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Impact of high speed railway on logistical competitiveness of civil aviation in China

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Abstract: With the rapid expansion of high speed railway in China, railways gradually speed up and bridge the speed gap between railway and civil aviation, thus, impose great impact on the logistical competitiveness of civil aviation. The paper applies transportation travel distance equilibrium model and finds out that high speed railways increase its competitive distance up to 1000 kilometers and gains competitive edge in passenger transportation market; as to freight, Chinese railway can drive civil aviation out within 800 kilometers. We use Logit model and made empirical study and result shows that civil aviation market share is inversely proportional to travelling distance, and 78.10 million passengers will turn to railways rather than choose civil aviation. In the face of severe competition from railways, Chinese civil aviation has to take firm measures to counterbalance the impact of high speed railways in logistical marketplace.

Keywords: High Speed Railway, Logistical Competeiveness, Civil Aviation.

1. Introduction

By the end of 2009, China's railway length reached 86000 kms. In 2009, total investment was a record of RMB770 billion ($113.24 billion, $1=RMB6.8), which is 80.3% of the total investment from 1995-2005, and 169.1% of that of 2008. Length of Dedicated Passenger Line (DPL) or High Speed Railway (HSR) in operation is 3,459.4 km, of which, 2,318.9 km put into service in 2009.

By September, 2010, the total length of HSR reached a historical record of 7055 kilometers (including upgradedexisting lines) and ranked no.1 in the world.

With the implementation of "Long and Medium Term Railway Network Plan", by the year 2012, the DPL network will be at least over 13000 kilometers and connect cities with over 500000 population.

On August, 1st, 2008, with the maximum operational speed of 350 km/h, Beijing-Tianjin intercity railway was put into operation just before the opening ceremony of 2008 Beijing Olympic Games, thereafter, numbers of DPL were put into operation, see Table 1.

Table 1: High speed railway lines in operation.

No	HSR	Date in operation	Length(km)
1	Hefei-Nanjing	2008.4.18	166
2	Jinan-Qingdao	2008.7.20	362.5
3	Beijing-Tianjin	2008.8.1	117
4	Hefei-Wuhan	2009.4.1	364
5	Shijiazhuang-Taiyuan	2009.4.1	189.93
6	Hangzhou-Wenzhou	2009.9.28	268
7	Wenzhou-Fuzhou	2009.9.28	320.97
8	Wuhan-Guangzhou	2009.12.26	1068.6
9	Zhengzhou-Xi'an	2010.2.6	458
10	Nanjing-Shanghai	2010.7.1	300.329
11	Shanghai-Hangzhou	2010.10.20	160
Total			3775.329

On average, there are 558 pairs of high speed training running on railway network, 888000 persons were sent out each day. By 2020, the total length of DPL will be over 17000 kilometers, and the total length of railway will be more than 120000 kilometers, see Figure 1.

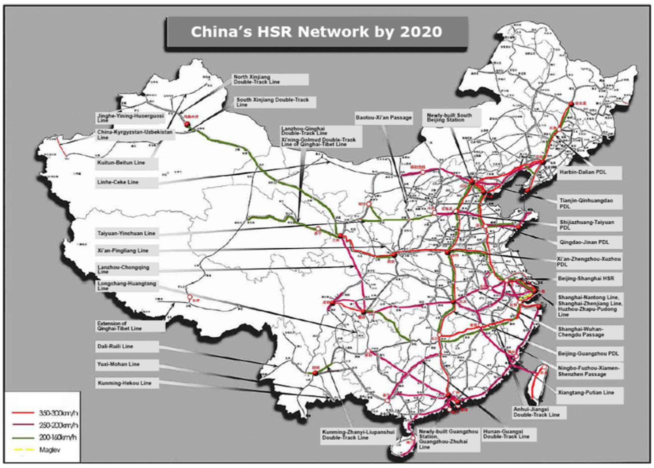

Fig. 1: Long and medium term DPL plan by 2020.

With the expansion of high speed railways, Chinese railways will speed up, and gain significant competitive edge in passenger and freight marketplace, what kind of impact will high speed railway exert on civil aviation, and how can civil aviation take measures to counterbalance HSR in logistical marketplace?

2. Literature Review

It's obvious that transportation cost accounts for a big proportion of the total logistical costs in China, and the proportion is in a rising tendency, see Figure 2.

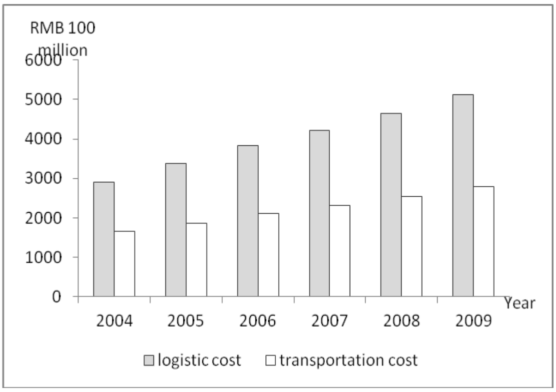

Fig. 2: Logistic cost for China.

Since China depends a lot on transportation to realize passenger and cargo spatial movement, some scholars (Li, et al., 2008) argue that China should reduce transportation cost to improve logistic efficiency.

It's very important for transportation sectors to save travel time, improve the quality of transportation product and provide just-in-time logistic service. Boyce (1997), Burns (2010), and ChaoheRong (2010) stressed the importance of punctuality and speed on see Figure 3.

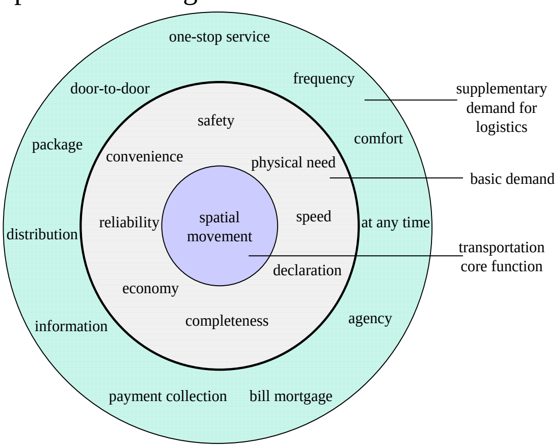

Fig. 3: The importance of speed for transportation product.

From Figure 3, we can see that transportation product has three layers, say, transportation core function, basic demand and supplementary demand for logistics, of which, speed and punctuality plays a key role in improving transportation quality. For example, China Railway Express (CRE) operates high speed parcel and postal services with fixed time, price, route and location that can greatly satisfy market demand and contribute to the rapid growth in express mail business.

If other factors are constant, travel time will be prominent in determining people's transportation choice. However, the neo-classical economics almost neglects the factor of time saving and therefore, time is excluded from utility function. Becker (1965) published an article by the name of time allocation theory, for the first time, time factor was incorporated into the budget constraint and utility function. Transportation is one of the few sectors attaching importance to time value. In competitiveness evaluation and logistical supply chain management, we have to appraise the impact of time saving. Therefore, some scholars further study the impact of time factor on consumer's utility, and others put forward quantitative method to make study on consumer's demand function and transportation mode choice. James McFadden, winner of 2000 Nobel Prize in economics, by adopting stated preference or stated choice methods, puts quantitative models such as polynomial Logit model into use to study traffic flow allocation.

As to the competition between aviation and railways, four phase model is frequently used to estimate market share allocation. However, regression model (Abrahams, 1983; Thune-Larsen, 1989), time serial model (Grubb & Mason, 2001; Profillidis, 2000) are the most widely used models in transportation competitiveness study.

In this paper, the authors apply transportation time equilibrium model to study the competitive distance for passenger and freight between HSR and civil aviation. Simultaneously, we also use Logit model to estimate the market, especially passenger transportation demand allocation. Statistics show that for 2008, 192.51 million passengers were transported by civil aviation, 3.6% increase compared with that of 2007. As for freight, there is only 4.08 million tons cargo for 2008, 1.4% growth in contrast to that of 2007. Therefore, this paper focuses mainly on passenger logistics rather than freight.

3. Modeling for Logistical Competitiveness and Empirical Study

We first set up a model to modulate the relationship between HSR and civil aviation from time saving perspective. Then, use the basic figures to estimate distance segment market.

3.1. Transportation Travel Distance Equilibrium

Transportation economics classifies transportation travel time into 4 periods, that is, (1) Period 1, from home to the place where you take the trains or aviation. (2) Period 2, waiting time, passengers or shippers have to wait in advance. (3) Period 3, journey on movable transportation tools like train, plane, car, bus or ship. (4) Period 4, from destination to your final place. We indicate the above 5 periods as follows:

$$T=T1+T2+T3+T4 \qquad (1)$$

Of which, T stands for total travel time, T1 is period 1, T2 period 2, T3 period 3, T4 period 4.

Let:

$$TOD=T1+T4 \qquad (2)$$

$$TW=T2 \qquad (3)$$

$$TJ=T3 \qquad (4)$$

TOD is the time spent from home to destination and from destination to home, TW is the waiting time, and TJ is the travel time on journey.

For railways, the total travel time is:

$$TR=TR1+TR2+TR3+TR4=TROD+TRW+TRJ \qquad (5)$$

For civil aviation, the total travel time is:

$$TA=TA1+TA2+TA3+TA4=TAOD+TAW+TAJ \qquad (6)$$

Generally speaking, trains run at a lower speed than airplane, however, the waiting time and OD time are higher than that of railways. Thus, within a certain distance, railway has comparative advantage to provide logistical service than airplane. After a certain threshold, airplane will have absolute advantage.

Let:

$$TR\text{-}TA = (TR1\text{-}TA1) + (TR2\text{-}TA2) + (TR3\text{-}TA3) + (TR4\text{-}TA4)$$
$$= (TROD\text{-}TAOD) + (TRW\text{-}TAW) + (TRJ\text{-}TAJ) \; (7)$$

Of which, TROD-TAOD is the time difference for OD transportation. Since railway station locates at metropolitan area while airport is far away from downtown, generally speaking, $TROD<TAOD$. TRW-TAW is the time difference for waiting time. Since passengers or shippers can go to railway station later than airport because the latter needs more time to go through security check and custom procedures, therefore, in a general way, $TRW<TAW$. TRJ-TAJ is the time difference for journey time. Since airplane travels faster than train, in general, $TRJ>TA$.

Thus, time saving for railway △T can be denoted as:

$$\Delta T = (TROD\text{-}TAOD) + (TRW\text{-}TAW) \qquad (8)$$

If the distance between point A and B is L, and the speed for railway is VR, for aviation VA, then journey time for railway and aviation are:

$$TRJ=L/\ VR \qquad (9)$$

$$TRA=L/\ VA \qquad (10)$$

Let:

$$\Delta T + L/VR=L/\ VA \qquad (11)$$

Then, we get the travel distance equilibrium formula as follows:

$$L^* = (\Delta T\times VR\times VA)/(VA\text{-}VR) \quad (12)$$

3.2. Empirical Study on Logistical Competitiveness

For most HSR lines, the designed speed is always 300 km/h or above. For example, Beijing-Tianjin intercity railway runs at 300 km/h. For Beijing-Shanghai HSR, the experimental operational speed hit a historical record of 486.1 km/h. For Shanghai-Hangzhou DPL, the maximum running speed achieved 416.6 km/h. For airplanes, we adopt 600 km/h, 800 km/h and 1000 km/h respectively. In the mass, 800 km/h is the ordinary speed. We substitute relative figures into formula (12). Then, we get the competitive distance for railway and aviation from temporal perspective.

3.3. Passenger Market Logistical Competence

We assume that origin to station time is 1 hours, waiting time for train 20 min, plane 1.5 hour, station to destination 30 minutes, and the speed for car is 80 km/h, the speed for airplane 1000 km/h. Then we can simulate the competitive advantage, see Figure 4.

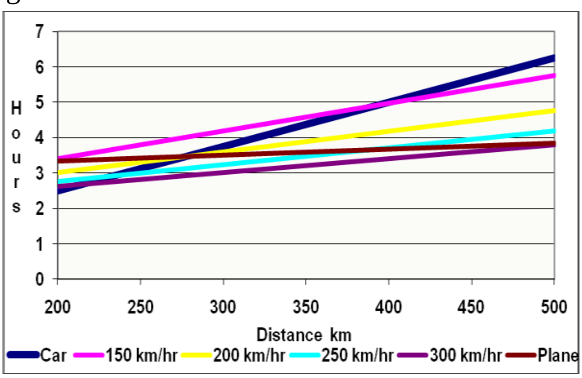

Fig. 4: Competitiveness advantage simulation.

We substitute figures in formula (12), then:

$$L^* = (\Delta T\times VR\times VA)/(VA-VR)=(1.17\times 300*1000)/(1000-300)=500 \qquad (13)$$

However, for Chinese railways, the ∆T can be 2 hours, and average operational speed for aviation can be 800 km/h, then we can get the L* as 960 kilometers.

If we take the real condition into consideration, we can find out railway can save more time from origination to destination, and spend less time waiting at railway station that airport. Thus, it's safe to justify that railway has comparative advantage within 1000 kilometers in passenger logistical marketplace.

3.4. Freight Market Logistical Competence

Ever since April 1st, 1997, Chinese railway has been upgraded for 6 times, or 6 time speed-up. The maximum operational speed on existing lines reached 250 km/h, see figure 5.

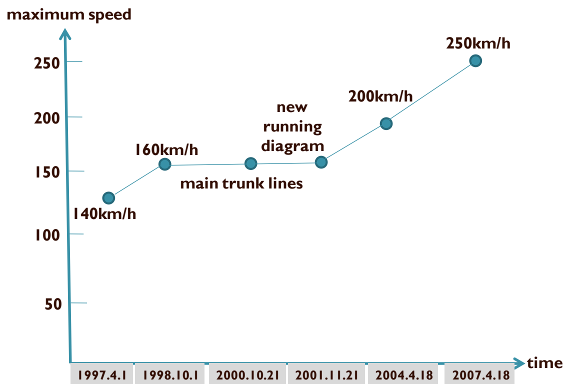

Fig. 5: Speed-up of Chinese railway.

From figure 6, we can see that the maximum operational speed was 140 km/h for 1997, and then the maximum speed reached 160 km/h for 1998, 200 km/h for 2004, and 250 km/h for 2007. It is well known that construction of high speed railway will release the existing line capacity and speed up freight trains. If the freight train operational speed VR is 200 km/h, △T is 3 hours, VA is 900 km/h, then, the equilibrium distance will be 771.42 kilometers.

4. Total Travel Time, Frequency and Logistical Market Share

In order to fully take advantage of time resource, it's imperative for transportation sector to reduce total travel time, increase operational frequency and take over more market share.

4.1. Total Travel Time

HSR is a new emerging transportation mode in China, and it will greatly change the potential market competence of railway, aviation and other transportation modes. To sum it up, high speed railway will obtain more market share while other transportation modes will lose market share in logistical service area, see Table 2.

Table 2: Total travel time for different transport mode.

Time period	HSR	Ordinary railway	Highway	Civil aviation
T1	++	+	++	+++
T2	+	++	++	+++
T3	++	+++	++++	+
T4	++	+	++	+++
T	↓	Long and medium distance	Short distance	Long distance

Note: more + stands for low quality.

Historical data shows that within 500 kilometers, railway occupies more than 40% of the total market share, for market between 500 to 1000 kilometers, market share is more than 18%. With the construction of more high speed railways, the competitive advantage for railways will increase dramatically, and the distance can be as far as 1000 kilometers.

4.2. Frequency

Except for speed, frequency can also reduce passenger or shippers' waiting time and thus cut down total travel time, see Table 3.

Table 3: Frequency and travel time for railways.

Train Frequency	Wait Time	Average Train Speed				
		150	200	250	300	350
hours	0	2.0	1.5	1.2	1.0	0.9
1	0.5	2.5	2.0	1.7	1.5	1.4
2	1	3.0	2.5	2.2	2.0	1.9
3	1.5	3.5	3.0	2.7	2.5	2.4
4	2	4.0	3.5	3.2	3.0	2.9
5	2.5	4.5	4.0	3.7	3.5	3.4
6	3	5.0	4.5	4.2	4.0	3.9
7	3.5	5.5	5.0	4.7	4.5	4.4
8	4	6.0	5.5	5.2	5.0	4.9
9	4.5	6.5	6.0	5.7	5.5	5.4
10	5	7.0	6.5	6.2	6.0	5.9
11	5.5	7.5	7.0	6.7	6.5	6.4
12	6	8.0	7.5	7.2	7.0	6.9

From Table 3, we can see that if train frequency increases from 2 hour per train to 1 hour per train, even the speed difference is 50 km/h, however, passenger or shipper's can feel the same travel time and regard them as indifferent. Therefore, besides speed, frequency can also influence competitive advantage of railway and civil aviation in logistical business sector.

4.3. Logit Model and Market Share for Railway and Civil Aviation

We assume that passenger can take railway or civil aviation, and let Si stands for the factors affecting passenger's choice for railway while Sj represents factors influencing passenger's choice for civil aviation, and the probability to choose railway is P(i), if Si ≥Sj, then:

$$P(i)=P\ (Si \geq Sj) \qquad (14)$$

Then, we set up a characteristic equation as follows:

$$S_i = \alpha_0^i + \alpha_1^i t_i + \alpha_2^i t_0 + \alpha_3^i f \qquad (15)$$

Of which, is constant value, ti is the journey time, t0 is the non-journey time, f is the comprehensive vector of price and other factors influencing Si.

Then, traffic flow distribution ratios for high speed railway and civil aviation are as follows:

$$P(i) = \frac{\exp(S_i)}{\exp(S_i) + \exp(S_j)} \qquad (16)$$

$$P(j) = \frac{\exp(S_j)}{\exp(S_i) + \exp(S_j)} \qquad (17)$$

According to the data we collected, we get the overall average distribution ratio for high speed railway is 44.33%, and total passengers transferred to HSR will reach 78.10 million, see Table 4.

Table 4: Distributary Ratio for HSR

Distributary Class	Civil aviation passengers for 2009	Distribution Number	Round Trip Lines
1	62050760	48762368	205
2	17288594	9425982	43
3	17382897	7861596	51
4	15785933	5543664	50
5	21547478	4597379	63
6	42123455	1904118	162
Total	176179117	78095108	574

Note: class 1 is 60% distributary ratio, and 50%, 40%, 30% , 15% and below 15% accordingly.

If the growth rate is 11%, then by the end of the twelfth five year plan, the total distributary number of passengers from civil aviation to HSR will reach 145.28 million. Thus, HSR will not only affect passenger transportation, but also greatly influence the freight market share.

5. Conclusion

The speed-up process, especially the construction of high speed railway network will bring forward great realistic and potential impacts on civil aviation in logistical marketplace. Keeping other factors constant, the paper set up a travel distance equilibrium model to analyze the effect of time saving on railway and civil aviation competence. For passenger market, HSR will be in an absolute advantage position within the distance of 1000 kilometers. For freight market, the speed-up of existing lines makes Chinese railway possess competitive edge within 800 kilometers. Except for speed, frequency also plays a key role in determining railway and civil aviation logistical competitiveness. The increasing frequency of railway running diagram injects more power for railway development in the future. Logit model shows that HSR will not only gain advantage in passenger market, but also will achieve dominant status in freight market. In order to compete with HSR, Chinese civil aviation has to take firm measures to counterbalance the impact of HSR.

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