The Accessibility Changes of Chinese High Speed Railway Network

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Abstract. High speed railways (HSRs) play a significant role in transportation network and China has undergone extensive development in HSRs in recent years. The principal aim of this paper is to evaluate the accessibility changes of rail transportation network in China after the introduction of HSRs from the national point of view. We build a national rail network covering 31 urban nodes (27 provinces and 4 municipalities) in China, and compare the situations in the years of 2006, 2009 and 2010. A weighted average accessibility indicator is used to measure the changes in accessibility in 2006, 2009 and 2010.

Keywords: High Speed Railways, Accessibility Indicator, China.

1. Introduction

High speed railways (HSRs), operated at a speed of 200 km/h or higher, bring a major improvement in the accessibility level of transportation networks, and modify the relative distance of different places (Gutierrez et al, 1996). There are several well-known HSR systems all over the world, for example Shinkansen in Japan and Train à Grande Vitesse (TGV) in France. Now the Chinese HSR network development is at an early stage with a limited number of lines, but the overall competitive strength of transportation network has increased because of great reduction of travel time among cities linked by HSRs. Although some researches have already analysed the accessibility changes by HSRs in China, they just focused on one specific HSR line, such as Jinghu HSR (linking Beijing and Shanghai) or Wuguang HSR (linking Wuhan and Guangzhou) (see, for example, Jiang et al, 2010). By building a national rail transport network, this paper tries to analyse the accessibility changes by HSRs from the national point of view.

2. Accessibility Indicator Selected

In general, accessibility is a measurement of location on a surface relative to suitable destinations, adjusted for the characteristics of transport network or networks linking points on that surface (Vickerman, 1974). According to Hansen (1959), “accessibility is defined as the potential of opportunities for interaction”. Hansen (1959) used the desire and ability of persons or companies to overcome spatial distance to adjust the spatial distribution of activities about a zone, and the concept can be expressed by the following formula:

$$ {}_1A_2 = \frac{S_2}{T_{1-2}^{x}} \tag{1}$$

Where ${}_1A_2$ is a relative measure of the accessibility at Zone 1 to an activity located within Zone 2, S_2 equals the size of the activity in Zone 2; i.e., number of jobs, people, etc., T_{1-2} equals the travel time or distance between Zone 1 and 2, x is an exponent describing the effect of the travel time between the zones. If more and more jobs are located nearer to Zone 1, the accessibility to employment at Zone 1 will grow.

The economic potential is a gravity-based measure which is a measure of the accessibility of a given volume of economic activity to a particular region, and its classical mathematical expression is as follows (Gutierrez, 2001):

$$P_i = \sum_{j=1}^{n} \frac{M_j}{T_{ij}^{a}} \tag{2}$$

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Where P_i is the economic potential of node i, a is a parameter reflecting the distance decay, M_j is the mass of the destination, T_{ij} is the travel time, cost or distance between node i and node j.

There are a wide variety of models to measure accessibility, and selecting a proper indicator is very important for measuring the accessibility. In fact, results could be different depending on the indicator we choose. This paper adopts the weighted average accessibility indicator described in Gutierrez et al (1996) and modified by one of the authors, Zhao, as shown below.

$$A_{i(t)} = \frac{\sum_{j=1}^{n}\left(T_{ij(t)} * GDP_{j(t)}\right)}{\sum_{j=1}^{n} GDP_{j(t)}} \quad (3)$$

Where $A_{i(t)}$ = the accessibility indicator of origin "i" in time "t", $T_{ij(t)}$ = the travel time through the rail and HSRs between the origin "i" and the destination "j" (in minutes) in time "t", $GDP_{j(t)}$ = the gross domestic product of the destination "j" in time "t", "i" subscripts refer to the origin, "j" subscripts refer to the destination, "t" subscripts refer to the time.

Although "in order to demonstrate the pure rail effect, the GDP economic activity measure in the indicator was fixed" (Gutierrez et al, 1996), we adjusted the original formula by using different GDP values from different times, because accessibility depends both on a variation of the access times and on the economic weights of regions. China is a rapidly developing country and has great economic gap between different regions. HSRs will bring different economic attraction and growth potential in developing regions and developed regions and modify their relative location. As a description of using fixed GDP will be shown in the following parts, we can compare the situations using fixed GDP or changed GDP. Also, because of their normally close ties, the GDP of the province as a whole rather than the GDP of its network transportation node is used in the calculations.

In this paper, this indicator is more suitable than those of economic potential. First, the goal of this paper is to indicate the accessibility changes which are brought in by the reduction of time distance between cities after the implement of HSRs from locational rather than economic point of view. Second, short distances contribute heavily and long distances contribute little in the economic potential indicator, while there is no distance decay in the weighted average accessibility indicator. This study aims to create a Chinese-wide transportation network and it is reasonable to consider the effect of long distances instead of short distances.

In conclusion, according to the aims of the study, the accessibility to destination is assumed to be a function of a weighted average of the minimal travel times by rail and the economic weight (GDP) of the destination in different years (2006, 2009 and 2010).

3. Rail Transportation network building and accessibility calculation

Until now, there have been six national campaigns called "Railway Speed Up" which enhanced the speed of national railways in China. When the sixth "Railway Speed Up" Campaign was commenced on April 18th, 2007, the first HSR service from Shanghai to Suzhou was put into use. After that, several China HSR trainsets entered into operation. According to the government website "XINHUANEWS" in http://news.xinhuanet.com/english2010/china/2010-12/07/c_13638518.htm, China now possesses the longest HSRs miles in the world and plans to create an extensive national HSR network to improve the accessibility levels of the linked cities, bringing them closer to each other in terms of travel times.

3.1. Network building in China

According to the Ministry of Railway's "Mid-to-Long Term Railway Network Plan" (revised in 2008), the national HSRs grid is composed of 8 HSR corridors, among which four running north-south and four going east-west, and has a total of 16,000 km in 2020.

There are 27 provinces and 4 municipalities (excluding Hong Kong, Macau and Taiwan) in China, and this paper includes all 31 for analysis. There are several reasons for this. In China, the municipalities and provincial capitals are not only political and economic centers, also major transport nodes where important dimensions of the local and regional transportation infrastructures are located. In this network covering 31 nodes, only 21 nodes had HSRs service in the year of 2010 and 10 did not (Fig. 1). Thus, because the HSR network hasn't covered whole China, we adopt the HSR data for the accessibility indicator if there is a HSR line passing by a node, or adopt the minimal time for regular trains if there is no HSR.

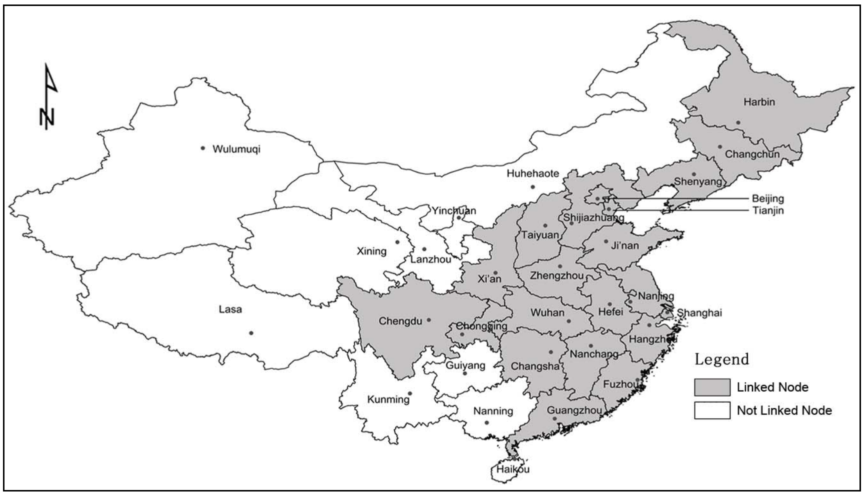

Fig. 1: Distribution of HSR nodes in 2010.

3.2. Accessibility of the 31 nodes calculation

Between 2007 and 2010, more than 10 HSR lines in China were inaugurated and many existing rail lines were upgraded. By 2008, the mileage of HSRs in operation totaled 649 km (http://www.economist.com/node/18488554), 2830 km in 2009 (http://news.xinhuanet.com/finance/2011-01/19/c_121000189_14.htm), and with a huge development the mileage rose to 8358 km in 2010 (http://www.chinadaily.com.cn/business/2011-06/14/content_12696251.htm). Because of great development, the travel times of rails in 2006, 2009 and 2010 are used for analyzing accessibility changes.

The GDP data of 31 provinces and municipalities in 2006, 2009 and 2010 were obtained from the Chinese National Bureau of Statistics database (http://www.stats.gov.cn/tjsj/ndsj/2010/indexeh.htm). In the rail transportation network, the travel times of different years from one point of origin to any other node are the minimal minutes, which is obtained by the new train schedule software called "China Railway Timetable". This software is developed by the China Railway Publishing House. In the data collection, the origins and destinations used in this paper are the 31 nodes in rail transportation network as mentioned before in China[1]

When we encounter the situation that a new line was inaugurated during a year, we use the mean of travel time which is the average of all travel times for before and after the change. Taking Hewu HSR (linking Hefei and Wuhan) for example, this line came into service in April 2009 and the travel time from Hefei to Wuhan was 125 minutes, while the previous time was 451 minutes, so the mean travel time in the year of 2009 is 207 minutes.

Transfer times which exist for indirect lines, refer to the time required in the intermediate stops to transfer to another train or station: 300 minutes is used as the average transfer time in transit based on the experience. This includes not only the time in waiting for the next train, but also the time when the user may change stations. For example, many railways to Tianjin need to transfer at Beijing and go to a different station to continue the trip.

The procedure of calculating the accessibility indicator in a Matlab is rather simple. The 31 urban agglomerations in China are represented by nodes on the rail transportation network, with the following attributes: name of the node, GDP, travel time, direct lines or indirect. Then an accessibility indicator for each node was obtained applying formula 3, and as shown in Table 1.

[1] The travel times between every two nodes among those 31 nodes in 2006, 2009 and 2010 are obtained from different "China Railway Timetable" versions in different times; each version lasts for several months, and some railways may have little changes during these months.

Table 1: Accessibility Indicators of the 31 Nodes.

Region	Node	2006 Accessibility in minutes	2009 Accessibility in minutes	2010 Accessibility in minutes	Difference percent	
					2009-2010	2006-2010
Huabei	Beijing	812.90	727.34	725.81	0.21	10.71
	Tianjin	952.07	896.70	904.39	-0.86	5.01
	Shijiazhuang	888.77	801.36	780.70	2.58	12.16
	Taiyuan	1403.20	1124.87	1067.29	5.12	23.94
	Huhehaote	1681.62	1583.10	1583.13	0.00	5.86
Dongbei	Shenyang	1585.00	1221.83	1201.92	1.63	24.17
	Changchun	1540.89	1496.46	1503.15	-0.45	2.45
	Harbin	1700.03	1645.42	1656.97	-0.70	2.53
Huadong	Shanghai	1058.69	841.50	789.98	6.12	25.38
	Nanjing	1064.04	902.42	854.65	5.29	19.68
	Hangzhou	1160.31	984.87	985.12	-0.03	15.10
	Hefei	1095.16	820.33	805.93	1.76	26.41
	Fuzhou	1696.59	1504.31	1448.18	3.73	14.64
	Nanchang	982.13	900.78	883.05	1.97	10.09
	Ji’nan	1094.51	925.85	927.49	-0.18	15.26
Zhongnan	Zhengzhou	787.79	704.71	693.61	1.58	11.95
	Wuhan	857.50	702.26	628.36	10.52	26.72
	Changsha	998.68	849.82	787.75	7.30	21.12
	Guangzhou	1453.62	1312.71	1287.36	1.93	11.44
	Nanning	1685.06	1695.91	1682.60	0.78	0.15
	Haikou	2284.04	1834.28	1818.60	0.85	20.38
Xi’nan	Chongqing	1733.56	1482.14	1525.54	-2.93	12.00
	Chengdu	1960.84	1718.31	1716.29	0.12	12.47
	Guiyang	1775.03	1585.10	1543.75	2.61	13.03
	Kunming	2338.82	2176.69	2102.19	3.42	10.12
	Lasa	3184.96	2970.10	2983.03	-0.44	6.34
Xibei	Xi’an	1192.92	1029.33	1022.47	0.67	14.29
	Lanzhou	1448.11	1355.29	1349.10	0.46	6.84
	Xining	1647.16	1517.15	1519.70	-0.17	7.74
	Yinchuan	1897.36	1897.53	1886.68	0.57	0.56
	Wulumuqi	3017.45	2780.60	2776.87	0.13	7.97

3.3. Accessibility Changes

As Table 1 shows, from 2006 to 2010, the accessibility indicator of each node has been produced and the accessibility has been greatly improved by the operation of HSRs. The node with the highest change is Wuhan with 26.72%, Hefei with 26.41%, Shanghai with 25.38%, then Shenyang with 24.17%, Taiyuan with 23.94% and Changsha with 21.12%. In contrast, nodes in the northwest and southwest parts have little improvement, like Nanning with 0.15%, Lasa with 6.84%, Lanzhou with 6.84%. But in overall, the HSRs have improved the competitive strength of rail system in China, making travels more convenient. Calculations of relative differences in the accessibility indicator between 2009 and 2010 offer somewhat different results. The HSR network has increased some places accessibility by substantially reducing the travel times. The node with the highest change is Wuhan with 10.52%, then Changsha with 7.30% and Shanghai with 6.12%. However, Table 1 also shows that the introduction of HSRs has had some negative effects where the accessibilities of ten nodes were slightly reduced from 2009 to 2010. A common reason for this is that when high speed and ordinary trains use the same tracks, the ordinary trains may need to stop at the passing stations in order to ensure that the high speed trains have the priority to run on time.

Then we use the fixed GDP to calculate, and the situation was different from the result above. As we adopt the GDP of 2006 for analysing, there were two nodes: Tianjin and Yinchuan experience a worse transport change from 2006 to 2010 and six nodes: Tianjin, Changchun, Harbin, Chongqing, Lasa and Xining experienced a worse change from 2009 to 2010. Changsha and Wuhan experience a greatest change from 2006 to 2010 and 2009 to 2010. The result of fixed GDP is not as reasonable as changed GDP, because negative situation of two nodes from 2006 to 2010. But the centre region, like Wuhan and Changsha experience good change in two methods.

In regional terms, the data indicates the most accessible areas of China stretch from the eastern region to the central region. The more peripheral nodes in terms of accessibility are in the northwest and southwest. The HSRs improve the accessibility level overall, but it indeed aggravate the transportation network gap among eastern, central and western regions. Nowadays there are great differences in speeds within the railway network in China, from 200 – 300 km/h or greater on the HSR lines to probably 60 km/h or less in some regions such as those in the northwest and southwest.

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