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Some Critical Issues in the Development of Chinese High-Speed Rail: Challenges and Coping Strategies

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Abstract

In this paper, several critical issues related to Chinese high-speed rails (CHSR) are analyzed, investigated and discussed, including development background, reasons for high ticket fare, some typical factors that influence the environmental life-cycle assessment, time and cost comparison of typical door-to-door travel routes between different transport modes and complementary strategies among different transport modes. First, the results show that the expanding high-speed rail network increased the pressure on the country's roads in the 2010 spring festival rush period due to the high ticket fare of CHSR. Second, due to lower than expected ridership because of the high ticket price and limited demand in less developed areas, some Chinese CHSR projects have become economically unsustainable. Third, without sufficient ridership and service life, the utilization of HSR was unable to show any advantages in the environmental impact compared with the other transport modes. In addition, the impact of shock from CHSR on Chinese domestic civil airlines is evident when the travel distance is below 1050 km. The key objective of the investigation is to enhance our understanding of the development and operation of Chinese high-speed rail. One of the key contributions of the current paper is the presented suggestions for complementary strategies between different transport modes to make full use of Chinese transportation resources to promote low carbon economy.

Keywords

Chinese High-Speed Rails, Development, Cost, Time, Environmental Life-Cycle Assessment, Strategies

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1. Introduction

1.1 Development of Chinese High-Speed Rails (CHSR)

Chinese high-speed rail (CHSR) refers to any commercial train service in China with an average speed of 200 km/h or higher [1]. Its network consists of upgraded conventional rail lines, newly built high-speed passenger designated lines whose trains run on conventional standard gauge, and the magnetic levitation (maglev) lines whose trains run on special maglev tracks. The country is currently undergoing a high-speed rail (HSR) building boom, in which 17,000 km of high-speed lines are under construction [2]. It was estimated that the entire CHSR network would reach 13,073 km by the end of 2011 and 25,000 km by the end of 2015 [1] [3].

One of the main purposes of developing such an extensive CHSR project is to reduce the gap between the large social transportation demand and the relatively limited capacity of the railway network during holidays, especially the Chinese Spring Festival. The Spring Festival, which is also named Lunar New Year, is the most important traditional Chinese festival. Many Chinese people travel from their places of work and study to reunite with their families during this festival, resulting in the Spring Festival Travel Rush. According to the official press release, during the 40-day Spring Festival Travel period in 2010, approximately 640 million people were expected to join in the largest annual human migration in the world. Previous data showed that passenger journeys totaled 1.66 billion during the Spring Festival Travel period in 2001, 1.9 billion in 2005 and 2.2 billion in 2010 [4]. The railway network in China experiences the greatest challenge, as the capacity of the China railway system is far below the social transportation demand during this peak period. During the festival, it is often difficult to obtain train tickets and the trains are severely overloaded and crowded.

Three major reasons may explain this congestion. Firstly, China is the most populated country in the world. Its population has increased to approximately 1.34 billion, as estimated by the Chinese National Bureau of Statistics [5]. In addition, unbalanced regional development in China propels at least 200 million migrants every year to find jobs along the more prosperous area, causing the developed areas, such as Beijing and Shanghai, to become more crowded [6]. In addition, a predominant proportion of university resources are accumulated in developed areas, especially in Chinese super cities such as Beijing, Shanghai and Guangzhou. For example, it is estimated that six million newcomers, mostly migrant workers from elsewhere in China, have moved to Beijing in the past decade, increasing the population to 19.6 million [7]. Thirdly, reuniting with family members during Chinese Lunar New Year is one of the most typical traditions in Chinese culture. Every year, when Chinese New year is arriving, the Chinese transportation system must face the challenge of not only carrying millions of universities students and migrant workers back home from the developed areas but also ferrying them back from home when the festival ends. For all of the reasons stated above, the annual spring festival witnesses the largest annual human migration in the world.

To alleviate the traffic congestion by mobilizing people as quickly as possible, the need for high-speed rails in China has increased. Through six rounds of "speed-up" campaigns from April 1997 to April 2007, 7700 km of the existing tracks were upgraded to reach 160 km/h, 3002 km to reach 200 km/h and 423 km to reach 250 km/h [1]. In addition to these six "speed-up" campaigns, the government has also embarked on an ambitious CHSR expansion to build new passenger-dedicated high-speed rail lines. According to the Chinese Ministry of Railway "Mid-to-Long Term Railway Network Plan" (revised in 2008), the high-speed rail network is composed of eight high-speed rail corridors (four running north-south and four running east-west) and spans a total of 12,000 km. Most of the new lines are designated for passenger travel only, and the high-speed trains on them can generally reach 300 - 350 km/h. According to the plan, this ambitious national grid project will be completed by 2020, with a total investment of 300 billion US$ [1]. **Figure 1** presents a map of the projected high-speed rail network in China by 2020 and the travel time by rail from Beijing to each of the provincial capitals [8]. The figure shows that among the total thirty-one provincial capital (or municipality directly under central government) cities in Chinese mainland whose area is approximately 9.6 million square kilometers, if Beijing (Capital of China) is set as the center, twenty-seven cities are within the eight-hour travel distance through the high-speed rail network. In addition, with these eight-hour-distance cities, thirteen cities are within the four-hour-distance and seven are within the six-hour-distance.

1.2. New Problems on CHSR

Despite the improved capacity of the China railway system after 5149 km of high-speed rails were put into service in 2009, the rapidly expanding high-speed rail network increased the pressure on the country's

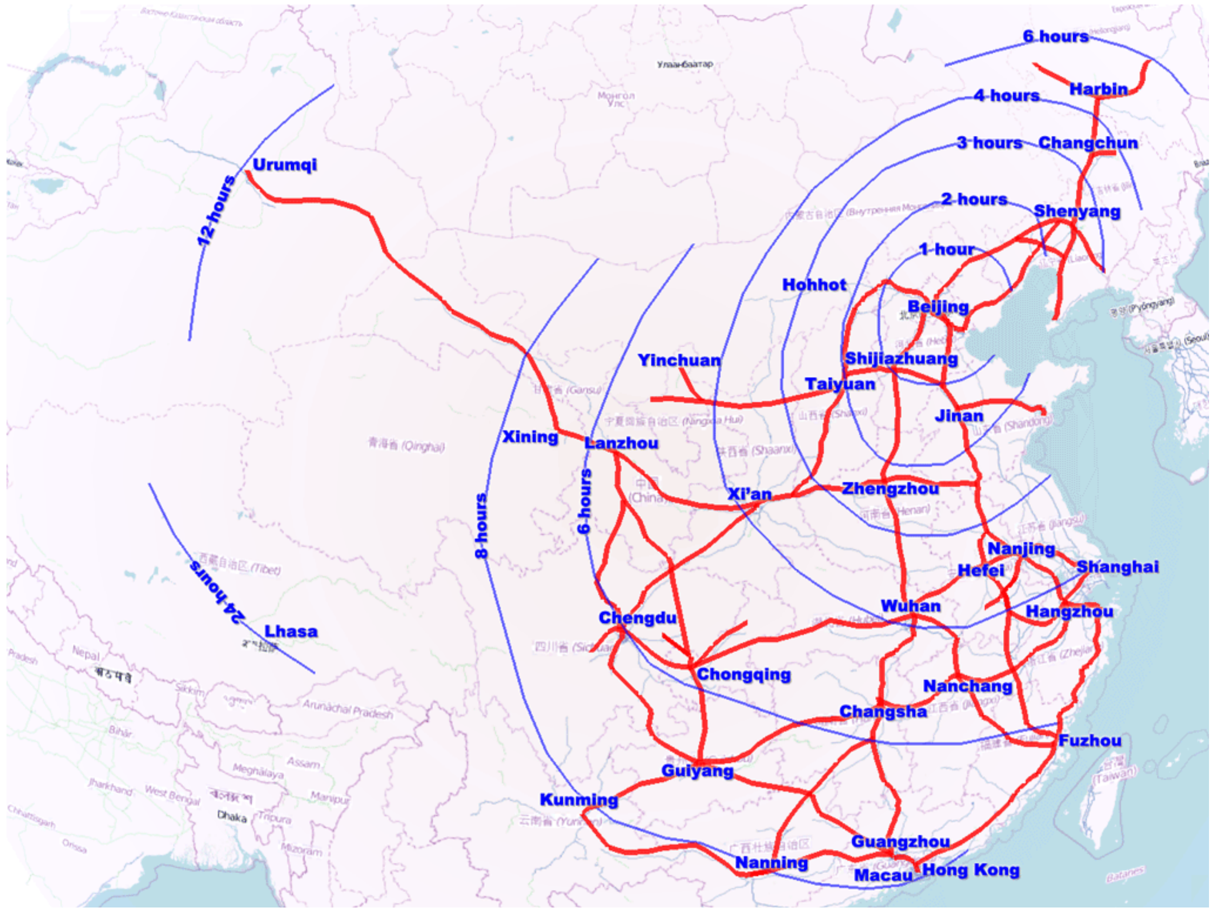

Figure 1. Projected high-speed rail network in China by 2020.

roads in the 2010 spring festival rush period [9]. This result is due to the high construction and operation cost of high-speed rails, which result in high ticket fares. For example, the fare of an ordinary sleeper service on high-speed rails between Shanghai and Chengdu costs up to 1,165 yuan ($181), whereas the fare of conventional trains only costs up to 467 yuan ($74) [10]. Consequently, the price of the high-speed rail is too high to be sustained. Thus, most passengers who earn a typical monthly salary choose conventional rails. Even those who can afford the cost may not believe that paying more than double the money is worth the saved few hours of time. Thus, the opening of high-speed train services has led to the decreased availability of conventional trains for budget-conscious passengers [9]. This has pushed many passengers who previously returned home by slow trains because of the cheap tickets onto long-distance buses.

Another example is the 10-day, 62-mile traffic jam in the northwest of Beijing in August 2010 [11] [12]. This traffic jam occurred on the Beijing-Tibet Expressway near Beijing and was caused by trucks carrying coal to Beijing. Unofficial sources claimed that each vehicle moved at the speed of 2 miles per day. The highway on which the jam occurred led to Inner Mongolia which is now the largest coal-producing province in China. Because passengers took political priority over coal, much of the coal was required to be transported by truck rather than freight trains. This situation led to the monumental traffic jam. The original goal of the high-speed rail network is to get the passengers off the conventional rails and allow freight trains to get coal and other freight off the highways. However, the high-speed rail fares are so high that ridership is low and the vast majority of rail riders utilize the conventional trains or road transport. This leads to a surplus of passenger capacity without alleviating the shortage of freight capacity.

While pushing some budget-conscious passengers to road transport, the high-speed railways have also split the market share of medium-or-short distance travel from airlines. For example, the Wuhan-Guangzhou high-speed railway (WG HSR) via Changsha has ferried 20.6 million passengers in the year since its opening in

December 2009 [13]. During that period, the number of flights between Changsha and Guangzhou (746 km) was cut from an average of 11.5 to five flights per day [14].

1.3. Article Structure

From the examples stated above, it is obvious that CHSR expansion can increase the railway transport volume and mobilize passengers more quickly. However, this expansion is unable to alleviate the burden of road transport due to the unaffordable CHSR fares for most of the budget-conscious conventional rail riders. Even worse, the burden will become more serious if the frequency of the conventional rails is decreased due to the operation of CHSR. Because the CHSR transport mode is unable to alleviate the traffic congestion encountered in China due to its high ticket fare, it is necessary to investigate feasible measures or alternative transport modes that may solve this puzzle. First, the reasons for the high ticket fares of CHSR are discussed in the second section. In the third section, the environmental impacts of different transportation modes are discussed. In the fourth section, typical door-to-door travel routes are selected to compare time and cost between the CHSR transport mode and air transportation mode. In the fifth section, complementary strategies between the air and CHSR transportation modes are put forward.

2. Reasons for the High Ticket Fare of CHSR

2.1. HSR Cost Structure

The CHSR cost structure includes internal and external costs. The internal costs are mainly divided into three types, HSR infrastructure constructing costs, operation costs and maintenance costs. According to Campos [15], the construction of new CHSR infrastructure involves three types of costs, planning and land costs, Infrastructure building costs and superstructures costs. Infrastructure building costs refer to all costs related to terrain preparation and platform building. Typically, this cost is approximately 10% - 25% of the total investment of infrastructure constructing costs. However, this amount may easily increase if a specific solution (such as viaducts, tunnels and bridges) is adopted to overcome the specified geographic obstacles. Superstructures costs include high-speed rail-specific elements such as electrification mechanisms, signaling systems, communications and safety installations, etc.

The HSR operation cost involves two parts. The first part refers to the purchasing cost of the rolling stocks and trains utilized. The second part includes costs of the labor, energy and other material consumed by the day-to-day operations of the guide ways, rolling stock and equipment, terminals and stations, ticket sales systems, signaling systems, traffic management and safety systems. The HSR maintenance costs refer to the maintenance costs of HSR infrastructure and rolling stocks, including labor cost and costs of energy and material consumption.

2.2. Large Investment in CHSR and the Resultant High Debt

On average, the per-kilometer infrastructure building costs of a high-speed line with a designed speed of 300 km per hour is approximately three times higher than a conventional railway line in China [16]. The price of a high-speed train that is capable of carrying 1200 people costs approximately five times more than a conventional train. For example, the actual total infrastructure building investment of the Beijing-Tianjin intercity high-speed line with a range of 113.54 kilometers is 20.6 billion RMB (3.21 billion US$), which is 8.3 billion RMB (1.3 billion US$) more than the total budget [17] [18]. The total investment of the Wuhan-Guangzhou high-speed line with a range of 1068 kilometers is also 27 billion RMB (4.2 billion US$) beyond the budget, reaching 120 billion RMB (18.75 billion US$) [19] [20].

To support the CHSR rail infrastructure, the total amount of debt held by the Chinese Ministry of Railways reached 1.8 trillion RMB (0.28 trillion US$) in 2011. According to the report of China Minsheng Bank Corp., Ltd., the peak period for the Chinese Ministry of Railways to repay the loan and interest is in 2014 [20]. It is estimated that the necessary paid interest alone will reach 100 billion RMB per year.

2.3. Inadequate Ridership due to the High Ticket Fare and Redundant Construction in CHSR

To break the cost even, high ticket fares and high ridership are essential. The most crowded CHSR, Wuhan-Guangzhou (WG CHSR) intercity line, can be used as an example. According to the feasibility report, given that the ticket fare is invariable, at least an 8% continuous increase in ridership per year is needed to recover the total cost in ten years [21]. The real case is that in 2010, the number of the passenger trip through WG CHSR reached 20.58 million. Correspondingly, its 5.2 billion RMB total revenue paid for the loan interest (2.6 billion RMB) and CHSR agency expenses (2.6 billion RMB) [22], however, this income was unable to cover the fee for the entire year's equipment amortization (3 billion RMB). However, the ridership of the other two routes, Zhengzhou-Xi'an (ZX) and Shijiazhuang-Taiyuan (ST), is not as optimistic. It is reported that due to the limited ridership, only eleven pairs of bulletin trains per day are operated in the ZX CHSR, whose maximum transport volume can allow one hundred and sixty pairs to operate through it per day [21] [23]. Therefore, this poor revenue of ZX and ST CHSR was unable to cover the loan interests, let alone the other fees such as agency expenses and the equipment amortization. The difference between the WG and ZX and ST CHSR lies in the different level of regional economy where these lines travel through. ZX CHSR travels through Henan, Shaanxi and ST CHSR via Hebei and Shanxi, whereas WG CHSR travels via Guangdong, Hunan and Hubei. The economic gross of provinces such as Henan, Shaanxi, Hebei and Shanxi is far lower than that of provinces such as Guangdong.

Redundant construction in CHSR projects is another critical factor that limits the increase of ridership on existing CHSR lines in the long run, making it more difficult to recover the costs. For example, as shown in the map in **Figure 2** [23], Tianjin and Nang jing are the two cities that the Beijing-Shanghai (Jing-Hu) CHSR passes.

Figure 2. Sketch map of redundant construction on Beijing-Shanghai (Jing-Hu) CHSR (WR21).

Therefore, to make full use of the existing resources, a high-speed line should have been built to connect Tianjin and Nanjin after the Beijing-Tianjin (Jing-Jin) CHSR and Shanghai-Nanjin (Hu-Ning) CHSR were constructed. In this way, the Jing-Hu CHSR could share Jing-Jin and Hu-Ning CHSR, which could save the repeated construction cost approximately 64.7 billion RMB. Ironically, the Beijing-Shang CHSR was planned and constructed separately, overlooking the existence of Jing-Jin CHSR and Hu-Ning CHSR. The consequence is that the ridership of Jing-Jin CHSR was diverted by Jing-Hu CHSR because passengers can either travel from Beijing to Tianjin through the one-stop Jing-Jin CHSR or travel through Jing-Hu CHSR and get off at the Tianjin station. Similarly, the ridership of Hu-Ning CHSR was affected by Jing-Hu CHSR. Thus, the repeated construction in some part of Jing-Hu CHSR not only costs more in infrastructure investment but also pushes the three high-speed rails stated above into cut-throat competition.

In conclusion, ridership is the essential factor that determines whether the CHSR is economically sustainable. The high costs of infrastructure construction, operation and maintenance fees urge the Chinese Rail Ministry to implement a high ticket fare strategy. However, lower than expected ridership due to the high ticket price and limited demand in less developed areas has made some CHSR projects economically unsustainable.

3. Factors Influencing Environmental Life-cycle Assessment of Different Transport Modes

3.1. The Influence of Ridership on Environmental Life-Cycle Assessment

Automobiles, conventional trains, high-speed trains and civil aircrafts are the four common transport modes for domestic city-to-city travel. Concerning the advantages and disadvantages of these modes, in addition to internal cost such as building, operation and maintenance cost, external cost is an essential criterion in providing a fair appraisal. External cost, also named environmental cost, includes energy consumption, air pollution harmful to human health and emission contributing to global warming, land take, barrier effects, visual intrusion, noise, etc. [15]. Taking the California corridors as references, Chester made a life-cycle environmental assessment of these four modes, including energy consumption, greenhouse gas emissions, SO_2 (sulfur dioxide), CO (carbon monoxide), NOX (Nitrogen oxide), VOC (volatile organic compound), and PM10 (particulate matter < 10 micrometers). **Table 1** presents the Per-PKT (Passenger Kilometer Traveled) end-use energy of different transport modes [24]. As shown in the table, for each transport mode, the Per-PKT end-use energy consumption varies inversely with the increase of occupancy. At high occupancy, the Per-PKT energy is at its lowest because the environmental performance is distributed over a large number of passengers. With the same occupancy, the high-speed rail has the potential to be the lowest energy consumer, compared with automobiles and civil aircrafts. However, this result may be reversed when the high-speed rail has a lower occupancy (20%) (due to its poor ridership) than the other transport modes (50%). As an example, due to its acute ridership shortage, only eleven pairs of bulletin trains per day are currently operating on the ZX CHSR line, which can allow one hundred and sixty pairs to operate through it per day. Thus, only 6.84% of the total transport volume is utilized in the typical period excluding Chinese traditional festivals. Therefore, at least in the short term, it does not show competitive advantages in environment impact compared to the other modes. It is essential to make a reasonable prediction of the ridership prior to mass CHSR investment along the specified routes to lower the rail's impact on the environment.

3.2. The Influence of HSR Service Life on Environmental Life-Cycle Assessment

In addition to the ridership, service life is an important factor in assessing the life-cycle environment im-pact. As the service life of a transport mode increases, the mode's impact on the environment decreases. Con

Table 1. The Per-PKT End-Use Energy Consumption at Different Occupancy (MJ/PKT).

Transport Modes	At Low Occupancy (20%)	At Middle Occupancy (50%)	At High Occupancy (100%)
High-Speed Rail	3.55	1.42	0.71
Conventional Trains	3.60	1.44	0.72
Automobiles	4.20	1.68	0.84
Civil Aircrafts	7.30	2.92	1.46

cerning the HSR infrastructure, land subsidence is one of the main factors in shortening its service life. For example, due to the over-pumping of underground water, the Taiwan high-speed rail (THSR) route between Yunlin county and Changhua county is now suffering from land subsidence [25], with the speed of around eight centimeters per year. As reported by Taiwan civil engineering official Li Hongyuan, the service life of THSR would reduce to less than ten years without effective rescue measures, which would aggravate its life-cycle environment impact.

Another example of the negative effect of land subsidence is Chinese Shijiazhuang-Taiyuan CHSR [26]. Due to the unresolved technical issues concerning the land subsidence, this line must now stop delivering four thousand tons of coal every year and plan to carry both high-speed passenger trains and freight trains. Thus, the limited utilization of Shi-Tai line also aggravates its environment cost.

4. Time and Cost Comparison between Different Transport Modes in Typical Door-to-Door Travel Routes

4.1 Time and Cost Comparison between Conventional Rail and CHSR in Typical Door-to-Door Travel Routes

The impact of CHSR on conventional rail and medium/long-distance coaches is minor because most of the Chinese budget-conscious passengers are reluctant to pay the high ticket fare of CHSR. The night conventional train services with hard sleeper facilities seem to be more competitive than the high-speed train service because the former can save the passenger the hotel charge for one night. For example, if a manger plans to travel by train from Beijing to the capital city Liaoning Province Shenyang (distance 705 km) and attend the next day's business conference, two types of train services are available, the conventional train service and the high-speed train service. The former service is the one-night train service that departs at ten p.m. and arrives at eight a.m. the next day. The hard sleeper ticket fare for this service is 183 RMB. The latter service is the high-speed train service that departs at six pm and arrives at eleven pm. The typical seat ticket fare for this service is 217 RMB. Overall, the one-night conventional train service is more economical because it can not only reduce the ticket cost but also save the passenger the hotel rate for one night.

4.2. Time and Cost Comparison between Air and CHSR in Typical Door-to-Door Travel Routes

The shock from CHSR on Chinese domestic civil airlines is evident, as a large portion of the CHSR ridership is diverted from the domestic air routes. The factors that lead passengers to switch from air to CHSR include cost, time, comfort, accessibility and convenience. To analyze the impact of these factors on the competing relationship between CHSR and Chinese domestic civil airlines, two typical door-to door routes are selected as examples. In one example, a traveler is planning a journey from Wuhan City Center-Donghu CBD to Guangzhou City Center-Beijing Road, whose distance is approximately 1069 km. Two major travel modes, by CHSR or by air, are available. Before calculating and comparing the total time and cost resulting from the choice of different transport modes, several assumptions and definitions are made, as below:

1) To complete this door-to door journey, the total time is divided into five segments, in which Time A defines the access time from the city center to CHSR station (airport), Time B defines the average boarding time, Time C defines the time in vehicle, Time D defines the time for baggage claim, and Time E defines the egress time from CHSR station (airport) to the city center.

2) Circumstances such as delay and traffic congestion are neglected.

3) Taxi was chosen as the transport mode between the city center and CHSR station (airport), whose time and cost during access and egress was estimated through the following website: http://ditu.baidu.com.

4) In **Table 2**, surplus fees include an airport construction fee and bunker surcharge.

The time and cost comparison for this journey is shown in **Table 2** and **Table 3**, respectively [14] [27] [28]. Of note, the boarding time of air travel mode includes the time for security check and to check in luggage. On average, this time costs between one hour and one hour and thirty minutes for typical passengers (not for VIP passengers). **Table 2** shows that although the time in-flight only costs one hour and thirty-five minutes, the least total saving time for the air travel mode is minor (only approximately twelve minutes). On the other side, as shown in table 3, the total fare of the air travel mode costs nearly twice the price of CHSR travel. To offer an

Table 2. Journey time comparison (From Donghu CBD, Wuhang to Beijing Road, Guangzhou).

Travel Mode	Time A	Time B	Time C	Time D	Time E	Total Time
By CHSR	43 m	30 m	3 h 16 m	0	1 h 11 m	5 h 40 m
By Air	1 h 12 m	40 m - 1 h 30 m	1 h 35 m	0 - 20 m	51 m	4 h 18 m - 5 h 28 m

Table 3. Journey fare comparison (From Donghu CBD, Wuhang to Beijing Road, Guangzhou).

Travel Mode	Ticket fare (Economic Class)	Surplus Fee*	Taxi Fee	Total Fee
By CHSR	75.38 (US$)	0	19 (US$)	94.38 (US$)
By Air	132.3 (US$)	24.7(US$)	24.6 (US$)	181.6 (US$)

equal total fare with the mode of CHSR travel, the air ticket fare must reduce to 35% of the original price, from 75.38 US$ to 45.08 US$, which seems to be unacceptable to the airlines in the long term. Therefore, anticipating the strong competition from Wuhan-Guangzhou CHSR, the number of flights between these two cities has decreased from more than twenty to nine per day and the average air ticket fare is only 40% of the original price [28].

A second example is a journey from Beijing City Center, Tian'anmen Square to Shanghai City Center, The bund, with the distance of approximately 1318 km. The time and cost comparisons between the air and CHSR modes are shown in **Table 4** and **Table 5**, respectively. As shown in **Table 4**, the total journey time of the CHSR mode is between six hours and two minutes and six hours and sixty-four minutes, whereas that of the air mode is between four hours and nineteen minutes and five hours and twenty-nine minutes. Thus, the least time-saving of the air mode is thirty-four minutes. If a passenger can check in online and does not need to check in luggage, the total save time can be reduced to two hours and twenty-five minutes. However, the total fare of the air mode is 227.4 US$, which is more than twice the fare of the CHSR mode. Thus, it can be concluded that the ridership diverted from the air mode to the Beijing-Shanghai route CHSR mode is likely primarily due to leisure trips because for most Chinese middle class travelers, saving half of the cost by choosing the CHSR mode is more attractive than saving a few hours by choosing the air mode. However, the business trip market share owned by the air mode is not easily diverted by the CHSR mode. This is because for the business travelers whose fare is paid by enterprises, the time saving and services provided by the air mode are more attracted than the CHSR mode.

In addition to time and cost, the factors that affect passengers' choice between these two modes include comfort, convenience, etc. Concerning the comparison of comfort, the advantage of the air mode includes considerate in-flight service, less in-vehicle time, free meals and drinks and entertainment (free film and music). The advantages of the CHSR mode include wider seat space, more space for carry-on luggage, and no prohibition in cell phone and lap computer use during the entire in-vehicle time. Concerning the convenience, the influence factors include the daily frequency of trains and flights, frequency of delay, and access and egress between the airport or HSR station and downtown. Because a large proportion of the CHSR stations are constructed at peripheral areas to boost the economic development of city outskirts, access and egress between the HSR station and city center are not convenient. The ridership of HSR will be affected unless massive transit systems, such as underground systems, are constructed and conveniently connected between the downtown and CHSR station. In Chinese first-tier cities such as Beijing and some second-tier cities such as Xi'an, a seamless joint between underground and CHSR has become a reality. However, in some second-tier cities such as Suzhou and most third-tier cities such as Yueyang and Taian, there are no plans to build transit systems to connect downtown areas and CHSR in the short term.

In conclusion, the impact of CHSR on air is dependent on the travel distance. Within the distance of 750 kilometers, the CHSR mode has overwhelming advantages compared to the air mode due to its relative lower ticket fare and relative minor increase in total journey time. This has been verified by the fact that the number of flights between Changsha and Guangzhou (746 km) has been cut from an average of 11.5 to five flights per day one year after CHSR began operating along this route [15]. When the travel distance is between 750 and 1050 kilometers, the shock of CHSR on air travel is evident. At least half of the market share of air travel will be diverted by CHSR unless a deep discount of air ticket is made and good time performance is ensured, which is also verified by the CHSR Wuhan-Guangzhou line (1069 km). When the distance is above one thousand and

Table 4. Journey time comparison (From Tian'anmen Square, Beijing to The bund, Shanghai).

Type	Time A	Time B	Time C	Time D	Time E	Total
By CHSR	24 m	30 m	4 h 48 m - 5 h 30 m	0	20 m	6 h 02 m - 6 h 44 m
BY Air	54 m	40 m - 1 h 30 m	2 h 10 m	0 - 20 m	35 m	4 h 19 m - 5 h 29 m

Table 5. Journey fare comparison (From Tian'anmen Square, Beijing to The bund, Shanghai).

Type	Ticket fare (Economic Class)	Surplus Fee*	Taxi Fee	Total Fare
By CHSR	86.7(US$)	0	16.9(US$)	103.2(US$)
By Air	180(US$)	24.7(US$)	22.7(US$)	227.4(US$)

one hundred kilometers, the time saving of the air mode is evident if passengers check in online with no delay or check-in luggage. In this case, the impact of CHSR on the business-trip market share of air travel is limited due to the valuable time cost. However, the leisure-trip market share of air remains diverted by CHSR due to its relatively lower ticket fare.

5. Complementary Strategies between the Air and CHSR Transportation Mode

To make full use of the transportation resources to promote low carbon economy, the relationship between the CHSR and air mode should be not only competition but also complementary [29]. To implement complementary strategies between these two modes, several measures can be taken, as follows:

1) Precise and comprehensive ridership forecast of CHSR in a specified route should be conducted by the government prior to investing in the construction of a new CHSR infrastructure. As stated by Section 3, with poor ridership, the HSR mode is unsustainable in both economy and environment. Such poor ridership may occur in Chinese western sparsely populated areas. Thus, the market share of these areas should belong to the low cost regional air mode transportation rather than the CHSR mode to avoid cut-throat competition.

2) The newly built CHSR station should be located near the airport or at a location with easy access to the airport through the public transit system, which can contribute to integrating the CHSR network with the air network for seamless transfer conjunction. One example of the advantage of this measure is that travelers can conveniently make the best use of both the short-distance advantage of the HSR mode and the long-distance advantage of the air mode when planning a journey, inducing more ridership for both of these modes.

3) By developing an air-rail combined transportation network, airport resources between the nearby cities could be shared to alleviate air traffic congestion during taking off and landing in Chinese mega cities such as Beijing, Shanghai and Guangzhou, which is helpful in reducing flight delays. For example, it is reported the total passenger trip of Beijing International Airport is expected to exceed its design capacity in 2012. To avoid air traffic jams in Beijing after 2012, some flights can be arranged to land in the Binhai Airport, which is located in the nearby city of Tianjin, and then send the passengers to Beijing downtown via the Beijing-Tianjin CHSR.

6. Summaries and Conclusions

In this paper, several critical issues related to Chinese high-speed rails were analyzed, investigated and discussed, including the following:

1) Development background—a high-speed rail building boom is occurring in China to alleviate the traffic congestion by mobilizing people as quickly as possible. This system is also expected to get passengers off the conventional rails and allow more freight trains on these rails. However, these goals were not reached due to the high ticket fare.

2) Reasons for high ticket fare—large investment in CHSR and the resultant high debt have urged the Chinese Rail Ministry to implement a high ticket fare strategy. However, due to lower than expected ridership because of the high ticket price and limited demand in less developed areas, some Chinese CHSR projects have become economically unsustainable.

3) Without sufficient ridership and service life, the utilization of HSR is unable to show any advantages in the environment impact compared with the other transport modes.

4) Time and cost comparison of typical door-to-door travel routes between the transport modes—the calculated results and the released data both show that the preferred distance for CHSR is less than 750 kilometers.

When the travel distance is between 750 and 1050 kilometers, the shock of CHSR on air travel is evident. At least half of the market share of air travel will be diverted by CHSR unless a deep discount for air tickets is made and good time performance is ensured. When the distance is above 1050 kilometers, the time saving of the air mode is evident. Such time saving is evident if passengers check in online without delay or check-in luggage.

5) Complementary strategies between the air and CHSR modes were put forward to avoid cut-throat competition between the two modes, induce more ridership for both modes and alleviate air traffic congestion.

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