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Research on Passengers' Preferences and Impact of High-Speed Rail on Air Transport Demand

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Abstract: The new high-speed rail (HSR) routes are expected to have a large impact on air transport demand. In some cases, HSR can be a complementary mode to air transport. However, a number of studies have pointed out that HSR can have a negative impact on air transport demand. Various approaches have been used to model mode choice behaviour, such as the discreet choice model, logistic regression and the analytical hierarchy process. OLS and MLE are two methods that are commonly used for parameter estimations. However, these approaches have some limitations. This study aims to understand the travel behaviour, mode choice model, travel variables and the impact of HSR operation on air transport demand through a systematic literature review. This study explores various approaches that are used to model mode choice and identify possible alternative approaches to overcome the limitations of current methods. The key variables that influence mode choice and the impact of HSR operation are elaborated in this study. Several points can be concluded from the analysis of the literature, such as: (1) the operation speed set by HSR should be reliable to enable it to compete with airplane travel time; (2) the model to represent mode choice behaviour should be derived from a suitable analysis method and Bayesian method is one of the alternatives for the parameter estimation; (3) there are various variables that are yet to be included in the current mode choice models, and they can be further explored to better present the needs of the customers; and (4) the impact of HSR operation on airplane travel demand, explained by previous studies, can be used as a reference for the policy maker in implementing transport projects.

Keywords: high-speed rail; impact; competition; air transport demand; policy maker

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1. Introduction

The significant increase in train speeds has led high-speed railway (HSR) to become an effective competitor for the air transport mode. HSR has attracted worldwide attention as a fast land transport mode. Many countries, such as China, Japan, South Korea, France, Germany, Spain and Italy, have developed various HSR rolling stock technologies. China's air transport industry has rapidly grown in the past 30 years and has been the second largest market in the world since 2005 [1]. Then, the HSR system was introduced in the transportation system as a new land transport mode in an effort to increase the service quality for customers [2–4]. China is one of the leaders in the development of HSR and has the most aggressive HSR development strategy in the world. From 2008 to 2015, the size of China's rail network reached 19,000 km. According to the China Medium and Long Term Railway Network Masterplan 2016, China is expected to have approximately 30,000 km of railway in 2020. The network will cover more than 80% of the major cities in China. The rapid growth in China's HSR has created competition with the growth in the aviation industry [2]. This growth has never been seen before and is causing a significant reallocation of air traffic in China's transport market [5]. Japan has a long history of competition between HSR and the air transport mode, which started with the opening

of the Shinkansen Tokaido route between Tokyo and Osaka in 1964. Since then, the total length of the HSR network in Japan has increased to 3000 km [6].

A large body of literature has discussed topics related to HSR development, including the methodology that is used to assess the HSR trip demand. The study by Lee et al. (2016) used a mixed logit model and the stated preference technique to assess the trip demand potential for HSR between Seoul and Jeju [7], while Park and Ha used stated preference and a binary logit model to assess the trip demand between Seoul and Daegu [8]. Mizutani and Sakai (2021) and Li et al. (2019) used Difference in Differences (DID) analysis to understand the effect of HSR on other modes [6,9]. Disaggregated mode choice models with data from a stated preference and revealed preference survey were used by Román et al. (2007) to analyse the potential demand of HSR [10]. Another method that can be used to analyse the potential trip demand is the nested logit model with revealed preference data [11]. Other methods that have been used in assessing HSR's potential demand are hierarchy panel regression [12], multinomial and binary logistic regression models [13] and the two-stage least square estimator (2SLS-IV) [14].

A number of studies have shown that HSR has a negative impact on air passengers' transport demand. While decision makers may consider HSR as an alternative to the air transport mode [15], it is also necessary for them to evaluate the factors that influence passengers' mode choice [16]. Previous studies have identified factors that significantly influence passenger mode choice. The factors include fares, cost differences, trip frequency, travel time, trip length, seat availability and security [2,5,17–22]. The passenger mode choice has also been found to be significantly influenced by demographic and economic factors, such as GDP, fuel prices, hub status, population and population density [21–23]. The availability of facilities such as duty free shops is another factor that significantly influences passenger mode choice [7].

The effect of HSR development is evident in several sectors, such as economic development [24] and the air transportation industry [1,2,17,18,25–33], as well as the existing conventional railway industry [27]. A study on the competition between transport modes showed varied results on the competitive distance of HSR due to its relationship with the travel time. Adler et. al. (2010) found that the longest route length for HSR is not more than 750 km [34], while Chen (2017) found that the largest impact of HSR on airlines occurred at route lengths between 500 and 800 km [35]. An analysis of the relationship between travel time and the HSR market share indicated that HSR will dominate the market when the travel time when using HSR is below 3 h [32]. Another study found that the occupancy rate of HSR can reach 50–90% if the travel time is around 2–3 h [2]. Mode choice is one of the most important aspects in transport planning and policy making. Therefore, it is important to define a mode choice model that is sensitive to the travel attributes that can influence a person in choosing a transport mode. The model can be used to identify the key factors that influence the passenger's mode choice and to predict the passenger's travel demand for the selected area or route [36]. The most commonly used approaches in mode choice modelling are the discreet choice model (logit binomial, multinomial logit, nested logit model), logistic regression, or the analytical hierarchy process. In parameter estimation, the most commonly used methods are ordinary least squares (OLS) and maximum likelihood (MLE). These two methods are usually used for linear regression. However, MLE and OLS have some limitations. One of them is related to the assumption that the regression will follow Gauss–Markov assumptions. These methods will become unsuitable if the regression does not follow Gauss–Markov assumptions. Another limitation is related to the sample size. If the sample size is too small ($n < 20$), the use of MLE may cause bias in the parameter estimation results. The resulting standard error may not be suitable and may lead to an incorrect confidence interval.

Therefore, this study explores the literature on the various methods and studies that are related to mode choice models and identifies possible ways to overcome the limitations of the current methods. This study also explores the attributes that have been used to explain the mode choice behaviour and considers possible new attributes that can be

included in the mode choice models. This study focuses on a literature review related to mode choice models and the impact of HSR on the air transport demand. Basic information on the literature related to passenger behaviour, passenger preferences, modelling variables and HSR impacts was collected from Scopus. Scopus is a navigation tool that provides the largest set of curated abstracts in the world and an indexation database with more than 24,000 indexed titles as per August 2020 [37]. Further filtering of the documents was conducted by reading through the abstracts and summaries of the articles. Furthermore, documents related to HSR were filtered through additional selection. The selection was based on whether the research used stated preference or revealed preference, influencing variables and the impact of HSR. The study aimed: (1) to analyse previous studies on mode choice models for HSR through a systematic literature review; (2) to understand the main attributes that are commonly used and the alternative main attributes; (3) to understand the main impact of the operation of HSR on air transport demand and policy making to determine the best alternative in planning a new transport system; and (4) to identify the methods and variables that were previously used in mode choice models and the potential future research.

This paper is divided into five sections: the introduction, bibliometric analysis, literature reviews, gaps and limitations, and conclusions. The literature search process is explained in the bibliometric analysis section, including the co-occurrence analysis to identify the related keywords. The literature review is divided into three different topics of interest: mode choice models and parameter estimation, attributes that influence travellers' mode choices, and the impact of high-speed trains on air passengers' demand. In the fourth section, the gaps and limitations in the previous studies are identified and explained. In the conclusions, the potential future research will be explored based on the identified gaps and limitations of previous studies.

2. Bibliometric Analysis

Data collection was performed based on the literature listed in the Scopus database with "high-speed rail", "high-speed train" and "high-speed railways" as the keywords. The search of the literature was conducted in three stages. In the first stage, where the search was not limited by the year, 13,938 articles were found. The second search was performed by limiting the time period of the literature to 2014–2023. In this stage, 2057 open-access articles were found. In the third stage, 1880 articles were found, which included journal papers, conference papers and reviews.

Then, based on the literature search, 67 countries were identified as the most productive and most collaborative. Among them, China is the most productive country, with 1339 documents and 10,853 citations, as well as the most powerful, with a total link strength of 403, as shown in Table 1. This is in line with the aggressive development of China's high-speed railway network in recent years, as shown in Figure 1. The recent development of the high-speed railway network in China may also influence the interest of researchers to explore the related research topics.

Research trend analysis was carried out by a literature search with "high-speed train", "high-speed train" and "high-speed railways" as the keywords. Visualisation was performed during co-occurrence analysis with the author keyword as the unit of analysis, as shown in Figure 2. The analysis identified 4665 related keywords. Then, the number of keywords was narrowed down by limiting the keywords based on their occurrence frequency, with a minimum of 5 times. Based on these criteria, 96 keywords were found. After further analysis by matching the selected keywords with the Library of Congress Subject Headings (LCSH) thesaurus, the number of keywords was reduced to 85 keywords. A large number of these keywords are related to infrastructure aspects (e.g., ballastless track and railway bridges), rolling stock aspects (e.g., aerodynamics and adaptive control) and demand aspects (e.g., accessibility and competition).

Table 1. The most productive and collaborative countries.

Number	Country	Documents	Citations	Total Link Strength
1	China	1339	10,853	403
2	United Kingdom	189	3131	176
3	United States	113	1938	122
4	Spain	88	1546	47
5	Italy	59	1033	43
6	Japan	44	404	26
7	South Korea	43	272	12
8	France	37	364	21
9	Hong Kong	35	754	44
10	Germany	34	488	33
11	Canada	33	1081	48
12	The Netherlands	29	636	28
13	Russian Federation	27	117	4
14	Australia	26	592	33
15	Sweden	23	208	16
16	Indonesia	17	37	3
17	Poland	17	85	8
18	Portugal	17	243	23
19	Taiwan	17	75	5
20	India	16	58	5

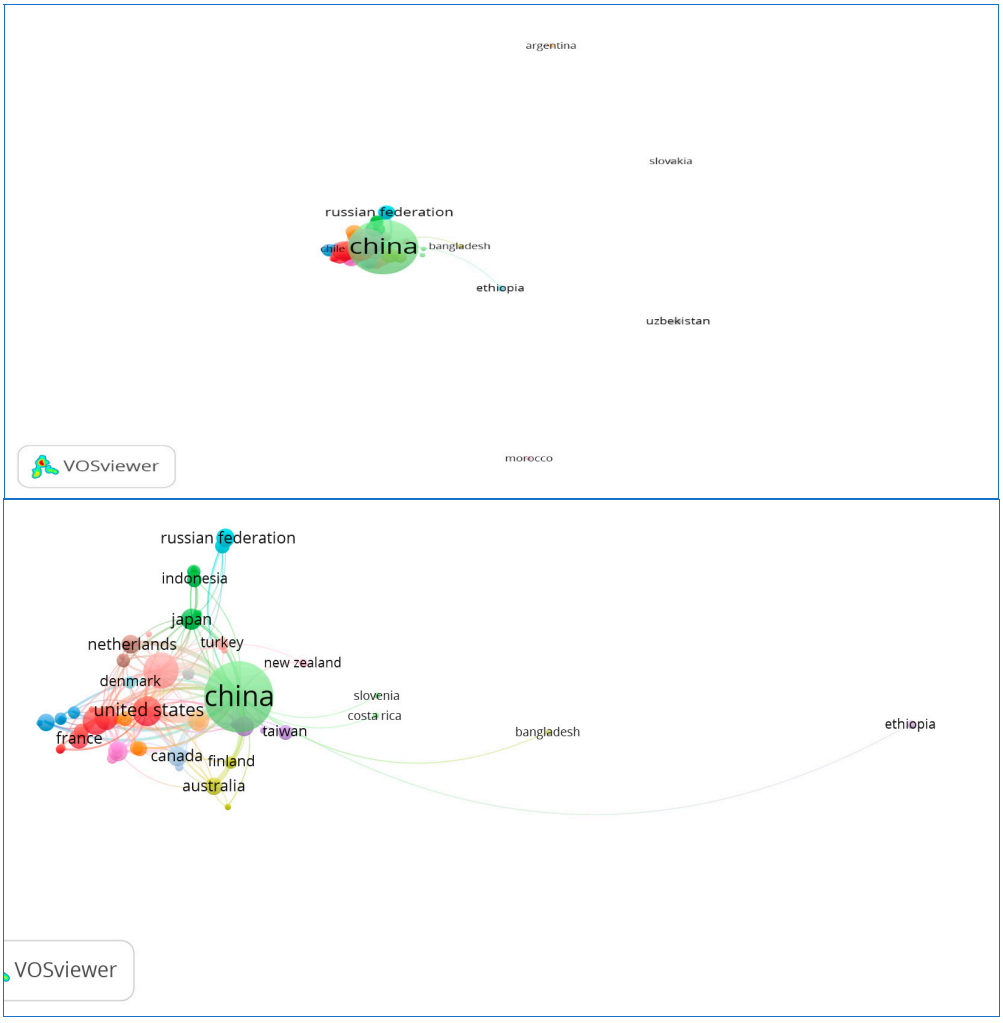

Figure 1. Visualisation of the most productive and collaborative countries.

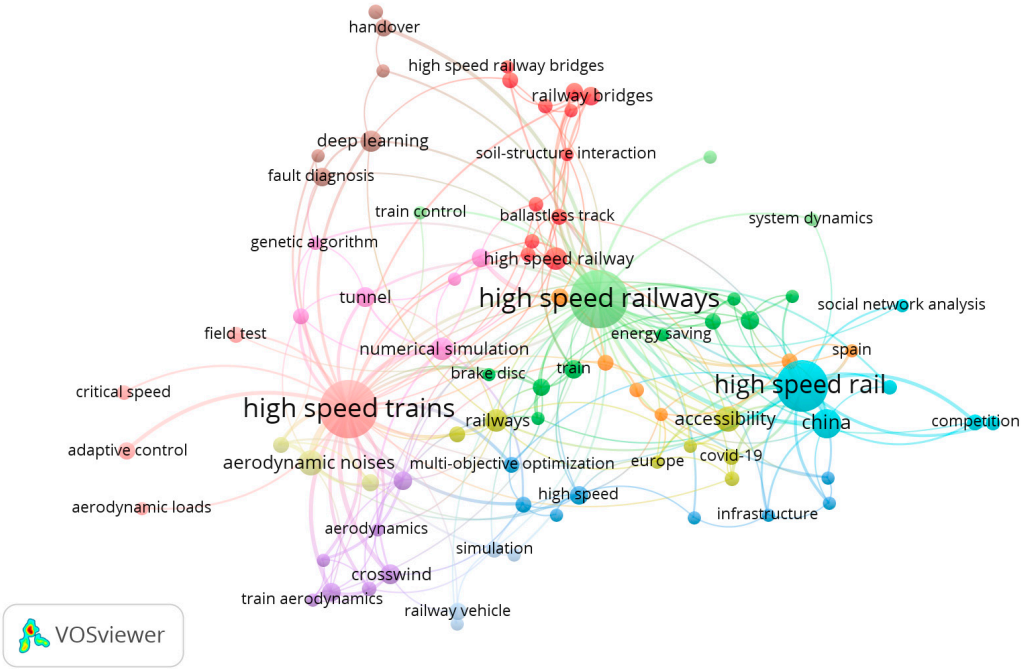

Figure 2. Visualisation based on network keywords from author keywords.

Co-occurrence analysis was performed with the keyword index as the unit of analysis, as shown in Figure 3. Based on the analysis results, 8549 keywords were found. A further selection process was conducted by matching the keywords with the LCSH thesaurus. The number of keywords found was reduced to 8452. After this, the analysis was narrowed down by focusing on keywords that occurred at least ten times. Based on this criterion, 264 keywords were found. Matching the keywords to the LCSH thesaurus reduced the number to 10,257 keywords. These keywords were further categorised into 7 clusters. The relationships between clusters were visualised, as shown in Figure 3.

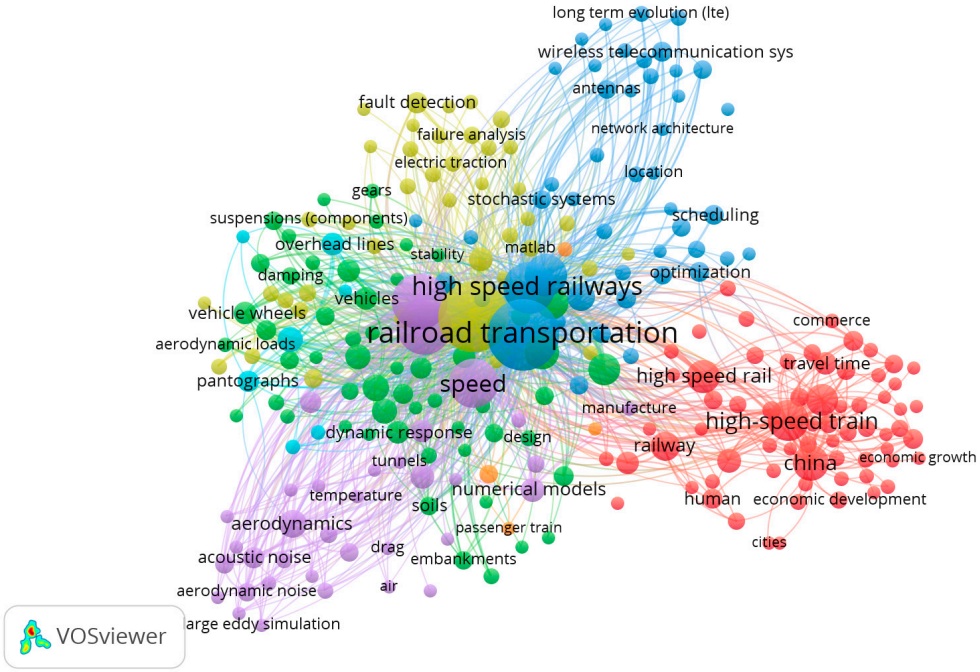

Figure 3. Visualisation based on network keywords from index keywords.

Overlay visualisation was carried out to identify the years in which the articles were published, as shown in Figure 4. High-speed railways or railway transport and China have clear or yellow circles, which means that a great deal of research on this topic was started in 2020 and conducted in China. This trend is in line with the finding that China is one of the most productive countries in research related to high-speed railways. The interest in this topic of research may have been triggered by the introduction of high-speed trains in the early 2000s and the rapid development of the high-speed network in recent years.

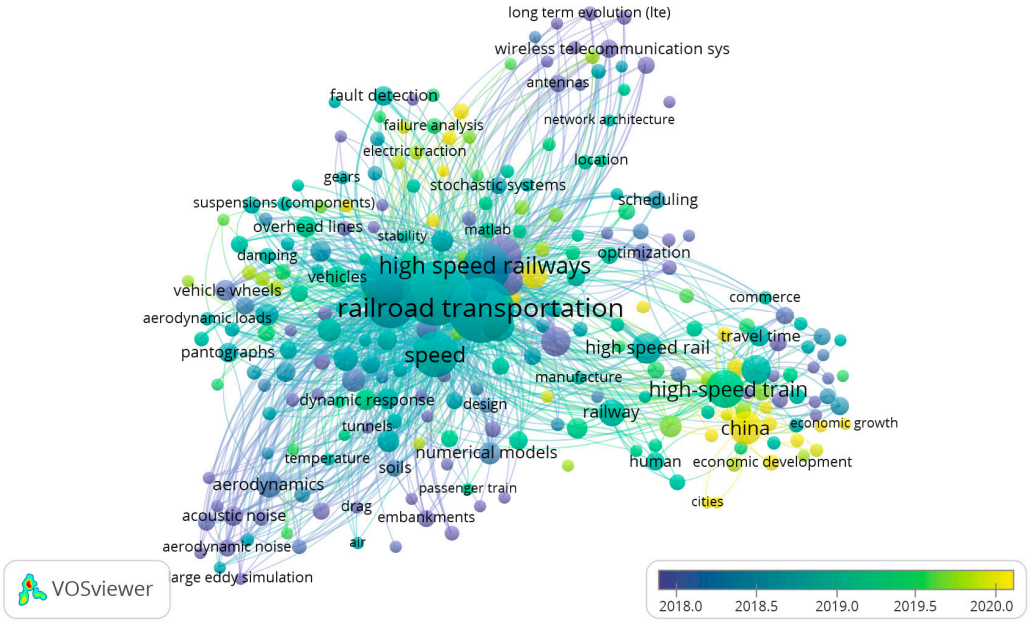

Figure 4. Visualisation based on year of publication.

After the mapping of the keywords, the literature search was further narrowed down to a specific group of topics. The keywords were filtered by focusing on topics related to passenger preferences and the effects of trains on the airplane passenger trip demand. The literature found in this stage was then further analysed.

3. Literature Review

3.1. Mode Choice Model and Parameter Estimation

Various academic studies have discussed the development of HSR and its impact on the air transport sector, including the modelling method that is used to investigate the travel demand of these two modes and to predict the travel demand of new modes. Transport mode choice models are usually developed based on data from stated preference or revealed preference surveys to understand respondents' preferences towards the offered modes. They can also be developed using available panel data sets. The stated preference technique was used for data collection in the study of the Seoul–Jeju HSR route. Then, the data were analysed using the mixed logit model to form a mode choice model. The result indicated that the compatibility of the model was increased with the addition of new variables [7]. Another study used the stated preference and binary logit model to analyse the travel demand between Seoul and Daegu. The operation of KTX on this route had a negative impact on the air transport demand [8]. Meanwhile, another study used Difference in Differences (DID) to understand the effect of the existence of HSR and the entrance of LCC airlines on FSC airline tickets [6]. A study using DID analysis and a panel data set on air transport and HSR in China from 2007 until 2014 showed a 50% reduction in air travel due to the increase in HSR's daily frequency [9].

Binary analysis as well as multinomial logit have been used to investigate passenger mode choices. The logit model assumes that maximising the utility is the basis of passenger mode choices. A study on mode choice in Chongqing, China, found that several factors,

such as socioeconomic factors and train service conditions, as well as variables such as fare, travel routines, travel distances and on-board facilities, played an important role in influencing whether a passenger will choose a conventional train or HSR [1]. HSR was a suitable substitution for air travel in the midst of competition between transport modes for the London–Paris route in 2003–2009. A study using multinomial and mixed logit models to understand the actual travel behaviour indicated that the travel time and travel frequency were the main factors that influenced passengers' travel behaviour [20].

Mixed preference and revealed preference techniques are commonly used to understand the impact of HSR operation on airplane travel demand. A study on mode choice for the transport corridor between Santiago and Concepcion in Chile used mixed preference and revealed preference. The study found that the travel time, ticket price, comfort and time reliability of services were the most important factors that influenced passengers' mode choice [38]. Disaggregated mode choice models were used to analyse the information from a stated preference and revealed preference database, and the authors found that the market size of the Madrid–Barcelona HSR is around 50% greater than the predictions made in a previous analysis [10]. In another study, the choice between car and rail travel was modelled through a schedule-based approach with a nested logit model and the "train" utility function, including late and early penalties, to analyse the impact of HSR between Roma and Napoli in Italy based on revealed preference data [11].

A systematic approach was used to analyse the impact of HSR operation on air travel demand using hierarchical regression with panel data on China domestic air travel from January 2011 until December 2017 [12]. A multinomial logistic regression model and binary logistic regression model were used to investigate the competition between HSR and LCC in the South Corridor of Thailand. The result showed that variables such as the travel time, fare difference, occupation, household income, educational level and trip purpose were the most influencing variables [13]. A two-stage least squares estimator (2SLS-IV) was used to develop an equation that showed that air transport operation decreased by 17% due to the introduction of HSR in Spain and, at the same time, the total transport system demand increased, which means that the decrease in air transport demand was actually larger [14].

A similar method is also frequently used in other research related to LCC and FSR airlines. A study investigated the demand of the air transport sector with the introduction of LCC to Haneda and Kansai International Airport (KIX), as well as the operation of the Chou Shinkansen Route, using stated preference techniques. Nested logit model parameters were used to develop the mode choice model, which considered the differences in fare sensitivity between business and non-business travellers [39]. The opening of LCC airlines in addition to FSC also expanded the total traffic through market segmentation, which was demonstrated using a linear regression model [23].

A study on mode choice between HSR and economy and business class airplanes in Japan used a discrete choice model with linear regression and ordinary least squares methods [6]. The most common method that is used to model the relationship between predictor and response variables is regression, i.e., both simple and multiple regression [2,14,17,18,21,22,36,40]. Correlated independent variables should not be included in the model, because the model can be considered unsatisfactory due to the correlations between variables [17]. Table 2 shows the type of models that have been used for mode choice modelling.

Table 2. Related studies of the type of model.

Type of Model	Research Method	Market	Papers
Binary logit model	Survey	Seoul–Daegu (South Korea), Iran, Indonesia, China	[1,8,28,41,42]
Nested logit model	Survey	Madrid–Barcelona (Spain), Italy, Japan	[10,11,39,43–45]

Table 2. *Cont.*

Type of Model	Research Method	Market	Papers
Multinomial logit model	Survey	UK, France, China, South Korea, Australia, Spain	[1,20,46–49]
Regression models	Panel data	USA, Spain, Japan, France, Italy, The Netherland	[12,14,17,18,21–23,30,31,50–64]
Regression models	Survey	Europe, China, Indonesia	[36,65–67]
Logistic regression model	Survey	China, Indonesia	[28,68]
Econometric models	Panel data	China, Europe	[2,22,25,69]
DID method	Panel data	China, Japan, South Korea, Taiwan	[6,9,35,40,70,71]
Monte Carlo simulation	Survey	Dallas and Houston, USA	[72]

3.2. Attributes That Influence Travellers' Mode Choices

A wider analysis of passenger travel behaviour showed that the traffic volume tends to increase and shift toward transport modes with a shorter travel time, including airplanes [73]. Two variables should be considered to assess the passenger's strategic behaviour in choosing a transport mode, namely, the fare and frequency [5]. In choosing a transport mode that will be used by the public transport user—in this case, airplane passengers—there are several factors that can influence the user, especially their perceptions and expectations in choosing a transport mode. This requires choice model estimation to predict the passenger market of a new transport mode or to identify the main source of traffic diversion. There are many studies on mode choice, including research on attributes or variables that may affect the mode choice behaviour. Several attributes have been analysed in various mode choice studies, such as fares, travel time, frequency, access time, egress time, comfort and convenience. Ticket price and trip frequency were used in a study on the effect of HSR on the air transport market. The result indicated that the operation of HSR has a negative impact on the air transport market [26]. Another study used the ticket price as a variable and the results showed that the competition with train services can induce more air traffic after the entrance of HSR, with faster travel times [17]. In addition, variables such as travel time, frequency and ticket fares for HSR have influenced the decrease in air transport passenger demand in China [18].

Travel distance and travel time are the two most influencing parameters in transport mode choice. Airplanes lead the market for trips longer than 700–800 km [19]. Trains created competition with airplanes by offering good services in terms of several aspects, such as frequency, travel duration, punctuality of the schedule, comfort, convenience and price. Analyses of the combination of HSR travel time and safety show that while it can increase the HSR speed and reduce the travel time, it also can cause a safety issue in developing HSR markets such as China [70]. The difference between HSR and airplane ticket prices plays an important role in influencing passengers in choosing between HSR and airplanes, while travel time has a greater effect on the air transport demand compared to HSR frequency [2]. A study on tourist behaviour on the London–Paris route found that trip frequency and travel time were the main deciding factors of travel behaviour [20].

Other variables that influence the air travel demand include GDP, fuel price (as a proxy for air ticket price), hub status and population density [23]. The Seoul–Jeju HSR route was analysed as an empirical case study by including two new variables, safety of transport and availability of duty free shops, in addition to other variables such as travel time, travel cost and service frequency [7].

Among factors that are considered to influence the air transport demand, the following four factors appear the most frequently in the literature for both LCC and FSC: ticket price, population, GDP and route distance [21]. Empirical analysis was performed for the domestic route data of four European Union countries, namely France, Germany,

Italy and Spain, to understand the competition and cooperation between HSR and air transport services in Europe, using the seat number, frequency, population, GDP and distance as the variables [22]. Table 3 shows the list of variables that have been used in mode choice models.

Table 3. Literature review of attributes that influence transport.

Variables	Market	Papers
Travel time	South Korea, Spain, Italy, UK, France, Japan, China	[2,7,11,18,20,23,36,39,43,65,70,74]
Travel cost, fare	South Korea, Spain, Italy, UK, France, USA, Japan	[2,7,8,10,11,20,22,39,43,50,51,65]
Frequency	South Korea, Spain, UK, France, Japan	[2,7,8,20,39,43,65,75]
Distance	South Korea, UK, France, China, USA, Japan	[2,8,20,22,35,40,50,51,69,75,76]
Population	USA, Europe, Spain, China, Japan, South Korea	[2,21–23,40,51,75]
GDP	Europe, China, Japan, South Korea	[2,22,23,40,69,75]
Access time	Spain, Italy, China, Japan	[10,11,36,39,43,76]
Income	Spain, China	[21,28,36]
Waiting time	Spain	[10]
Comfort	Spain	[19,43]

3.3. Impact of High-Speed Rail on Air Transport Demand

A large body of literature has mentioned that the existence of HSR will exert a negative impact on the aviation industry. This is related to the potential decrease in the airplane passenger demand. Demand analysis is the key element in evaluating public policy for a planned project. HSR travel demand prediction needs reliable parameter estimation to accurately predict the market size [43]. This is important because it is related to investment decisions that will define the social benefit of the project. The operation of HSR in China has caused a severe decrease in the demand of the 'Big Three' airlines in China in the small market, but it is not significant in the 'fat' market [2].

The impact of HSR on the air transport market in China was investigated using a panel data set from 30 different routes. The result showed that the competition between transport modes will encourage fare reductions and a lower trip frequency: air fares will be lowered by 0.397 CNY/km (34%) and trip frequency will be lowered by 60.2% for routes with HSR services [5]. An analysis of panel data from 2001 to 2014 revealed that the HSR service has a significant effect on the domestic air travel demand. It caused a decrease in air transport demand by 45% after the introduction of the Wuhan–Guangzhou HSR line, and a 34% decrease after the opening of the Beijing–Shanghai HSR line [35]. Data on 138 routes from 2007 until 2013 were analysed to identify the impact of the introduction of HSR services, and it was found that there was a 27% decrease in air travel demand.

The result of model analysis of the Seoul–Daegu route showed that there was an actual change in air transport demand and passenger preference when comparing the period before the launch of KTX to that after the launch of KTX, from 14 to 28% [8]. After the introduction of KTX Gyeongbu, the domestic air travel demand decreased by approximately 20–90% based on air traffic volume data. The decrease in air transport demand for domestic routes caused an operational deficit for the airline industry, a loss of potential customers and the closure of local airports [8].

The result of DID analysis to identify the impact of HSR on air passengers found a large, negative effect, especially for short-distance routes (less than 850 km) [70]. Another

study found that, when the fare differences between airplanes and HSR increase by 10%, the air transport demand will decrease by 17.9–21.98%; meanwhile, when the HSR travel time is 10% less, the air transport demand will decrease by approximately 9.43–11.57% [2]. A study in Australia on the plan for high-speed railway development found that the competitive travel time between the planned HSR and existing airplane service may cause a decrease in air transport demand on several routes, such as Sydney–Canberra (70%), Canberra–Melbourne (50%) and Sydney–Melbourne (20%) [32].

Other studies also divided service classes to examine the effect of HSR on air travel demand based on low-cost carrier (LCC) and full-service carrier (FSC) classes. Low-cost carriers (LCC) provide affordable ticket prices by reducing several services and facilities, such as catering services, with minimal reservations, so that they can reduce the operation cost and offer a competitive ticket price. The term was introduced in the aviation industry to refer to operation structures with low fares compared to their competitors. On the other hand, full-service carriers (FSC) provide and offer full services to passengers, such as entertainment facilities and catering services. On the effect of different flight classes, a study found that the introduction of LCC caused a significant negative impact in FSC. When the LCC is operated independently, it will cause a decrease in FSC traffic by 20% and overall air transport by 38.9%. When it is operated together, the decrease will be 14.3% and 33.3%, respectively [23]. In recent years, the entrance of LCC and the expansion of the HSR network in China have had a significant impact on the aviation market [25]. A study found that the reduction in airplane economy class ticket prices is larger than that for business class tickets. Meanwhile, the number of passengers in business class has decreased more than that in the economy class since the introduction of HSR [53].

The impact of HSR on travel demand is far more significant than that of LCC [77]. This is in line with another study that predicted the air traffic demand in Europe (France, Germany, Italy, Spain and UK). It showed that an increase in HSR speed would lead to a reduction in the air passenger demand, especially for the short-route market, while the expansion of LCC has caused a significant increase in European air traffic [23].

Another study shows that different market settings will lead to different impacts of LCC on the competition between full-service rail (FSR) and FSC [78]. A model analysis shows that business passengers and leisure passengers display different behaviours in choosing HSR as their transport mode for the Seoul–Jeju corridor. Business passengers tend to choose a safer transport mode regardless of its fare, while leisure passengers prefer to use duty free shops more than business passengers [7]. Eleven attributes, namely seat comfort, schedule or frequency, fares, the option to choose seats, cancelation fees, airport lounges, frequent flyer programs, business seat selection, in-flight meal availability, payment methods and in-flight entertainment, were used to analyse the choice between FSC and LCC in South Africa [79]. A good model can be developed from a suitable analysis method, as well as obtaining variables that can reflect the needs of the service users. Table 4 shows a list of various studies related to the impact of HSR on air transport demand.

Table 4. Related studies of the impact of HSR operation on air transport demand.

Papers	Method	Dist.	Results
[8]	RP	293	Air traffic dropped 28% after HSR operation.
[10]	SP and RP	625	The market reach of the Madrid–Barcelona high-speed rail exceeds the previously estimated 35% analysis by about 50%.
[76]	-	-	Price and scheduling frequency are both treated as choice variables in a numerical study of China's markets.
[19]	Data	-	The extension of the high-speed rail has become a major competitor in the air radial and interior connections that run parallel to an AVE line, forcing airlines to employ smaller planes and even causing the cancellation of some routes.

Table 4. *Cont.*

Papers	Method	Dist.	Results
[69]	City-pairs and airfare monthly data	-	The price levels of the business and leisure segments are reduced as a result of rivalry between FSCs; the average fare decreases in the business and leisure classes are EUR 232 and 113, respectively.
[23]	Level year panel data (route)	-	Low-cost carriers have had a greater impact on expanding air travel, mainly through medium routes, which have seen a 50% decline in air traffic due to increased daily HSR trips.
[75]	Level cross sectional data	-	With shorter HSR travel times, fewer air seats and frequencies are available. The impact of HSR journey time on air services is substantially greater than the impact of HSR frequency.
[21]	Time series monthly data	-	The air transport mode accounted for only 13.9% of HSR passenger demand.
[36]	SP		The most critical aspect impacting the AH service's market share is the en route travel/journey time.
[7]	SP	-	Business travellers were more likely than leisure passengers to choose a safe method of transport regardless of fee, whereas leisure passengers preferred to buy at duty-free shops.
[74]	Observations on a monthly	-	Demand for air travel has decreased as a result of greater competition from high-speed rail.
[18]	Panel data	-	In general, the introduction of new HSR lines reduces air transport demand by 27%.
[70]	Panel data	-	The impact of HSR speed on airline traffic is greater than the impact of HSR speed on airline fare.
[9]	Level year panel data (route)	-	Due to an increase in the frequency of daily HSR journeys, shows a 50% drop in air travel.
[53]	Panel data	-	Following the introduction of HSR, there was a lesser decline in both airfare and air travel demand on the routes served.
[30]	Panel data	-	The operation of the independently owned LCR has an impact on current rail, FSR and air traffic.
[6]	Survey	-	The effects of the HSR extension on FSC's airfares were consistently negative, with the negative effects being more pronounced in the short-haul sectors.
[57]	Panel data		It reduces HSR service frequencies, but it reduces HSR service frequencies with a short number of stops even more.
[48]	SP	247	The estimate derived from our data is 26% of diverted air transport traffic.
[49]	SP	-	Railways' market share will increase from 8.9% in 2000 to 22.8% in 2010, and HSR will be able to compete with AT over lengths greater than 500 km.
[33]	Data	1069	HSR can reduce AT frequency by up to 32% on a daily basis.
[80]	Data		Two–four years following the implementation of HSR, induced demand will be in the range of 10–20%.
[81]	Data		In China, HSR has the potential to reduce AT's market share for medium-haul travel.
[71]	Level year panel data (route)		In medium-haul routes, the substitution effect is most noticeable (between 500 and 1000 km).
[14]	Level monthly panel data (route)	-	Shows that air operations are reduced by 17% due to the introduction of high-speed rail.
[77]	Level quarterly panel data (route)		The advent of HSR puts downward pressure on the airline Lerner index and yield by 15.5 and 14.6%, respectively.

Table 4. *Cont.*

Papers	Method	Dist.	Results
[59]	Level daily panel data (route)	-	The Rome Fiumicino–Milan Linate route is 15.5% cheaper, and the Rome Fiumicino–Milan Linate route is 29% cheaper. HSR competition on the Milan–Malpensa route.
[60]	Level daily panel data (route)	-	Airlines can raise air fares by 3.9% due to a 10% increase in train journey time.
[61]	Level monthly panel data (route)	-	Based on the full sample, HSR may exert a positive pressure on airline flight frequencies, although no statistically significant influence was identified in subsamples of short-haul routes (less than 550 km).
[82]	SP and RP	-	Found that air transport (air-to-HSR) and conventional rail services are more likely to cause a demand shift (rail-to-HSR).
[21]	Panel data (route)	-	During the period 1999–2012, air travel accounted for only 13.9% of HSR passenger demand.
[62]	Panel data	-	HSR travel time has a shock effect on flight transport.
[12]	Panel data	-	The inclusion of HSR reduces air passenger volume by 17.88% and flight frequency by 15.80%.
[14]	Route-level data	-	The inclusion of HSR reduces air travel demand by 17%.
[63]	Survey	-	There is a reduction in flight frequency due to HSR.
[64]	Panel data	-	Number of airline passengers declined by 29.84% for all market segments.
[83]	Panel data		HSR as a low-end substitute for air travel in China.

Appendix A shows a list complete of various studies related to the type of models that have been used for mode choice modelling, list of variables that have been used in mode choice models and impact of HSR on air transport demand.

4. Gaps and Limitations

Research on mode choice behaviour under the impact of HSR operation on airplane travel demand has become an interesting challenge in the last few decades. While several studies showed that there is no significant impact of HSR on the air travel demand, the majority of previous studies indicated that HSR has a significant impact on the airplane travel demand, influenced by attributes such as travel time and ticket fare differences between the two modes. The studies also found that the parameter estimation model will define the reliability of the model based on the statistical test result. Based on this literature review, factors and challenges in mode choice development can be explained.

4.1. Travel Speed

Every country that develops high-speed train (HST) technologies competes to produce the fastest HST technology. The National Shinkansen Railway Development Act No. 71 indicates that, in 1970, HST could reach a maximum speed of more than 200 km/h [37]. With recent development, the L0 series Maglev can reach a maximum speed of 601 km/h, while TGV POS, CRH380 Hexie, Shanghai Maglev and Hemu-430X can reach maximum speeds of 574, 486, 460 and 421 km/h, respectively [84].

The operating speed of HSR should be defined at the beginning of the planning stage, especially for countries that are newly developing a HSR system, since it will be related to the total travel time of HSR. Various studies have indicated that travel time is an important factor that influences the mode choice [10,11,21,41,65,78].

4.2. Research Method and Type of Model

The research method will highly influence the models that are produced from the study. For a country that already has a HSR system, the revealed preference method and

the available data panel can be used to develop the mode choice models [8,17,40,56,85]. Meanwhile, the stated preference method is suitable for countries who plan to develop a HSR network [20,28,39].

Various academic literature on HSR development has discussed models that are used to investigate the travel demands of HST and airplanes, and to predict the travel demands of newly introduced modes. A study on mode choice between HST and economy and business class airplanes in Japan used the discrete choice model to calculate the utility of the modes, using linear regression with the ordinary least squares method [6]. The relationship between predictor and response variables is usually modelled using regression methods, both simple and multiple regression [86]. Another study stated that independent variables that are corelated with each other are recommended to be included in the model. A model can be rendered unreliable due to errors in selecting the variables that are used in the analysis [17]. However, in some cases, linear regression with the OLS method and maximum likelihood is deemed unsuitable. This is usually because the regression does not follow Gauss–Markov assumptions. In such cases, Bayesian MCMC–Gibbs Sampling is considered to be a more suitable method [87]. The most commonly used parameter estimation method in linear regression is the MLE method. However, for cases with a very small sample size ($n < 30$), the result of the MLE method can be biased. In addition, the standard errors may not be accurate, leading to the incorrect confidence interval and statistical test [88].

One of the possible alternative methods for parameter estimation is Bayesian methods. Bayesian methods offer more flexibility in complex stochastic model analysis. Therefore, this type of method is expected to be able to overcome the limitations of the classical models, with advantages such as an ability to model complex conditions and the use of assumptions that do not fit the reality and simplification.

4.3. HSR Travel Attributes

Travel attributes are an important aspect that can influence the mode choices of passengers. Each mode has attributes that represent the mode, where each attribute has utility that will be considered by the traveller. Modes with the maximum utility value will be more likely to be chosen by travellers. The introduction of HSR has had a significant effect on the demand of the three major airlines in China, and the variable with the most significant influence is the ticket fare differences between HSR and airplanes [2]. Another study found that the operation of the Beijing–Guangzhuo HSR changed the market figure of this route, and attributes such as travel costs, tickets, travel time, comfort, convenience and punctuality are the main considered factors [55]. Factors that influence the air travel demand include the ticket price, population, GDP and the route distance, for both LCC and FSC [21]. Empirical analyses were performed on the domestic route data of four European Union countries, France, Germany, Italy and Spain, to understand the competition and cooperation between HSR and air transport services in Europe, using seat availability, service frequency, population, GDP and distance as the variables [22]. A model on the competition between air transport and HSR on the Seoul–Jeju route indicated that the air fare, travel time, trip frequency, security and duty free shop availability were the most influencing variables [7].

A review of the literature has shown that a great deal of research has been conducted on mode choice modelling between airplanes and HSR. Up to 92 travel attributes have been used to model mode choices between airplanes and HSR. Among them, the eight most commonly used attributes are the travel time, travel cost, frequency, distance, population, Gross Domestic Product, access time and level of income. Around 54 research studies used regression models, with MLE and OLS as the most commonly used parameter estimation methods. Table 5 shows the summary of the travel attributes identified from the literature review.

Table 5. Most commonly used travel attributes.

Travel Attribute	Number of Studies	Percentage
Travel Time	31	18.02%
Travel Cost/Fare	28	16.28%
Frequency	24	13.95%
Travel Distance	24	13.95%
Population	22	12.79%
GDP	18	10.47%
Access Time	14	8.14%
Level of Income	11	6.40%
Total	172	100%

Travel attributes that are commonly used usually cover aspects such as the social economy, the condition of the transport system and the infrastructure condition. The models were reviewed globally and based on the attributes offered in the models. In fact, there are a number of attributes that can influence travel behaviour.

4.4. Negative Impact of HSR Operation

Mode choice modelling, including choosing the appropriate travel attributes and parameter estimation models, is required to understand the mode acceptance rate and to predict the travel demand. Travel demand estimation models for the mode choice between airplanes and HSR will be an important tool for transport policy makers in the future. The impact of HSR operation on the aviation industry has gained significant attention. Various studies have shown the substitution effect on the air transport demand due to HSR operation, which attracts former air transport passengers [2,18,22,29,31]. Specifically, the effect is evident in the LCC and FSC classes [11,29,77,89–91].

The shift from air transport to HSR has gained a great deal of support, since air transport has been shown to have a negative impact on the environment [64,92,93]. However, the investment cost for HSR development should be taken into consideration. A study by Albalate and Bel (2012) [94] showed that the HSR investment cost was approximately USD 22.5–50 million/mile. HSR investment is 1.45–3 times more expensive than the investment for conventional railway systems [27,95]. Overall, the HSR investment cost in China is relatively lower than in other countries [96]. A study by [97] found that the expansion of the HSR network could induce economic losses and a high-risk market due to the high construction costs. However, it also can increase social welfare [98]. Therefore, the government should implement the appropriate regulations to balance and optimise the advantages of these two modes [99]. An assessment of the potential effect of the integration of both modes should also be performed, since it could potentially increase the trip frequency and reduce the emissions [100,101]. The literature review and analysis showed the important impact of HSR on the aviation industry. Therefore, the decision maker should be equipped with the appropriate data, methods and analysis to obtain the best plan for HSR development.

5. Conclusions

This study can serve as fundamental data to build a strategy regarding which variables should be offered by airlines when new competitors emerge on the existing route or when airlines are joined as a newcomer on the existing route. This paper provides a critical review of passenger preferences and the impact of HSR in the last 25 years. The prediction of HSR travel demand, which substitutes for air travel demand, is relevant to the economic analysis since it offers a prediction of the number of passengers that can be used for the cost–benefit analysis and feasibility study of the new HSR network.

The systematic analysis of various references shows that: (1) speed is the main factor that can influence mode choice behaviour since it is related to the travel time variable, which significantly influences the preferences of HSR passengers; (2) there are various analysis methods, and their application depends on the availability of the data from SP/RP

or the data panel; (3) the eight most commonly used attributes in mode choice models are the travel time, travel cost, frequency, distance, access time, population, GDP, access time and monthly level income; (4) Bayesian methods are one alternative among the parameter estimation methods that can overcome the limitations of current methods; and (5) the operation of HSR in various countries has had a negative effect on the airplane travel demand.

This paper further investigated the effect of the service level and HSR ticket fare from the available literature. It was found that the differences in ticket price between airplanes and HSR, as well as the service frequency, have a negative effect on the air passenger demand. Fare differences and travel time differences have a strong impact on air passenger demand. This finding shows that HSR policy should pay attention to HSR travel time, ticket price and service frequency in order to compete with airplanes [2]. Several additional variables, such as trip frequency, fares, airline hubs and the geographical structure of the city, can also influence the mode choice. Travel time reduction, service quality and better accessibility to the station are the main factors in the success of HSR implementation [11]. Other studies emphasised that the main factors that cause passengers to exclude HSR from their mode choice are fares, travel habits and long-distance travel facilities [1].

Travel time, ticket price, comfort and convenience are variables that influence the decisions of passengers to choose HSR for the Teheran–Isfahan route [41]. The total travel time (including access time, waiting time and running time), frequency and fare are commonly used in research on mode choice. In addition, variables such as the socio-economic characteristics of passengers, delay and comfort can also be considered in mode choice models. Meanwhile, a study on the opening of new routes should include new variables that can represent the actual market condition in order to more realistically understand the mode choice behaviour [7].

For future study, one may consider platforms in addition to Scopus to enrich the range of references. This study also indicates that the stated preference, revealed preference and panel data methods still have some drawbacks; therefore, it is necessary to conduct a crosscheck with survey data, especially for countries that wish to implement HSR as a new transport mode. This study also identified the eight most commonly used attributes in mode choice models. Future studies may explore new variables that are rarely used in mode choice models, especially variables that are related to local conditions. Each area has its own characteristics that may influence travellers' mode choice.

Lastly, parameter estimation is required, when developing mathematical models of mode choice, to test the statistical parameters to ensure that the models can closely represent the real condition. A good model will help the policy maker to obtain an idea about air passengers' responses to the introduction of high-speed railway to the market. It is important for the government to understand the market condition and ensure that HSR will be a competitive mode, since investment in HSR requires a large amount of funds.

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Appendix A

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[8]	Fare, frequency, distance	Binary logit model	RP	Seoul–Daegu (South Korea)	293	Air traffic dropped 28% after HSR operation.
[10]	Access time, waiting time, travel cost, headway, in-vehicle time	Nested logit model	SP and RP	Madrid–Barcelona (Spain)	625	The market reach of the Madrid–Barcelona high-speed rail exceeds the previously estimated 35% analysis by about 50%.
[50]	Fare, air passenger, distance, number of passengers, route	Regression models (OLS)	Level year panel data (route)	World	-	This conclusion implies that low-cost carriers do not consider airport or route dominance/concentration when setting prices, and so do not levy price surcharges.
[43]	Frequency, access time, egress time, travel cost, reliability, travel time, comfort	Nested logit model	SP and RP	Madrid–Barcelona (Spain)	625	The air transport fare price and access-egress times may have a significant impact on HSR market share.
[11]	Access time, egress time, travel cost, travel time	Nested logit mode choice model	Survey	Rome–Naples	-	In general, car users are inflexible when it comes to HSR travel time and cost.
[65]	Fare, frequency, travel time	Regression models	-	Europe	-	The most critical variable in the battle between HSR and AT is travel/journey time.
[20]	Fare, distance, frequency, travel time	Multinomial and mixed logit models	SP	United Kingdom and France	-	The key determining elements in the competition between HSR and AT are travel time and service frequency.
[76]	Distance, access time, speed, fix cost, seat cost, GBT, VOT, Operating hours	-	-	China	-	Price and scheduling frequency are both treated as choice variables in a numerical study of China's markets.
[19]	Transit time. comfort, fix cost	-	Data	Spain	-	The extension of the high-speed rail has become a major competitor in the air radial and interior connections that run parallel to an AVE line, forcing airlines to employ smaller planes and even causing the cancellation of some routes.
[69]	Fare, distance, GDP	Econometric model	City-pairs and airfare monthly data	Europe	-	The price levels of the business and leisure segments are reduced as a result of rivalry between FSCs; the average fare decreases in the business and leisure classes are EUR 232 and 113, respectively.
[51]	Fare, distance, population, licence	Regression models (OLS)	route-year-quarter level	USA	-	New competition can be formed as a result of a merger, and the consequent fare reductions must be recorded to counteract the effects of lost competition.
[66]	Fare, frequency, transit time	Regression models	-	-	-	-

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[23]	Travel time, population, GDP, fuel process, density	Regression models (OLS)	Level year panel data (route)	Europe	-	Low-cost carriers have had a greater impact on expanding air travel, mainly through medium routes, which have seen a 50% decline in air traffic due to increased daily HSR trips.
[75]	Frequency, distance, transit time, population, GDP, number of ait transit, seat availability	Weighted CLAD	Level cross sectional data	Europe	-	With shorter HSR travel times, fewer air seats and frequencies are available. The impact of HSR journey time on air services is substantially greater than the impact of HSR frequency.
[22]	Fare, distance, seat cost, population, GDP	Multivariate econometric regression	Level year panel data (route)	Europe	-	HSR can provide feeding services to long-haul air services in hub airports, especially in hub airports with HRS stations, according to evidence.
[21]	Population, number passenger, number of air transfer, unemployment rate	Dynamic linear regression	Time series monthly data	Madrid–Barjas	-	The air transport mode accounted for only 13.9% of HSR passenger demand.
[39]	Fare, frequency, access time, egress time, travel time	Nested-logit model	SP	Japan	-	Even after the Linear Chuo Shinkansen commences service, the introduction of LCCs to/from Tokyo-Haneda airport will raise total aviation demand.
[21]	Population, number of passengers, number of ait transit, Unemployment rate	Dynamic linear regression	Time series monthly data	Spain	-	The air mode accounted for only 13.9% of HSR passenger demand.
[36]	Access time, egress time, travel time, income, trip purpose	Regression models	SP	Beijing-Guangzhou, China		The most critical aspect impacting the AH service's market share is the en route travel/journey time.
[40]	Distance, population, GDP, LCC	D-in-D estimator	Level year panel data (route)	China, Japan, South Korea	-	A more significant reduction in seat capacity for airlines in China than in Japan and Korea with the same high-speed rail service.
[7]	Frequency, travel cost, travel time, safety, free duty shopping area	Mixed logit model	SP	Seoul–Jeju, South Korea	-	Business travellers were more likely than leisure passengers to choose a safe method of transportation regardless of fee, whereas leisure passengers preferred to buy at duty-free shops.
[68]	Gender, age, travel time, number of cars, licence, income, occupancy, type of residence, number of elders and children, stay time, number traveling together	Logistic regression model	Collected data (RP)	Beijing	-	The logistic regression mode is outperformed by this cluster-based logistic regression model. It has a higher prediction accuracy for data, especially when it comes to forecasting the mode of transportation.

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[46]	Travel cost, travel time, on time delivery, percentage delay delivery	Multinomial logit and mixed logit	SP	Rio Grande do Sul, Brazil	-	Initiatives and investments to promote multimodality should place a premium on increasing the reliability of intermodal options and combining cost-cutting and reliability policies.
[2]	Fare, frequency, distance, travel time, population, GDP	Econometric models	Level year panel data (route)	China	-	In the fight between HSR and AT, fares play a crucial role.
[52]	Access time, egress time, travel time, service, GTB	Regression models	Data	Shanghai–Wuhan	830	When the hub airport is constrained in capacity and air–rail integration is not prohibitively expensive, reducing air–rail connection time improves societal welfare.
[74]	Fare, travel time	Demand functions	Observations on a monthly	Spain	-	Demand for air travel has decreased as a result of greater competition from high-speed rail.
[35]	Distance, population, GDP, OD contains a hub city	DID approach	Panel data	China	-	The effects are substantially more pronounced for air routes that connect large hubs within a distance of 500 to 800 km.
[18]	Fare, frequency, travel time, population, GDP	Regression models	Panel data	China	-	In general, the introduction of new HSR lines reduces air transport demand by 27%.
[70]	Travel time, safety	DID method	Panel data	China	-	The impact of HSR speed on airline traffic is greater than the impact of HSR speed on airline fare.
[41]	Fare, transit time, comfort	Binomial logit model	Survey	Tehran–Isfahan, Iran		The most crucial determinant in influencing the percentage of each mode is travel time, and which passengers are more sensitive to than the others.
[28]	Age, gender, education level, job, income, trip purpose, fare, travel time, mode to airport	Binomial logit model, logistic regression	SP	Jakarta–Surabaya, Indonesia	718	The amount of passengers' income is the most relevant passenger feature in this study.
[9]	Fare, frequency, distance, access time, population, GDP, average internet usage of arrival and departure city	D-in-D estimator	Level year panel data (route)	China	-	Due to an increase in the frequency of daily HSR journeys, shows a 50% drop in air travel.
[53]	Fare, travel time, population, GDP	Regression models (OLS)	Panel data	Beijing–Shanghai	-	Following the introduction of HSR, there was a lesser decline in both airfare and air travel demand on the routes served.
[54]	Fare, population, GDP, LCC	Regression models (OLS)	Panel data	China and Japan	-	As HSR connectivity or accessibility improves, airport domestic and overall traffic declines on average in China, but little changes in Japan.

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[12]	Distance, population, GDP	Regression models	Panel data	China	-	When the difference in in-vehicle travel time between HSR and air reduces, the impact of HSR entry increases at a faster pace for air passenger volumes.
[102]	Fare, travel time	Binomial logit model, regression	SP	Jakarta–Surabaya, Indonesia	718	The operation of the high-speed train between Jakarta and Surabaya has a negative influence on air transport demand, particularly for passenger planes.
[85]	Distance, population, income, number of passengers, number of air transits, tourist	The HHI and Lerner index	Paned data	China	-	The arrival of HSR reduced market power as measured by the Lerner indices, both unweighted and weighted.
[103]	Fare, frequency, access time, egress time, travel time	Multinomial distribution and full enumeration	SP	Lebanon	-	Modelling single trip/day decisions rather than weekly decisions would result in model estimates that were limited in terms of the full impact of the suggested policies over longer time periods.
[30]	Fare, frequency, traffic, profit, profit railway,	Regression models	Panel data	Paris–Marseille	-	The operation of the independently owned LCR has an impact on current rail, FSR and air traffic.
[55]	Fare, frequency, travel time, comfort	Regression models	Panel data	Beijing–Guangzhou		The method separates the market from the traveller's personal characteristics, allowing it to forecast the deep-level passenger flow structure.
[17]	Frequency, travel time, population, GDP, seat availability, welfare, route	Regression models (OLS)	Panel data	China	-	If the HSR travel time is more than 5 h greater than the air travel time, air traffic tends to grow.
[1]	Distance, gender, age, income, job, education level	Binary and multinomial logit	Survey	Chongqing, China	-	Reveals that the pricing, travel habits and amenities for long-distance trips are all important variables that prevent passengers from using the HSR system.
[25]	Frequency, distance	Econometric models	Panel data	China	-	Proposes that all types of carriers, particularly low-cost carriers (LCCs) and high-speed rail (HSR) operators, contribute effective competition to the aviation market by lowering airline profitability and airfares.
[104]	Travel cost, gender, age, travel time, number of cars, income, type of residence, education level, household type	Random forest technique and Bayesian network analysis	Survey	Malaysia	-	The researchers discovered the ten most important characteristics impacting university students' usage of ride-sharing for various travel objectives, as well as the most important predictors of ride-sharing use among students for school, shopping and leisure.

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[56]	Population, GDP	Regression models	Panel data	Beijing–Tianjin–Hebei	-	The centre city gains more from expanded air–HSR (high speed rail) intermodal connectivity because it may draw air passengers from nearby non-centre cities; therefore, improved intra-city-cluster rail connectivity worsens the air-connectivity gap inside the city cluster.
[42]	Fare, travel time	Binomial logit model (regression)	SP	Jakarta–Surabaya, Indonesia	718	The operation of the high-speed train between Jakarta and Surabaya would have a negative influence on the demand for executive train passengers.
[6]	Fare, distance, travel time, population, income, route	DID (Difference in Differences)	Survey	Japan	-	The effects of the HSR extension on FSC's airfares were consistently negative, with the negative effects being more pronounced in the short-haul sectors.
[105]	Access time, gender, age, travel time, number of cars, income, trip purpose, safety, job, access mode, departure mode, departure time, ticketing purchasing method	Bayesian binary logit	Survey	China	-	The intercity travel mode competition is influenced by factors such as travel distance, intercity travel cost, intercity travel time, safety, comfort, punctuality, access time and departure time.
[106]	Travel time, occupancy, flow	Neural network and binary logistic regression model	Panel data	Los Angeles and California		With a worldwide accuracy of 79.50%, the neural network model outperformed the binary logistic regression model in forecasting crashes.
[57]	Fare, frequency, distance	Regression models	Panel data	Shanghai and Beijing, China		It reduces HSR service frequencies, but it reduces HSR service frequencies with a short number of stops even more.
[67]	Fare, travel time	Logit model (regression models)	RP	Jakarta–Bandung, Indonesia	142	Passengers are transferred from the current train to the Jakarta–Bandung high-speed rail.
[47]	Fare, access time, travel time and frequency	MNL and NL logit models	SP	South Korea	-	When it comes to passenger choice, access time and travel time are quite essential.
[38]	Travel time, fare, comfort, and service delay	Nested logit model	SP and RP	Santiago–Conception (Chile)	434	In the rivalry between HSR and AT, reliability is the most crucial factor.
[107]	-	-	Survey	Paris–Lyons (France)	275	On the basis of surveys carried out both before and after its inauguration, a negative impact on AT demand was found.

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[48]	Time, frequency, first class fare, economy fare, discount economy, off peak, family discount	Multinomial logit model	SP	Sydney–Canberra (Australia)	247	The estimate derived from our data is 26% of diverted air transport traffic.
[49]	Total number of trips, travel time, cost, time interval (frequency), income, work trip, population, capital stock	Multinomial logit model	SP	Spain	-	Railways' market share will increase from 8.9% in 2000 to 22.8% in 2010, and HSR will be able to compete with AT over lengths greater than 500 km.
[108]	Cost, frequency, check-in, parking, mode airport (car)	Binomial and mixed logit models	SP and RP	Madrid –Barcelona (Spain)	625	The key determining variables in the competition between HSR and AT are fare pricing and service frequency.
[33]	-	-	Data	Wuhan–Guangzhou (China)	1069	HSR can reduce AT frequency by up to 32% on a daily basis.
[80]	-	-	Data	Europe and South Korea		Two–four years following the implementation of HSR, induced demand will be in the range of 10–20%.
[81]	-	-	Data	China		In China, HSR has the potential to reduce AT's market share for medium-haul travel.
[71]	Population, GDP, access, distance, number air passengers	D-in-D estimation	Level year panel data (route)	East Asian regions (Mainland China, Japan, South Korea and Taiwan)		In medium-haul routes, the substitution effect is most noticeable (between 500 and 1000 km).
[14]	Air passengers, train passengers, Iberia market share, distance	2SLS-IV	Level monthly panel data (route)	Spain	-	Shows that air operations are reduced by 17% due to the introduction of high-speed rail.
[77]	Distance, number of air passengers, frequency, population, GDP	FGLS with Lerner index	Level quarterly panel data (route)	China		The advent of HSR puts downward pressure on the airline Lerner index and yield by 15.5% and 14.6%, respectively.
[58]	Fare, market share, HHI, booking day, holiday	Regression-GLS	Level daily panel data (route)	Italy	-	On routes with less competition, air fares are higher; on routes with more competition, air fares are lower closer to departure date.
[59]	Market share, inter-modal competition, booking day, off-peak	Regression-GLS	Level daily panel data (route)	Italy	-	The Rome Fiumicino–Milan Linate route is 15.5% cheaper, and the Rome Fiumicino–Milan Linate route is 29% cheaper. HSR competition on the Milan–Malpensa route.
[60]	Fare, travel time, booking day, HHI	Regression-GLS	Level daily panel data (route)	Italy	-	Airlines can raise air fares by 3.9% due to a 10% increase in train journey time.

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[61]	Frequency, distance, population, GDP, HHI, airport access, tourism, road quality	-	Level monthly panel data (route)	Europe	-	Based on the full sample, HSR may exert positive pressure on airline flight frequencies, although no statistically significant influence was identified in subsamples of short-haul routes (less than 550 km).
[109]	Seat/flight, market size, distance, HHI	Regression models (OLS)	Level cross-sectional data (route)	World	-	There was no discernible effect of HSR on air passenger demand.
[44]	Frequency, transfer, Fare, distance	Nested logit model	Intercity travel survey	Japan	-	Only markets with a medium access/egress distance compete with air transport.
[45]	Fare, travel time, distance, frequency, the number of departures and total seat capacity	Nested logit model	SP	Tokyo–Osaka	503	The key determining elements in competitiveness are travel time, frequency of service and fare price.
[82]	In-vehicle time, access and exit time from/to the airport, reliability, price, frequency	Discrete choice	SP and RP	Bari–Rome and Brindisi–Rome	-	Found that air transportation (air-to-HSR) and conventional rail services are more likely to cause a demand shift (rail-to-HSR).
[21]	Fare, population, GDP, distance	Dynamic linear regression model	Panel data (route)	Spain	-	During the period 1999–2012, air travel accounted for only 13.9% of HSR passenger demand.
[62]	Passengers, frequency, GDP, population, pollution, speed, rail time	Regression models	Panel data	China	-	HSR travel time has a shock effect on flight transportation.
[12]	Population, GDP, distance	Regression models	Panel data	China	-	The inclusion of HSR reduces air passenger volume by 17.88% and flight frequency by 15.80%.
[14]	Air passengers, air operations, train passengers, distance, GDP	Regression models	Route-level data	Spain	-	The inclusion of HSR reduces air travel demand by 17%.
[63]	Travel time, daily departure options, fares, and the inconvenience associated with transferring at airports	Regression models	Survey	The Netherlands	-	There is a reduction in flight frequency due to HSR.
[31]	GDP, population, distance, administrative level	Regression models	Panel data OD	China	-	Cities that have HSR networks have very good activities when compared to cities that are only connected by air transportation.
[72]	Ticket price, travel time, frequency	Monte Carlo simulation	SP	Dallas and Houston, USA	-	Service frequency when choosing a means of transportation between Dallas and Houston is crucial.

Papers	Variables of Choice	Type of Model	Research Method	Case Study	Dist.	Results
[64]	GDP, population, industrial structure, distance, speed, LCC, HHI	Regression models	Panel data	China	-	Number of airline passengers declined by 29.84% for all market segments.
[83]	Launch, treatment route, accident	DID approach	Panel data	China	-	HSR as a low-end substitute for air travel in China.

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