Journal of Transport Geography 40 (2014) 123–132

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Impacts on accessibility of China's present and future HSR network ☆

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ARTICLE INFO

Keywords:
High-speed rail
Transport network
Accessibility
China

ABSTRACT

Although the construction of China's high-speed rail (HSR) network only started in 2003, the network is already the largest in the world. This paper analyses the impact of the evolving HSR network on the accessibility by HSR and conventional ground transport of 333 prefecture-level cities and 4 municipalities. This paper employs three indicators of accessibility, and analyses three Scenarios. It shows that the HSR network will bring about substantial improvement in accessibility, and lead to national time–space convergence, but will also increase the inequality of nodal accessibility between eastern, central, and western regions, between cities with different sizes of population (excluding the case of the daily accessibility indicator) and between cities that differ in the shortest distance to HSR stations. The HSR network enlarges internal disparities in each of the regions and the five types of cities. The internal inequality of nodal accessibility in all three Scenarios generally increases from the eastern region via the central region to the western region, as well as from very large cities to small cities, varying inversely with the level of economic development and population size. Spatially, accessibility increases generally conform to the distance decay rule but with minor fluctuations. The 50 cities with the largest increases in accessibility are mostly located 50 km or less away from HSR stations and have populations of over 3 million, with the smaller ones located along HSR lines or around large cities such as Beijing, Shanghai, and Guangzhou. As time progresses, the planned HSR network will result in more balanced development, but regional disparities in accessibility will still be greater than before the construction of the HSR.

1. Introduction

China's first HSR route (Shenyang–Qinhuangdao) with a speed of 200 km/h was opened in 2003, almost 50 years later after the world's first HSR route opened in Japan in 1964. By July 2013, however, China had the largest HSR networks in the world (9760 km), accounting for 46% of the world total (UIC, 2013). China, therefore, took only ten years to construct a HSR network on a scale that in the rest of the world took almost half a century. As early as December 1990, the Ministry of Railways (MOR) submitted the Beijing–Shanghai HSR planning proposal to the National People's Congress. Designed to reduce a deficiency of transport capacity, it was not approved because of the huge investment involved, and a lack of relevant technologies. During 1997–2007, China gradually implemented six rounds of railway speed upgrades, referred to as the Railway Speed Up. After the Speed Up, trains could run at speeds of up to 200 km/h. After that, the MOR shifted its focus from increasing existing rail line speeds to constructing new HSR lines. In 2008, the first newly-built HSR line (Beijing–Tianjin) with a maximum speed of 350 km/h came into operation, symbolizing China's entry into a period of 'rapid HSR development'. In 2004, to increase investment in HSR networks as well as in conventional rail networks to combat the Asian and global financial crisis, the MOR announced the 'Mid-to-long Term Railway Network Plan', revising it in 2008. This plan proposed the construction of 'four-vertical and four-horizontal' Passenger Dedicated Lines (PDLs, 12,000 km), intercity HSRs (4000 km) and upgraded HSRs (40,000 km) to create a complete HSR network by 2020.

Accessibility has long been a central issue in transport geography, and is a commonly used indicator in the field of transport network analysis, transport planning, and land-use (Gutiérrez et al., 1996; Geurs and van Wee, 2004). Accessibility indicators have often been used to measure the impact of HSR networks at a

☆ This article belongs to the Special Issue on The Changing Landscapes of Transport and Logistics in China.

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http://dx.doi.org/10.1016/j.jtrangeo.2014.07.004
0966-6923/

variety of scales, including international (Vickerman, 1997; Gutiérrez et al., 1998), national (Kim, 2000), and regional scales (Hou and Li, 2011). At the city level, HSR-induced increases in accessibility varied with the location of HSR stations and the quality of the transport network connecting surrounding cities to HSR stations (Ortega et al., 2012). A number of scholars examined the impact of HSR on regional equity (Blum et al., 1997; Sasaki et al., 1997), showing that the development of HSR increases the imbalances between congested central regions and poorer peripheral areas, and enhances a 'core-periphery' accessibility structure (Gutiérrez et al., 1996; Vickerman, 1995). Usually, cities along HSR lines see much larger increases in accessibility. This tendency is called the 'corridor effect' (Shaw et al., 2014). Similarly, the opening of Japanese Shinkansen resulted in the concentration of economic activities and employment opportunities along the HSR corridor, and helped form the 'Pacific belt industrial area' (Kamada, 1980; Hirota, 1984; Nakamura and Ueda, 1989). However, Monzón et al. (2013) found that, in the case of the Spanish HSR network, cities in a poorer initial location enjoyed the highest percentage improvements in accessibility, and that regional accessibility differences were reduced. As existing research offers different results in different countries, the impact of China's HSR network on regional accessibility disparities is still an important research question.

Accessibility is traditionally defined as the potential for opportunities for interaction (Hansen, 1959), and can be divided into three groups according to the function of accessibility measures, namely, spatial separation, cumulative-opportunity, and spatial interaction measures (Liu, 2007). The first group involves calculating the topological length, the shortest distance, time, or cost between two nodes (Bruinsma and Rietveld, 1998; Mackiewicz and Rataiczak, 1996) and only measures the connectivity of the transport network. Today, this concept could be represented by the weighted average travel time (WATT), calculated the average travel time between one node and all the other nodes weighted by the mass of the destinations (measured by Gross Domestic Product (GDP)) (Gutiérrez, 2001). The second group focuses on the proximity of cities to development opportunities and involves estimating the size of the population or the scale of the economic activities that can be reached from a node within a certain period of time. Called daily accessibility (DA) (Black and Conroy, 1977), the time limit is usually fixed at 3 or 4 h, making a daily return journey possible (Lutter et al., 1992). The third group comprises what are called potential values (PV). These indicators emphasize the relationships between distance and the distribution of activities, and combine indicators of the degree of spatial separation and the size of the population or the scale of economic activities to measure population or economic potential (Vickerman, 1997, 1999; Hou and Li, 2011). The WATT, DA and PV are the most popular accessibility indicators and reflect different aspects of accessibility.

Although some geographers have already addressed the impact of HSR on accessibility in China, further improvements in terms of methods, scope, and perspectives are still warranted. Chen (2012) showed that China's HSR network resulted in dramatic time–space shrinkage and improved travel between cities, but the expected impact on the "space-economy" is not yet known. Cao et al. (2013) chose 49 cities (most are provincial capitals and municipalities) to analyze the influence of the HSR network on accessibility in China, and reported that cities in the eastern region and the central region have high WATT values, while cities along the Beijing–Shanghai HSR route and in the Pearl River Delta Region have higher PV scores than other cities. This research, however, ignored the effects of HSR network on medium- and small-sized cities. A timetable-based accessibility evaluation was carried out by Shaw et al. (2014) to analyze the impact of HSR on railroad network accessibility in China from the perspective of travel time, travel cost, and distance. Travel time accessibility measures showed an obvious 'corridor effect'. However, this research ignored the effects on cities without HSR stations. All these studies contribute to our understanding of the impact of HSR on accessibility in China. However, the following questions have not yet been clearly addressed: (1) Do measured changes in accessibility depend on the chosen indicator, and, if so, to what extent? Do all indicators produce similar results? (2) What is the impact of the HSR network on cities in the interior and on peripheral cities not connected directly to the network? (3) In what way should one model the connections of the HSR network with other ground transport networks in evaluating changes in accessibility?

More specifically, this paper will contribute to the existing literature by evaluating the impact of the present and planned HSR networks on accessibility and by answering the following questions: (1) How much does the HSR network result in national time–space convergence? Do the results differ according to the indicator used? (2) Does the HSR network increase or decrease disparities in accessibility, and, if so, to what extent? What impact will planned additions to the network have? (3) Do cities whose accessibility increases most increase because of geometric location, population size, or distance from HSR stations? To answer these questions, Section 2 outlines the research methods, Section 3 presents the overall trends in accessibility, Section 4 examines the geography of accessibility, and Section 5 concludes.

2. Study area, data and methodology

2.1. Study area and data sources

In China the MOR divides the HSR network into four parts: upgraded pre-existing rail lines with speeds of over 200 km/h; PDLs with speeds of over 250 km/h; newly built conventional rail lines with speeds of 200–250 km/h for both passengers and freight; and intercity HSR lines with speeds over 250 km/h. However, because of the Wenzhou–Yongjia HSR line accident in 2011, the average operating speed of high speed trains run on some of the upgraded conventional railway lines was reduced to 160 km/h. Therefore, HSR in this paper is defined as the newly-built railway lines with average speeds of over 250 km/h, and upgraded railway lines with average speeds of over 160 km/h. The HSR lines in 2012 include the railway lines with G, C, and D prefix trains (Fig. 1).

The study area comprises 333 prefecture-level divisions and 4 municipalities in mainland China (excluding Hong Kong, Macao, and Taiwan). All the cities are classified into five types by the population of the municipal districts. The five types are three megacities (Beijing, Shanghai, and Chongqing with populations of over 10 million), 16 very large cities (3–10 million), 108 large cities (1–3 million), 119 medium-sized cities (0.5–1 million), and 91 small cities (below 0.5 million). These groups account respectively for 0.9%, 4.7%, 32.0%, 32.5%, and 27.0% of the 337 cities. Of these cities, 111 (32.9%) have HSR stations in their municipal districts. This group includes all three megacities, 15 very large cities (93.8% of the group), 48 large cities (44.4%), 36 medium-sized cities (30.3%), and 9 small cities (9.9%). The data for the study comprises two parts: (1) a GIS database, obtained from the Thematic Database for the Human-earth System of the Chinese Academy of Sciences, and the 1:4 M Database of the National Fundamental Geographic Information System of China; and (2) socio-economic data, sourced from the 'China City Statistical Yearbook, 2011', 'China's Regional Economic Statistical Yearbook, 2011', 'China Population and Employment Statistical Yearbook, 2011', etc.