hub choose civil aviation for 11.7% of all civil aviation passengers, and those who choose high-speed rail for 25.8% of all high-speed rail passengers. With the increase of travel distance, passengers begin to choose civil aviation for travel. In this travel distance segment, the time advantage and fare advantage of high-speed rail have advantages over civil aviation, and the number of passengers choosing high-speed rail is more than civil aviation.

When the travel distance increases to 700-1000km, high-speed rail passengers account for 10.4% of all railway passengers, and civil aviation passengers account for 10.7% of all civil aviation passengers, and the proportion of passengers choosing the two modes of transportation is almost the same. At this stage, the time spent on high-speed rail travel, including waiting time and en route time, is close to the time spent on civil aviation travel, and the fare advantage of high-speed rail is no longer obvious. This mileage is the travel distance segment where the competition between high-speed rail and civil aviation is more intense.

When the travel distance is greater than 1000km, the time and price advantages of civil aviation are prominent. Among the passengers traveling from Hongqiao Hub with a distance of 1000-1500km, 59.7% of them chose civil aviation, and 19.6% chose high-speed rail. At this time, the time spent on railway travel has been greater than the critical point of 3h journey fatigue, and the choice of civil aviation travel, the transit time is generally not more than 3h. At the same time, tickets purchased in advance may be discounted, sometimes even lower than high-speed rail fares. When the passenger travel distance is greater than 1500km, civil aviation has an absolute competitive advantage. In terms of travel economy, comfort, timeliness and so on, civil aviation is the best choice.

4. HONGQIAO HUB PASSENGER TRAVEL CHOICE BEHAVIOR OF HIGH-SPEED RAIL AND CIVIL AVIATION

4.1 Hongqiao Hub passenger travel choice behavior model for high-speed rail and civil aviation

There are only two modes of transportation involved in this paper, high-speed rail and civil aviation, and passengers choose one of these two schemes, which is suitable for Binary Logit selection model. The formula for calculating the selection probability of option 1 (choose civil aviation, =1) and option 2 (choose high-speed rail, =2) is as follows:

$$P_{1n} = \frac{e^{V_{1n}}}{e^{V_{1n}} + e^{V_{2n}}} = \frac{1}{1 + e^{-(V_{1n} - V_{2n})}} \quad (1)$$

$$P_{2n} = 1 - P_{1n} = \frac{e^{V_{2n}}}{e^{V_{1n}} + e^{V_{2n}}} = \frac{1}{1 + e^{(V_{1n} - V_{2n})}} \quad (2)$$

Where, P_{in} is the probability of the passenger n choosing the scheme i ($= 1, 2$), and V_{in} is the utility fixed term of the passenger n choosing the scheme i ($= 1, 2$).

The influencing factors of travel choice behavior of passengers are generally divided into passenger attributes and travel attributes (Jianan and Peng, 2012). Personal attributes of passengers such as age, gender, occupation and income have an impact on the preference of passengers for different modes of transportation during travel. The variables that passengers pay attention to during travel are fare, transit time, number of companions, number of luggage pieces and time before departure. The utility of passengers choosing different modes of transportation is determined by the above influencing factors, and its utility function is expressed as follows:

$$U_i = V_i + e_i = \sum_{k=1}^K \beta_k x_k + e_i \quad (3)$$

Where, U_i is the utility of plan i ($= 1, 2$) chosen by passenger n , e_i is the random phase of the utility of choice i ($= 1, 2$) for passenger n , x_k is the horizontal value of the k explanatory variable, β_k is the undetermined coefficient corresponding to explanatory variable k , K is the number of explanatory variables.

After the model and influencing factors were determined, statistical analysis software SPSS20.0 was used for parameter calibration. As there are many influencing factors, the single factor analysis is used to eliminate unnecessary indicators in order to retain the most effective indicators for

multi-factor analysis and prevent the instability and inaccuracy of the results. Firstly, independent sample T test was used to screen out significant influencing factors of the results, and then multi-factor analysis was conducted. The calibration results are shown in Table 2.

Where, B is the variable coefficient, S.E. represents the standard deviation, Wald is the statistic, and Exp(B) represents the change in the forecast probability caused by one unit increase in the subvariable. The selection of model variables is determined according to the significance level. If the

significance level is less than 0.05, it indicates that the variable has an impact on passenger travel behavior and should be included in the passenger travel choice behavior model; otherwise, it should be deleted. The significance level of seven variables, age, travel distance, travel time, travel cost, cost source, advance ticket purchase time, and pre-trip waiting time, was all less than 0.05, and the significance level of Hosmer and Lemeshow test statistics was greater than 0.05, indicating that these variables had a strong correlation with passenger travel choice behavior. The fitting effect of regression equation is ideal.

Table 2: Parameter calibration results

Influencing factor	B	S.E.	Wald	Degree of freedom	significance	Exp(B)
age	1.083	0.299	13.109	1	0.000	2.953
Travel distance	-1.307	0.217	36.378	1	0.000	0.271
Travel time	3.220	0.373	74.463	1	0.000	25.021
Travel expense	-2.489	0.295	71.070	1	0.000	0.083
Source of expenses	-0.787	0.312	6.369	1	0.012	0.455
Advance ticket purchase time	-0.550	0.140	15.421	1	0.000	0.577
The waiting time before the program	-0.732	0.126	33.882	1	0.000	0.481
constant	6.578	1.461	20.268	1	0.000	719.058

4.2 Travel choice analysis of Hongqiao Hub

In the calibrated model, the absolute value of the coefficient of the influencing factor reflects the degree of influence of the factor on the choice of passenger travel behavior, and the positive or negative of the symbol indicates the change trend of passenger choice with the factor (Rui et al., 2016). Based on 7 influencing factors, this paper analyzes the preference of passengers in choosing high-speed rail and civil aviation at Hongqiao Hub from different aspects.

4.2.1 Age

Among the attributes of passengers themselves, age is an important factor that affects passengers' travel choice. As passengers get older, the probability of choosing high-speed rail increases. These passengers have enough time, the unit time value is low, they are not willing to pay high civil aviation tickets, and the physical discomfort during takeoff and landing also makes some elderly passengers more inclined to high-speed rail travel.

4.2.2 Travel distance

Passengers who travel a long distance will choose civil aviation if the time value is higher, and the journey time is shorter, and the total journey time will be less than that of high-speed rail. More passengers who travel closer will choose high-speed rail travel, fast, convenient, fast, and high on-time rate.

4.2.3 Travel time

Travel time is different, prompting passengers to choose different travel methods. For the same travel time, if the high-speed rail cannot reach the destination, the passenger will choose to travel by air. For example, from Shanghai to Guangzhou, the high-speed rail takes 8 hours, while the civil air takes 3 hours. If the passenger has a higher time value, he will choose the civil air travel.

4.2.4 Travel expenses

The cost of high-speed rail travel is different from that of civil aviation travel. The price of high-speed rail ticket is 0.45 yuan /km based on the pricing standard of second-class seats on Beijing-Shanghai, Wu-Guangzhou and Shanghai-Kunming high-speed rail lines, and the benchmark price of air ticket is 0.75 yuan /km according to the Domestic Freight Reform Plan of Civil Aviation promulgated by The State Council (Feng et al., 2017). For the same distance, the cost of air travel is generally higher than that of high-speed rail, and passengers who are not willing to pay high costs will choose high-speed rail travel.

4.2.5 Sources of expenses

The sources of transportation expenses are generally divided into public expenses and self-funded two kinds, business, official travel is more public expenses, while visiting relatives and friends, travel shopping and other travelers mainly pay their own expenses. Passengers with public transportation expenses do not care about the fare in choosing the mode

of travel, and choose the appropriate means of transportation within the acceptable price.

4.2.6 Purchase tickets in advance

There are many high-speed trains and fixed ticket prices, while there are few civil aviation flights, and ticket prices fluctuate according to the departure time and purchase time. High-speed rail passengers generally buy tickets 1-3 days in advance or even on the day of travel, and civil aviation passengers buy tickets in advance, even more than 10 days in advance.

4.2.7 Pre-process waiting time

Passengers traveling by civil aviation need to replace their boarding passes 1 hour to 40 minutes in advance. Compared with civil aviation, high-speed rail has a shorter waiting time before departure, and only needs to check in 15 minutes in advance. According to the survey results, the waiting time of high-speed rail passengers is mainly 30-60 minutes, and that of civil aviation passengers is mostly 60-90 minutes. The time value of civil aviation passengers is high, and shortening the waiting time before flight will increase the attractiveness of civil aviation.

5. CONCLUSION AND DISCUSSION

Hongqiao Comprehensive Transportation Hub is the first high-speed passenger transportation hub in China that integrates civil aviation and high-speed rail. Passengers can choose two different high-speed passenger transportation modes from one transportation hub, civil aviation and high-speed rail. Due to the differences in speed, price and departure time between high-speed rail and civil aviation, radiation circles with different distances centered on Hongqiao Hub are formed: the high-speed rail radiation zone within 300km radius, the high-speed rail civil aviation mixed service zone with a radius of 300-1000km, and the civil aviation radiation zone with a radius greater than 1000km. Passengers in the high-speed rail radiation area are more inclined to choose high-speed rail, while those in the civil aviation radiation area are more likely to choose civil aviation. In the mixed service area of high-speed rail and civil aviation, the competition between high-speed rail and civil aviation services is fierce, and the travel choice of passengers may be both high-speed rail and civil aviation.

Factors affecting travel behavior can be divided into individual attributes and travel characteristic attributes. Individual attributes include gender, age, occupation, education background, income, travel preference and time value, etc. Travel characteristic attributes include travel purpose, travel distance, transportation cost, transportation time, transportation cost source, total number of baggage, number of traveling companions and annual travel frequency. There are two modes of transportation choice for passengers in Hongqiao Hub, so the Binary Logit (Binary Logit) selection behavior model is used to determine the influencing factors. The result shows that age, travel distance, travel time, travel cost, cost source, advance ticket purchase time and pre-departure waiting time are the factors that affect passengers' choice of transportation mode. According to different influencing factors, countermeasures are proposed, which can

improve the services of high-speed rail and civil aviation, improve passenger satisfaction, and attract more passengers to travel through Hongqiao Hub.

Hongqiao Hub organically integrates two high-speed passenger transport modes of high-speed rail and civil aviation to form an integrated passenger transport hub of air and rail, which promotes cooperation while competing between the two. When civil aviation flights are delayed due to weather or air restrictions, passengers can timely change the mode of transportation and choose high-speed rail to reach the destination to ensure the stability of travel. High-speed rail and civil aviation can provide air and rail combined transport services, set up the Hongqiao Airport city terminal in the high-speed rail station, and expand the service area of the airport through high-speed rail passenger transport. After arriving at the Hongqiao Hub through civil aviation services, passengers can directly walk to the Hongqiao high-speed rail station or via the shuttle bus, and use the high-speed rail passenger service to quickly reach the destination. This kind of cooperation between civil aviation service and high-speed rail service brings about changes in passenger travel mode, which will be focused on in future research.

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