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Sustainability Development of High-Speed Rail and Airline—Understanding Passengers' Preferences: A Case Study of the Beijing–Shanghai Corridor

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Abstract: With the rapid construction of high-speed railways (HSR), the supply structure of the transportation modes in China has changed greatly. In order to seek the sustainable development of HSR and air transport from the perspective of passenger mode choice behavior, this paper applied a binary logit model to explore the mode choice patterns in the Beijing–Shanghai corridor, which has the most successfully operated HSR line in China. By using the data collected in airports and HSR stations in the two cities, passenger flow composition and passenger mode choice behavior was analyzed. It was found that passengers' preference for air transport decreases with the accompanying number of passengers and access time, and increases with income; female passengers and younger passengers have a higher probability of choosing air transport, ceteris paribus; and leisure passengers are more price-sensitive, they tend to travel by air transport when the air transport prices are lower. The study results reveal the travel characteristics of passengers between Beijing–Shanghai and provide information for policy design and infrastructure management.

Keywords: binary logit model; passenger mode choice behavior; HSR; air transport

1. Introduction

Over the past few decades, passenger transport has seen important changes concerning the modal distribution of demand. Air transport's dominant position began to lose to high-speed railways (HSR) for median–long distances. This has resulted from the comparable service attributes of HSR with air transport [1,2]. In Europe and Asia, the expansion of the HSR network has caused air transport demand to drop significantly. For example, after the introduction of TGV Sud-Est between Paris and Lyon in 1981, the market share for air transport dropped from 31% to 7%. The same phenomenon was also witnessed between Madrid and Seville in 1992 after the introduction of AVE service; air transport market share dropped from 40% to 13%. In Japan, after the opening of Shinkansen, air transport service between Osaka–Hiroshima and Hiroshima–Fukuoka were closed.

The most adverse competition between air transport and HSR was in China, since it constructed the largest HSR network of 25,000 km in just nine years, leaving quite a small time window for air transport to respond. More than 10 flights were cancelled after the opening of the corresponding HSR service, eg., Zhengzhou–Xi'an, Nanjing–Wuhan, and Wuhan–Nanchang, and air transport traffic decreased 60% and 40% respectively on the Changsha–Guangzhou corridor (707 km) and the Wuhan–Guangzhou corridor (1069 km) after the opening of the Wuhan–Guangzhou HSR in December 2009. HSR has greatly improved traffic accessibility [3], forming a new trend for traveling between cites [4,5]. According to the "Railway '13th Five-Year' development plan" [6], a "eight vertical and eight horizontal trunk line" of more than 30,000 km will be constructed by 2020, which will cover more than 45% of air transport routes and 65% of the air transport market. By 2030, the large-scale construction of the HSR network will substantially improve accessibility [7]. Thus, we still expect intense competition between them for many years to come [8], and exploring the sustainability development of HSR and air transport has also become particularly important.

Understanding passengers' perceptions of and preferences in interurban transport can help authorities better understand passengers' travel demand, and thus improve their service levels. It also seeks new ideas for the sustainability development of HSR and air transport. There are many published research studies in the literature regarding passengers' preferences of HSR and air transport in different countries, e.g., Spain [9–12], Korea [13,14], Taiwan Province [15], Japan [16,17], Chile [18] (they look at airplane and a fictitious HSR trip), and London–Paris [19]. Most of these studies are discrete choice analyses using SP (stated preference) data. González-Savignat [9] used SP techniques to evaluate the potential of future high-speed trains to compete with current demand for the air transport service in Spain. The author developed a demand model in a hypothetical context to predict the passenger behavior in the upcoming future and simulate different policy scenarios under changing service supply conditions. Ortúzar [18] developed an SP experiment to look at air transport and a fictitious HSR between Santiago and Concepción in Chile considering travel time, fare, comfort, and service delay. They also incorporated mixed revealed preference (RP)/SP models from previous studies to compare with the SP data. Park and Ha [14] considered the air–HSR competition between Seoul and Daegu in Korea; they developed a linear utility function considering fare, frequency, access, and egress time, and estimated the model using SP data. However, they just looked at the trip-related variables, leaving out the socio-demographic variables. Two of them used RP (revealed preference) data, Román et al. [12] calculated the value of travel time savings (VOT) for the Madrid–Barcelona corridor, based on the estimation of discrete choice models among air transport, HSR, and bus, using a revealed preference survey. They found that the VOT for HSR and air transport are much higher than that of bus, savings of waiting time weighed more than savings of access time, and the latter weighed more than savings of in-vehicle travel time. Behrens and Pels [19] studied the behavior of travelers in the London–Paris passenger market via mixed logit models using cross-sectional RP data over the period 2003–2009. They found frequency, total travel time, and distance to the United Kingdom (UK) port to be the main determinants of travelers' behavior; they also found that business and leisure passengers behave differently in the regard to these characteristics. Lee et al. [20], taking Seoul-Jeju route as case, used SP techniques and a mixed logit model to analyze the passengers' transport mode choice behavior when air transport was in competition with HSR. They found that business passengers were apt to choose a safety secured mode of transportation regardless of fare, while leisure passengers preferred to use duty-free shops more than business passengers did.

Obviously, the factors affecting passenger mode choice behavior can be divided into two aspects: personal attributes and trip attributes. Personal attributes, such as vocation, age, income, and purpose [21–24], are indispensable. Georggi and Pendyala [23] indicated that the proportion of passengers who choose airlines increased with income. Yu [25] pointed out that age significantly affects passenger mode choices behavior, for example, the older passengers prefer a safe and convenient transport mode, while safety (risk management) has a positive impact on passengers' preference for airlines [26]. Thrane [27] found that the probability of choosing airlines or public mode decreases with the increase of travel companions. The research of Dargay et al. [21] and Hess et al. [28] showed that the travel purpose also affects the passenger mode choice behavior, and business and leisure passengers have very different mode choice behaviors. Paulley et al. [29] and Santos [30] pointed out that income and education play an active role in public transport mode share patterns. Trip attributes, such as distance [31], fare, and departure time [32] are also the key factors affecting passenger mode choice behavior: Rothengatter [33] indicated that airlines and HSR was fiercely competitive between 400–800 km; Wang et al. [34] pointed out that passengers who care about travel costs are more likely to choose ordinary trains, while passengers who care more about comfort, punctuality, and efficiency are more likely to choose airlines and HSR; Gonzalez- Savignat [9] found that the total travel time is the most important factor to determine market share, while Jung and Yoo [13] pointed out that access time has a greater impact on passengers than journey time, and that airport connecting time is a very important factor for passengers, especially for business travelers [28,35]. Generally, traffic accessibility has a significant positive correlation with house prices [36,37]. Nowadays, environmental factors, which have become increasingly important for the sustainability development of transportation, are also beginning to be considered by some travelers. In general, compared with air transport, HSR has less of an impact on the environment [38,39]. In terms of CO_2 emissions in China, the expansion of road, airline, and waterway infrastructures lead to long-run increases in CO_2 emissions; waterways especially have the strongest positive impact on CO_2 emissions, followed by road, while railway expansion leads to long-run decreases in CO_2 emissions [40]. However, the psychological benefits of a green brand help to enhance the overall image of environmental airlines [41].

We can see that while there have been many studies of interurban travel demand regarding air–rail competition, few studies have focused on the case of China. Besides, many existing literatures use SP data, which have the disadvantage of being affected by the hypothetical bias problem. This paper contributes to the empirical literature on the passengers' preference on air transport versus HSR using RP data in the Beijing–Shanghai corridor. As to the authors' knowledge, this is the first ex-post mode choice study after the introduction of the HSR in China for international readers. Unlike other intermodal competition literature, our model specification considers how individual characteristics (such as gender, age, occupation, income level, trip purpose, travel companion number, etc.) affect modal choice. The model that we developed here is not a standard mode split model, the in-vehicle time is not included; since the main mode travel time is the same for all HSR respondents and air transport respondents respectively, we emphasized the characteristics of the individual. The objective is to establish the differences between the passengers on air transport and HSR in the Beijing–Shanghai corridor and provide policy suggestions to improve their service levels.

The structure of the paper is as follows. Section 2 outlines the mode. Section 3 gives a brief background of the high-speed transport market in the Beijing–Shanghai corridor, and then describes the data collection in detail and data statistics. Section 4 analyzes the results. Section 5 gives policy suggestions and the conclusion.

2. Methodology

2.1. Econometric Methodology

As there are only two dependent variables in this study, namely HSR and air transport, and these two choice alternatives in question are not nested, we deploy the binary logit model here to analyze the passenger mode choice behavior in the Beijing–Shanghai line. We consider that their utility function U_{in} is constituted by two parts: the observable utility V_{in} and random utility ε_{in}, thus the utility function for passenger i choosing mode n is:

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

According to utility maximization theory, the probability for passenger i choosing transport mode n is:

$$\begin{aligned} P_{in} &= \text{Prob}(U_{in} > \max U_{im}; n \neq m, n \in A_i) \\ &= \text{Prob}(V_{in} + \varepsilon_{in} > \max(V_{im} + \varepsilon_{im}); n \neq m, n \in A_i) \end{aligned} \tag{2}$$

In Formula (2), U_{im} stands for the utility of transport mode except n, and A_i stands for the passenger's mode choice set. Suppose that ε_{in} follows Gumbel distribution, then, the general form of logit model for passenger i choosing transport mode n is:

$$P_{in} = \frac{e^{V_{in}}}{\sum\limits_{j \in A_i} e^{V_{im}}} \quad (3)$$

We assume the observable utility part V_{in} in Equation (1) has a linear relation with its influencing factors X_{ink}, which is:

$$V_{in} = \sum_{k=1}^{K} \theta_k X_{ink} \quad (4)$$

In which X_{ink} stands for the kth factor than influences passenger i on his nth choice, and θ_k is the parameter for the kth influencing factor.

When adopting the binary logit model, we consider plan variable $n = 1$ when air transport is chosen, and plan variable $n = 0$ when HSR is chosen. Thus, the probability for passenger i choosing air transport can be expressed as:

$$P_i(n = 1|\mathbf{X}) = \frac{e^{V_i}}{1 + e^{V_i}} = \frac{1}{1 + e^{-V_i}} = \frac{1}{1 + e^{-\sum\limits_{k=1}^{K} \theta_k X_{ik}}} \quad (5)$$

The probability to choose HSR is:

$$P_i(n = 0|\mathbf{X}) = 1 - P_i(n = 1|\mathbf{X}) \quad (6)$$

2.2. Model Specification

The survey dataset included trip-related variables and socio-demographic characteristics. To reveal further the reasons underlying these interactions, a series of binary logit models were used to investigate these factors' impact on travelers' propensities in choosing HSR and air transport. The explanatory variables that were used in the models are listed in Table 1. Access time and price differential were set as continuous variables and separated in different ranges. Other factors were set as dummy variables and also separated into different ranges. Note that this is not a standard mode split model, as we didn't put the in-vehicle time in the model; since the main mode travel time is the same for all HSR respondents and air transport respondents respectively, we emphasized more the characteristics of the individual.

Table 1. Specifications for explanatory variables. HSR: high-speed railways.

Variables	Details and Measurements
Trip-related characteristics	
Travel companions (D[a])	Number of travel companions. It is divided into three intervals: travel alone, one person, and two or more
Access time (C)	Time passengers take to get to airport/train station plus waiting time, measured in hours
Access mode (D)	Dummy = one for car and zero for public transport
Travel purpose (D)	Dummy = one for business and zero for leisure
Departure time (D)	Four dummy variables are created for departure time: before 9:59, 10:00–12:59, 13:00–15:59 (set as reference), and after 16:00
Price differential (C [b])	The difference between HSR ticket price and air transport fare measured in United States dollars (USD)
Socio-demographic variables	
Gender (D)	Dummy = one for male and zero for female
Occupation (D)	Dummy = one for enterprise and zero for otherwise
Income (D)	Four dummies are created for personal income per month and measured in USD: less than 749 USD, 750–1499 USD, 1500–2999 USD (set as reference), and more than 3000 USD
Age (D)	Four dummies are included: 18–29 years old, 30–39 years old, 40–49 years old (set as reference), and more than 50 years old

a. D in the parenthesis means they are dummy variables, and C in the parenthesis means they are continuous variables. b. Notations: $pricedifferential_i = \frac{price(\text{air})_i - price(\text{HSR})_i}{\min(price(\text{air}) - price(\text{HSR}))}$.

2.3. Predictions

Passenger mode choice behavior is affected by many factors. Compared with the low-speed mode, the fares of the high-speed mode are higher; thus, the passengers' expectations for the high-speed mode are higher. At present, the HSR fare is generally lower than airfare in China, and the huge gap between the HSR fare and the airfare is one of the important factors affecting passengers' travel choice. Passengers consider not only the travel time, but also the access time, the travel purpose, number of travel companions, and other factors. In addition, the passengers' characteristics also affect passenger travel choice behavior. According to existing studies and our survey, we make the following predictions as shown in Table 2.

Table 2. Predictions for explanatory variables.

Variables	HSR	Air	Reasons
Trip-related Characteristics			
Travel companions	+		Compared with air, HSR seats have larger space and less restrictions on travel. Passengers can move freely and communicate conveniently. Therefore, we believe that with the increase of the companions, passengers prefer to travel by HSR.
Access time	+		For passengers who choose air travel, if the access time and waiting time are too long, their time advantage will be reduced. Therefore, we considered that the longer the access time, the more likely it is that the passenger will select HSR.
Access mode		+	Matching income and travel time, we think that compared with public transport, passengers who use cars as an access mode prefer air travel.
Travel purpose		+	Many studies have indicated that different travel purposes have a significant impact on passenger mode choice [21,28]. Business travelers pay more attention to time and less attention to fare [28]. Therefore, we consider that business travelers prefer to travel by air, while leisure travelers prefer to travel by HSR.
Departure time		+	According to our survey, the probability of choosing air increases with the departure time getting late.
Price differential	+		Many passengers choose HSR because of the fares. At present, China's HSR fares are fixed, while airfares are floated. We consider that the bigger the fare gap between HSR and air, the more likely it is that passengers will choose HSR.
Socio-demographic variables			
Gender	+		Compared with males, females have higher requirements for their waiting environment. Therefore, we consider that females are more likely to travel by air due to the better waiting environment.
Occupation		+	According to our survey, most large companies have long-term business relations with airlines or air ticketing agents.
Income		+	Bhat's [42] studies showed that the high-income groups are less sensitive to price and more sensitive to time, and they prefer to travel by air. Therefore, we consider that high-income passengers prefer to choose air.
Age	+		The older passengers prefer safe and convenient transport modes [25]. As far as stationarity and safety are concerned, we consider that, with the increase of age, passengers prefer to travel by HSR.

Note: + indicates that with the increase of the factor's value (according to the specification for explanatory variables in Table 1), compared with another transport mode, the passengers are more likely to choose this transport mode.

3. Study Area and Data

3.1. Beijing–Shanghai Corridor

The Beijing–Shanghai HSR was one of the "four vertical lines" in China's Mid and Long-Term Railway Network plan, and now it is one of the "eight vertical lines". It begins in Beijing South station and ends at Shanghai's Hongqiao station, with a total length of 1318 km and traversing Beijing, Tianjing, Heibei, Shandong, Jiangsu, Anhui, and Shanghai, which occupies 6.5% of the country's land area and 26.7% of the country's population (see Figure 1).

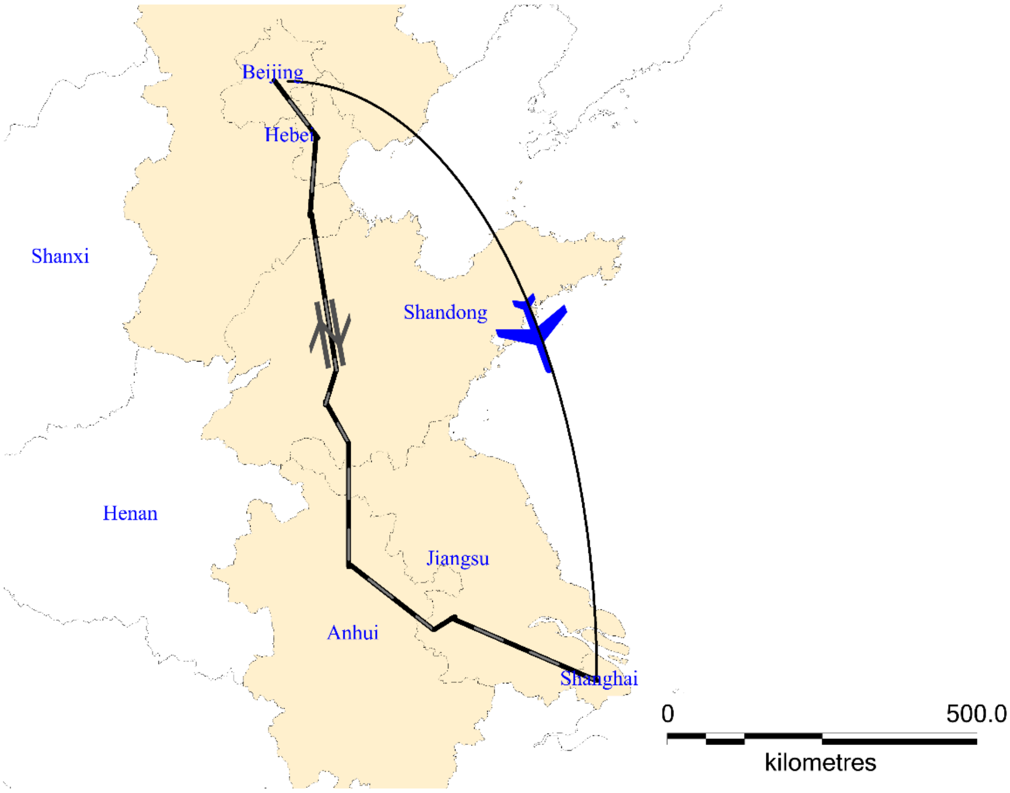

Figure 1. Beijing–Shanghai passenger transportation corridor.

This line was the first one designed for a maximum speed of 380 km/h in commercial operations, and now is operated at a maximum speed of 300 km/h in order to reduce operation costs. At this speed, the fastest train takes 4 h and 48 min to travel from Beijing to Shanghai with only one stop at Nanjing; the other trains takes 5 h 30 min on average to finish this journey. The second-class fare for the whole journey is 553 CNY (86 USD), train ticket price is fixed in China, and rarely provides discounts. As shown in Table 3, 34–38 pairs of services are provided in this line per day, with the first train departing at 06:43 and the last train departing at 19:08. After four years of running, this line has transported 330 million passengers, and claimed profits of 1.2 billion in 2014, which was the first and only HSR line to claim to be profitable in China.

Table 3. Comparison between air transport and HSR service in the Beijing–Shanghai line.

Item	Air Express	HSR
Price	first class 3650 CNY (500 USD)[a] business class 2950 CNY (461 USD) economy class 1240 CNY (194 USD)	business class 1748 CNY (273 USD) first class 933 CNY (146 USD) second class 553 CNY (86 USD)[b]
In-vehicle time	2 h 10 min	5 h 30 min on average, 4 h 18 min at least
Service/day	44–56 pairs	38 pairs
Intervals	5–30 min	5–45 min
First flight/train time	6:35	6:43
Last departure	21:50	19:08
On time rate	81.70%[c]	100%

a. Air transport fare has discounted tickets, and the economy class ticket price can have at most a 25% discount rate, and passengers have to pay another 50 CNY (7.8 USD) in airport construction fees to buy the ticket. b. All of the price data in this study comes from the economy class of air transport and second class of HSR. c. The on-time rate of air transport is calculated using the data on Umetrip by the author.

The air transport service between Beijing Capital airport and Shanghai Hongqiao airport is called the Beijing–Shanghai Air Transport Express, which has been operated by China Airline, China Eastern Airline, Shanghai Airline, China Southern Airline, and Hainan Airline since 2007; they have separate check-in counters, security channels, terminal areas, boarding, and baggage claim areas. The ticket collecting and boarding time is greatly reduced, thus ensuring a three-hour total journey time. As can be seen from Table 3, the full price for economy class is 1240 CNY (194 USD), and the discounted tickets are often provided at non-peak times; sometimes, the discount is as high as 25%. The service frequency is high: 44–56 pairs of flights are operated per day. The airports and airlines give priority to this line to guarantee its high on-time rate, which is 81.7%, compared with the 68.37% national average on-time rate (CAAC, 2014). When the HSR first opened in 2011, the air transport traffic experienced a slight drop and then kept growing till today.

3.2. Passenger Travel Choice Behavior Survey

The analysis of demand in the Beijing–Shanghai corridor is based on a RP (revealed preference) survey that gathered information about passengers' travel behavior in two modes: air transport and HSR. The survey method was the personal interview, and data collection was performed using a paper and pencil questionnaire completed by the interviewees. The survey was distributed evenly through different times of the day and different days of the week to cater for the peak and off-peak periods in this corridor. The survey was conducted from 27 November 27 to 2 December 2014. The survey objects were specific Beijing–Shanghai/Shanghai–Beijing OD passengers who were users of HSR and air transport. HSR passengers were selected at random in the departure areas of the corresponding train in Beijing South station and Shanghai Hongqiao station, while air transport passengers were approached near the boarding gates of the corresponding flights in Beijing Capital airport and Shanghai Hongqiao airport.

We designed a RP survey questionnaire (as Appendix A shows) that contains two sections of questions: trip-related information (travel companion numbers, access time, access mode, travel purpose, departure time, and ticket price), and socio-demographic information (gender, occupation, income, and age). A total of 1000 questionnaires were handed out, and 937 of them have valid results (Some questionnaires are not valid due to passengers' incomplete filling-in or severe alterations), all of the statistical analyses in this study are based on the 937 observations. The modal split in our sample is 525 HSR passengers: 412 air transport passengers. We do not have the real modal share data for this corridor, while the annual air transport traffic in 2014 was 6.4 million, annual HSR traffic for the entire corridor including middle transfer was 74.8 million. According to an interview with an HSR manager (as Appendix B show), the market share for air transport and HSR is roughly the same in this corridor. Thus, the modal split in our sample is sensible.

Table 4 shows the descriptive analysis of the sample. According to the overall data characteristics of the surveyed passengers, male passengers are in the majority, and most of the passengers are young (aged under 40). Workers employed by enterprises are the main occupation, which comprised nearly 60% of the respondents, and most of them had a medium–high income level, since the average monthly income in Beijing and Shanghai was 650 USD. From the perspective of travel purposes, passengers traveling for business are in the majority, and their travel costs are mostly paid for by the company. Most of the passengers travel alone; their access time is mainly distributed between 1–3 h.

By comparing the passenger characteristics of HSR and air transport, we can see that air transport has a larger proportion of female passengers than HSR, and the income level for air transport passengers is higher: a monthly income of more than 1500 USD occupies 54% of the total passengers investigated, and the corresponding ratio for HSR is only 11%. The majority (80%) of respondents chose air transport work for enterprise, compared with 44% choosing HSR. The air transport passengers are mostly paid for by their companies (78%), and have more preference for traveling alone, while the company-paid HSR passenger ratio is only 45%.

Table 4. Descriptive statistics of the sample. HSR: high-speed railways.

Item	Category	Chosen Mode		Total
		HSR	Air Transport	
Choice		525	412	937
Gender	Male	368 (70%)	241 (58%)	609 (65%)
	Female	157 (30%)	171 (42%)	328 (35%)
Age	18–29	290 (55%)	220 (53%)	510 (54%)
	30–39	108 (21%)	168 (41%)	276 (29%)
	40–49	78 (15%)	22 (5%)	100 (11%)
	50–59	43 (8%)	2 (1%)	45 (5%)
	>59	6 (1%)	0	6 (1%)
Occupation	Enterprise	231 (44%)	329 (80%)	560 (60%)
	Others	294 (56%)	83 (20%)	377 (40%)
Monthly Income(USD)	<750	284 (54%)	50 (12%)	334 (36%)
	750–1500	182 (35%)	142 (34%)	324 (34%)
	1500–3000	40 (7%)	106 (26%)	146 (16%)
	>3000	19 (4%)	114 (28%)	133 (14%)
Travel purpose	Business purpose	290 (55%)	358 (87%)	648 (69%)
	Leisure purpose	235 (45%)	54 (13%)	289 (31%)
Trip cost source	Company paid	234 (45%)	321 (78%)	555 (59%)
	Self-paid	291 (55%)	91 (22%)	382 (41%)
Travel companions	0	200 (38%)	267 (65%)	467 (50%)
	1	132 (25%)	92 (22%)	224 (24%)
	2–4	163 (31%)	46 (11%)	209 (22%)
	>4	30 (6%)	7 (2%)	37 (4%)
Access mode[a]	Car	202 (38%)	240 (58%)	442 (47%)
	Public transport	323 (62%)	172 (42%)	495 (53%)
Access time (transfer time + waiting time, hour)	<1	83 (16%)	0	83 (9%)
	1–1.99	232 (44%)	181 (44%)	413 (44%)
	2–2.99	109 (21%)	208 (51%)	317 (34%)
	3–4	41 (8%)	14 (3%)	55 (6%)
	>4	60 (11%)	9 (2%)	69 (7%)

a. Private car and taxi are counted as car; transfer, subway, bus, and other modes are counted as public transport.

4. Results and Analysis

The models were estimated by maximum likelihood estimation using STATA 13.1. The first model was estimated using the full combined datasets, as seen in Table 5. Further, two sub-models were estimated using data classified by different travel purposes, namely business travel and leisure travel (see Table 6). However, the estimated coefficients can only reveal the impact of the explanatory variable on the utility, but do not show its influence on choice probability. To shed more light on this issue, predicted probabilities of choosing air transport for representative male business travelers and female leisure travelers of selected combinations of independent variables are presented in Table 6, in which for each specific predication, the price differential is set to zero, and all of the remaining variables are set to their mean values.

4.1. Initial Regression

Table 5 shows the binary logit regression results using full datasets, and Table 6 presents the predicted probabilities of choosing air transport for representative male business travelers and female leisure travelers. From the regression results, we can see that most of the estimated coefficients are in line with our initial hypothesis. For trip-related features, as we predict, the preference for HSR grows with companion numbers. In other words, passengers traveling with someone else have a greater preference for HSR, whereas those traveling alone are more inclined to use air transport. More precisely, Column B in Table 6 shows that a typical female leisure traveler traveling alone has a 96% probability of choosing air transport, whereas the analog probability of traveling with more than one person is 39%. The reason is that passengers traveling alone prefer to have more private space, and passengers who are traveling in a group like to communicate. HSR has lower noise, spacious seating, and allows for walking in the aisle; it's more convenient for conversation, and those traveling with companions can enjoy the journey more. Furthermore, the in-transit time for HSR is longer than air transport, and with the comfortable seating, it's more suitable for group traveling.

Table 5. Binary logit regression model for choice of air transport over HSR (full dataset).

Independent Variables	Coefficients	Std. Dev.
Trip-Related Characteristics		
Travel companions (Dummy variables)		
0	2.136***	0.558
1	2.033***	0.572
Access time	−0.477***	0.134
Access mode (car = 1;otherwise = 0)	0.791**	0.319
Travel purpose (business = 1;leisure = 0)	1.516***	0.522
Departure time (dummy variables)		
Before 09:59	−0.698**	0.335
10:00–12:59	−0.635*	0.383
After 16:00	3.939***	0.882
Price differential for leisure passengers	−0.306**	0.125
Socio-demographic variables		
Gender (male = 1;female = 0)	−3.185***	0.366
Occupation (enterprise = 1, otherwise = 0)	0.841**	0.355
Income (Dummy variables)		
<750 USD	−2.554***	0.506
750–1500USD	−1.635***	0.419
> = 3000USD	0.724**	0.445
Age (Dummy variables)		
18–29	2.216***	0.737
30–39	1.636**	0.164
40–49	0.903	0.857
Constant	−2.156*	1.167
l*(0)	−478.114	
l*(θ)	−176.463	
Pseudo R2	0.6309	
Number of observations	937	

*** Significance levels of 1%; ** Significance levels of 5%; * Significance levels of 10%.

We can see from the regression result that with the longer access time, more passengers will choose to travel by HSR. To highlight this further, the probability of choosing air transport when access time varies is given in Table 6. As can be seen in Column B, when the access time goes from one hour to four hours, the probability of choosing air transport drops from 98% to 6%. They have a longer access time because they are poor and use a cheap access mode. So, that is influenced by their income level. The access mode gives more evidence for the second explanation, the result shows passengers using their car as the access mode are more likely to choose air transport. Passengers who are not rich and generally come from the countryside usually have to take the public transport to the central station for this trip; as a result, the access time for these passengers will be much longer than passengers departing from city. The results prove the reasonableness of our predictions for access time and access mode.

Passengers traveling for business purposes are more likely to travel by air transport, the main reason being that business travelers value their time more and tend to travel by the most time-efficient transport mode (Table 2 points out that the previous studies had shown this result). What's more, most of the business travelers are paid by their companies; thus, they do not need to care much about the fare as the leisure passengers do. Furthermore, business travelers who travel a lot often obtain a specific air transport company's frequent-flyer plan (FFP) membership, they can get the accumulation of mileage (can exchange them for bonus trips) and enjoy the better served airport lounge. Business travelers also care more about their social status; they represent their companies when they travel for business, preferring to take the better-served transport mode to show the public a good impression of their companies. Thus, business travelers differ a lot from leisure travelers in choosing transport mode, which is why we analyze them separately in the following part.

Table 6. Transportation mode choice: selected predicted probabilities for air transport (%).

	Column A	Column B
	Male Business Traveler	**Female Leisure Traveler**
Travel companions		
0	69	96
1	73	96
>1	55	39
Access time		
<1 h	81	98
1–1.99 h	69	86
2–2.99 h	55	65
3–4 h	37	16
>4 h	21	6
Access mode		
Car	55	39
Public transport	35	15
Departure time		
<10:00	28	
10:00–12:59	22	
13:00–15:59	55	
>15:59	99	
Price differential		
15 USD	55	70
30 USD	50	48
45 USD	44	27
60 USD	39	13
75 USD	33	6
Occupation		
Enterprise	56	39
Otherwise	24	6
Income		
<750 USD	29	27
750–1499 USD	55	39
1500–2999 USD	55	70
> = 3000 USD	81	70
Age		
18–29	51	5
30–39	55	39
> = 40	22	5

Note: The predicted probabilities are based on results developed in Table 7. All of the price differentials are set to zero, occupation is set as enterprise, access mode is as car. Male business travelers' remaining variables are set to business travelers' mean value, and female leisure travelers' remaining variables are set to leisure travelers' mean value.

Passengers who have to attend a conference the next morning and are departing after 16:00 are more likely to travel by air transport, which is 99% for male business travelers, as we calculated in Column A Table 6. As we imagine, this is because the in-vehicle time for HSR from Beijing to Shanghai is 5.5 hours; if passengers depart before 13:00, traveling by HSR can ensure that they get to their destination before 19:00; if they choose to depart later in the day, there is a greater likelihood that they will choose to travel by air transport, which has just two hours of in-vehicle time.

For the price differential variable, we didn't put the business travelers' data in the full dataset model: although the regression result shows that it is significant that business travelers are more likely to choose air transport when the price differential becomes larger, all else being equal, we do not think it is the reason influencing passengers' mode choice. Most business travelers' travel fares are paid by their company; thus, they are indifferent to ticket price, and the reason we get this result is that most of the business travelers have to travel in the peak time, which has higher ticket prices, and is the result of the air transport companies' pricing strategy. We calculate the self-paid business travelers' price differential in the second split model. As for leisure passengers, most of them pay the ticket price by themselves; thus, ticket price will be an important factor in their mode choice decision process. The regression result shows that when the price gap between air transport and HSR becomes larger, more passengers will choose to travel by HSR. As the reason that we give in Table 2, in China, the train fare is fixed: this also means that when air transport ticket prices become higher, more leisure passengers will choose HSR. This trend is clear in column B in Table 6: when the price differential is 15 USD, 70% of female travelers will choose air transport, and by contrast, the probability with a differential of 75 USD is just 6%.

The socio-demographic variables also play an important part in explaining the mode choice behavior, and the regression results are consistent with our predictions. First, we can see that the female passengers have more preference for air transport. In our survey, we found out that compared to male passengers, female passengers have higher requirements for the waiting room environment and security issues. Although the HSR stations in China are newly built, and its environment is much improved compared with traditional train stations, its waiting area is much more crowded and clamorous than airports, and the security procedure is not as strict as the airport, thus making the female passengers have more preference for air transport, which offers a better served and more secure environment.

As for occupation, people working in enterprises prefer air transport, whether they travel for business purpose or leisure purposes. The likely explanation is that people working in enterprise are more used to travel by air transport. When they travel for business purposes, most of them will be paid for by their company, and they will take the better quality of air transport service. When traveling for other purposes, they have propensity to choose air transport. As can be seen in Table 6, male business travelers and female leisure travelers have a 32% and 33% greater probability of choosing air transport when they work in enterprises, respectively.

When it comes to income, the regression result shows that people with income less than 750 USD/month have a bigger tendency to choose HSR, and as people earn more, their preference for air transport grows. As can be seen in column A of Table 6, people earning more than 3000 USD per month have an 81% probability of choosing air transport, compared with a 29% probability for people with a monthly income less than 750 USD. The reason is that the more one earns, the higher the unit time value and the more willingness to pay for conserving time.

Age also affects choice of transportation mode: people aged between 18–40 are more likely to choose air transport. This can be partly be explained as that in Beijing and Shanghai, most people in this age section have stable work, and most of the travelers in this line are business travelers; they travel more and they value their time more, and thus there is a large possibility that they will choose air transport. For people over 40 years old, while some of them still work, more of them are retired or have other occupations (workers, farmers, self-employers, etc.); thus, they are reluctant to pay a higher ticket price for air transport. This can also be explained as a generational taste issue: younger people like new things; thus, they prefer air transport, while older people are more traditional and like to travel by train. What's more, the physical discomfort caused by aircraft taking off and landing makes older passengers tend to choose HSR to travel.

4.2. Specific Regression according to Different Travel Purpose

In Table 7, we do the regression for business and leisure travelers separately: the results show that most of the variables in the full dataset model also hold in the business models; however, for the leisure model, the departure time doesn't show significance. That is because business travelers account for nearly 70% of the full dataset, and can have a greater influence on the regression result for the first model. When comparing the business and leisure models, we can see that business people have a greater tendency to choose HSR early in the day, which is before 13:00, and favor air transport later in the day, which is after 16:00. For the leisure model, it doesn't show departure time preference; rather, the likely explanation is that after 16:00 is the peak when most air transport tickets are fully priced. Very few leisure travelers depart at this time; thus, they just spread out evenly in the daytime for HSR and air transport. As a result, we can't get the regression result of departure time for the leisure model. As for income, for leisure passengers, we didn't get a significant result for the dummy variables of more than 3000 USD, because we do not have sufficient data for this type of passenger: passengers with more than 3000 USD only account for 3% of the total leisure data. Comparing the price differential for self-paid business passengers and leisure passengers in Table 6, we can see that although they are both sensitive to the price changes, leisure passengers are more affected. With the price differential changes from less than 15 USD to more than 75 USD, the probability of choosing air transport for female leisure passengers drops by 64%, compared to 22% for male business passengers.

Table 7. Regression results for business and leisure travelers.

Independent Variables	Business		Leisure	
	Coefficients	**Std. Dev.**	**Coefficients**	**Std. Dev.**
Trip-Related Characteristics				
Travel companions				
0	2.998***	1.123	3.905**	1.637
1	3.418***	1.130	3.683**	1.648
Access time	–3.769**	0.155	–2.300***	0.656
Access mode (car = 1; otherwise = 0)	0.757**	0.384	1.264*	0.767
Departure time (dummy variables)				
before 10:00	–1.235***	0.397		
10:00–13:00	–1.451***	0.477		
after 16:00	4.552***	1.297		
Price differential (leisure)			–0.908**	0.356
Price differential (self-paid business)	–0.180**	0.082		
Socio-demographic variables				
Gender (male = 1; female = 0)	–3.519***	0.456	–1.740**	0.734
Occupation (enterprise = 1; otherwise = 0)	1.168**	0.465	2.258**	0.947
Income (dummy variables)				
<750 USD	–1.841***	0.611	–1.817**	0.526
750–1500 USD	–0.880*	0.499	–1.290*	0.852
>3000 USD	0.922*	0.537		
Age (dummy variables)				
18–29	2.134**	0.850		
30–39	1.778**	0.876	2.457**	1.115
40–49	0.840	1.002		
Constant	–2.050	1.479	1.746*	2.155
l*(0)	–322.794		–117.375	
l*(θ)	–199.629		–31.290	
Pseudo R2	0.629		0.733	
Number of observations	525		412	

*** Significance levels of 1%; ** Significance levels of 5%; * Significance levels of 10%.

5. Discussion and Conclusions

Studies on what determines passengers' transportation mode choices of HSR and air transport in China are few and far between, as these two kinds of transportation modes are developing so fast and are of vital importance. We chose to use Beijing–Shanghai passengers' travel information to analyze how the two sets of determinants, namely, socio-demographic variables and trip-related variables, influence their mode choices. By means of a binary logit regression model, the study's most important results are as follows:

- Passengers' preference for air transport decreases with accompanying number of passengers and access time, and increases with income.
- Business passengers have a greater tendency to choose HSR early in the day, and favor air transport later in the day.
- Female passengers and younger passengers have a higher probability of choosing air transport.
- Leisure passengers are more price sensitive: they tend to travel by air transport when the air transport prices are lower.

Based on the previous discussions, considering the sustainability development of HSR and air transport, some policy suggestions for relevant authorities are provided.

(1) Compared with the yield management system of air transport companies, the fixed ticket pricing strategy of HSR cannot reflect passenger's demand variation with the change of departure time. As the advantage of HSR decreases with the departure time compared to air transport, differential pricing can be adopted by China Railway Company to differentiate between peak and off-peak periods to make better use of the passenger transport infrastructure.

(2) HSR stations should take more account of female, business, and high-income passengers in planning facilities, as the study shows that they have higher requirements for travel. HSR operators can build a women-only waiting room and VIP waiting room to improve the waiting experience for particular passenger groups. For business passengers who travel frequently, HSR can offer them VIP membership service and discount ticket prices in order to attract more high-income customers.

(3) Joint tickets for the access transport and the HSR can be provided for passengers who travel a long way to the HSR stations: our study shows that passengers in the countryside prefer train rather than air transport, and they all spend a long time accessing the HSR stations. The discounted joint tickets can be provided, or HSR operators can reimburse their access transport ticket when they purchase the HSR tickets.

The study focuses on the passengers' preference of air transport versus HSR, and analyzes the passenger mode choice behavior using the binary logit regression model. The factors that we surveyed as affecting passenger mode choice behavior contain two sections: trip-related characteristics and socio-demographic variables. Therefore, this study reveals the travel characteristics of passengers, and has reference value and significance for policy design and infrastructure management. However, there are still some limitations to the study in terms of the analysis of passenger mode choice behavior. The factors not only refer to gender, age, occupation, income, travel purpose, cost source, companions, and access time, but also involve education, services, and et al. Therefore, future research needs to further improve the passenger choice model, and consider more factors.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Questionnaire on Travel Choice of Passengers in Beijing–Shanghai Corridor

Date:	Staff No.:
Questionnaire No.:	

Dear Travelers:

Hello! This survey was created in order to study the passenger choice behavior between HSR and airlines, and design passenger products that better meet the requirements. This questionnaire is anonymous and will keep your personal information confidential. Thank you very much for your assistance.

Your Personal Information

Gender: _____ Age:_____ Monthly income: _____

Your working city: _________ Residential city:__________

Occupation: □self-employed □business manager □company employee □civil servant □teacher or researcher □student □peasant □soldier □retiree □other___

Please fill in the following information according to your personal situation

[1] The number of your train/flight:__________

Departure station/airport:___________

Arriving station/airport:____________

[2] Travel purpose:

□official □business □study or training □leisure travel

□visiting relatives or friends □other____

[3] Source of travel payment:

□public-paid □self-paid

[4] Travel companions:

□oneself □1 □2–4 □4

[5] Transport mode to the station/airport:

□bus □subway □self-driving □taxi □other____

Access time: ______minute

Access cost: ¥______

[6] The tickets fare you purchased: ¥

[7] How many days before the train/flight departure did you purchase your ticket?

□1 □2–4 □5–9 □10–14 □>15

[8] Waiting time in station/airport: minutes.

[9] How many times do you travel by air every year?

□<6 □7–12 □13–30 □>30

[10] How many times do you travel by train every year?

□<6 □7–12 □13–30 □>30

[11] Please mark the following factors that will affect your travel experience.

(10 is the most important and 0 is the least important)

Factors	Safety	Access time	Waiting time	Travel time
Score				
Factors	fare	Access mode	Departure interval	Comfort
Score				

[12] Please mark the comfort of the following transport modes:
(10 is the most comfortable, 0 is the most uncomfortable, and there is no need to score the transport mode that you have not experienced)

Transport mode	HSR			EMU train		
	business class	1st class	2st class	soft berth	1st class	2st class
Score						
Transport mode	Express train			Airplane		Coaches
	soft berth	hard berth	seat	business class	Economy class	
Score						

[13] If you need to travel from Beijing to Shanghai (from Shanghai to Beijing) at different periods of time, which of the followings is your first choice:

Options	A	B	C	D	E	E	F
Transport mode	HSR			EMU train		Air plane	
	business class	1st class	2st class	1st class	2st class	Business class	Economy class
Travel time（hour）	5.5			10		2.5	
Fare（¥）	1748	933	553	648	408	1480	690

1. Between 6:00 and 10:00, your choice is: ______
2. Between 10:00 and 13:00, your choice is: _____
3. Between 13:00 and 16:00, your choice is: _____
4. Between 16:00 and 20:00, your choice is: _____
5. Between 20:00 and 23:00, your choice is: _____

[14] If you travel by HSR from Beijing to Shanghai (from Shanghai to Beijing), which period of time is your first choice:

□6:00-10:00 am. □10:00–13:00 noon □13:00–16:00 pm. □16:00–20:00 pm. □After 20:00

[15] If you travel by air from Beijing to Shanghai (from Shanghai to Beijing), which period of time is your first choice:

□6:00–10:00 am. □10:00–13:00 noon □13:00–16:00 pm. □16:00–20:00 pm. □After 20:00

[16] In the following different fares, which one would you choose (economy class for airline, second class for HSR)?

□Airfare is ¥918, HSR fare is ¥829. □Airfare is ¥918, HSR fare is ¥663.

□Airfare is ¥918, HSR fare is ¥553. □Airfare is ¥918, HSR fare is ¥442.

□Airfare is ¥918, HSR fare is ¥332. □Airfare is ¥1240, HSR fare is ¥553.

□Airfare is ¥1000, HSR fare is ¥553. □Airfare is ¥800, HSR fare is ¥553.

□Airfare is ¥600, HSR fare is ¥553. □Airfare is ¥400, HSR fare is ¥553.

[17] What do you think need to be improved about this trip that you are not satisfied with? (For example: access mode, ticket purchase procedure, fare, departure interval, service, etc.)

____

____

This is the end of the questionnaire. Thank you for your cooperation.

Appendix B

Conversation with HSR manager

Question 1: What is the current operation situation of the Beijing–Shanghai high-speed railway?

Answer 1: The Beijing–Shanghai high-speed railway was opened in June 2011. The operating mileage is 1381 kilometers, and daily departures are 38 pairs. The Beijing–Shanghai high-speed railway has been in operation for nearly three and a half years. During this period, the overall operation is stable and in good order. The evaluation of the whole society is also positive. In 2013, the national passenger traffic volume of high-speed railway was about 530 million, while the passenger traffic volume of the Beijing–Shanghai corridor accounted for nearly one-seventh, and still shows a rapid growth trend.

Question 2: Has the opening and operation of the Beijing–Shanghai high-speed railway affected civil aviation?

Answer 2: If you look at the air passenger traffic volume of the Beijing–Shanghai corridor over the last few years, you will find that the opening of high-speed rail has had an impact on civil aviation, but no substantial harm was caused. Although the air passenger traffic volume of the Beijing–Shanghai corridor has decreased slightly in the last three years, the annual passenger traffic volume has remained above 6.7 million. Overall, the market share for civil aviation and high-speed rail is roughly the same in this corridor.

Question 3: What is the main customer base for high-speed rail? What are the obvious characteristics of gender, age, and income?

Answer 3: Generally speaking, middle-income and low-income travelers prefer high-speed rail. For high-income passengers, most of them have become airline VIPs, and so choosing air travel will enjoy more VIP treatment. In this respect, the waiting room and other aspects of high-speed rail need improving. Generally speaking, compared with female passengers, male passengers account for a larger proportion. The passengers spanned all ages, but the middle-aged passengers are the majority.

Question 4: How about the occupancy for high-speed rail? Are there any differences at different times?

Answer 4: I can't give you an exact figure about the occupancy. I can only say that the attendance rate is still very high. For the Beijing–Shanghai corridor that concerns you, according to the current situation, passenger traffic volume is expected to exceed 100 million this year. The number of passengers is different at different times. Usually, the passenger flow before 15:00 or 16:00 is relatively large, and passenger flow is also large on the weekends.

Question 5: How about transfers to and from high-speed railway stations?

Answer 5: In terms of the Beijing South Railway Station, it is convenient to take the subway, bus, or taxi to most places.

Question 6: What are the passengers not satisfied with?

Answer 6: At present, the passengers still have some opinions about our waiting environment, of course, not about all high-speed rail stations' waiting environment. The daily passenger traffic volume of the Beijing South Railway Station is very large, which inevitably leads to noise and crowding.

Question 7: What aspects need to be improved in the future?

Answer 7: We believe that the future development of China's high-speed railway will be better. At present, the high-speed rail fares are not expensive, and the fare is fixed. In the future, we will consider carrying out discount fares or floating fares. Other aspects of service will also be improved, such as improving the food ordering service. Many improvements are still being envisaged, and we believe that the service of high-speed rail will be better and better in the future.

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