Journal of Transport Geography 54 (2016) 91–101

Contents lists available at ScienceDirect

Journal of Transport Geography

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

A multimodal approach to assessing accessibility of a high-speed railway station

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ARTICLE INFO

Article history:
Received 17 November 2014
Received in revised form 2 February 2016
Accepted 13 May 2016
Available online xxxx

Keywords:
Accessibility
High-speed rail (HSR)
Travel time
Accessible region
Road network

ABSTRACT

In China, accessibility has been profoundly improved by the large-scale construction and operation of high-speed rail (HSR), with far-reaching implications for population flows and socioeconomic development. As a novel attempt to compare the shortest travel times, accessible regions, service populations, and population potential of one- to four-hour isochrones under four scenarios in Tanggu Railway Station (i.e., base scenario, hypothetical scenario 1, hypothetical scenario 2, and actual scenario), this paper analyses three factors' influences on and contributions to accessibility change: the advent of HSR, conventional railway route adjustment, and road network improvement. The results indicate that station accessibility significantly improved from 2007 to 2012. HSR has not only brought a time-space contraction effect to the region from the station to the north-western area but also strengthened interactions among different regions. Due to the reduction of some conventional railway routes, the shortest travel times from the station to the north-eastern areas have slightly increased. Although this factor has some negative effects, it has not affected the ascending trend of enhanced accessibility. Road network improvement is identified as a key factor with balanced impacts on all four-hour isochrones. The results of this study generate supportive information for the planning and construction of HSR stations and networks and provide references for comprehensive transport policymaking.

1. Introduction

High-speed rail (HSR), with its high speed, large freight volume, low transport cost, punctuality, safety and comfort, high efficiency and returns, energy conservation, and environmental friendliness, plays an important role in passenger traffic among cities and commuter circles. The most direct influence of HSR is accessibility improvement (Adler et al., 2010; Monzón et al., 2013). Accessibility improvement plays an important role in restructuring spatial variation and new economic patterns among regions (Maækiewicz and Ratajczak, 1996). HSR shortens the space-time distance and promotes the mobility of and interactions between people engaged in different economic activities. It can also facilitate development and links in different economic, societal, and cultural aspects (Gutiérrez, 2001; Ureña et al., 2009.), and, in turn, trigger a new wave of economic growth (Tierney, 2012). Because of these positive possibilities, since its first operation in Japan in 1964, HSR has been favourably introduced in Europe and other countries (Ryder, 2012). These nations all hope to enhance regional competitiveness and cohesion through HSR and to promote the economic integration and development of station areas (Cheng et al., 2014). China, a vast territory with high population density in its eastern and central regions, has strong demands, and it has experienced remarkable achievements through the construction and operation of HSR (Cao et al., 2013; Jiao et al., 2014; Shaw et al., 2014). By the end of 2013, the operation mileage of HSR in China had reached approximately12,000 km, and the mileage under construction was over8,000 km. China has been the country with the longest operation mileage and the largest construction scale in the world (China's Ministry of Railway's's, 2008).

The aim of this paper is to analyse the contributions of multiple transport modes to the accessibility of HSR stations. Based on train timetables and road networks, we attempt to analyse the influence of three factors on accessibility: the advent of HSR, conventional train route adjustment, and road network improvement. The paper is structured as follows: Section 2 summarizes the existing literature analysing accessibility due to HSR. Section 3 provides detailed information on the case study area. Section 4 introduced the analysis framework for estimating each factor's contribution to accessibility. Indicators' calculation results and accessibility changes are presented in Section 5. The three factors are analysed quantitatively in Section 6. Finally, the conclusion, discussion and future work are summarized in Section 7.

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http://dx.doi.org/10.1016/j.jtrangeo.2016.05.007
0966-6923/

2. Literature review

Since first proposed by Hansen (1959), accessibility has been an important concept that has been widely applied in urban planning, transport geography, and other aspects. Scholars have offered different definitions and methods of measurement for accessibility (Chang and Lee, 2008; Curtis and Scheurer, 2010; Geurs and van Wee, 2004; Kim and Kwan, 2003; Kwan et al., 2003; Páez et al., 2012; Vandenbulcke et al., 2009). Accessibility indicators can be divided into three groups (Cao et al., 2013): travel time (Cheng et al., 2014; Coto-Millán et al., 2007; Gutiérrez, 2001; Gutiérrez et al., 1996; Hou and Li, 2011), contour measure (Geurs and van Wee, 2004; Handy and Niemeier, 1997) and daily accessibility (Cheng et al., 2014; Gutiérrez, 2001; Gutiérrez et al., 1996; Hou and Li, 2011), and potential models (Cheng et al., 2014; Hansen, 1959; Hou and Li, 2011; Vickerman, 1997).

The concept and measurement of accessibility have been introduced in assessments of the impact of HSR (Chang et al., 2000; Martínez Sánchez-Mateos and Givoni, 2012). Gutiérrez et al. (1996) used GIS and weighted average distance indicators to evaluate the accessibility impacts of the future European HSR network, by comparing the current situation with the outlined plan for 2010; they noted the spatial distribution of accessibility changes at the European level. Gutiérrez (2001) adopted GIS and weighted average travel times, economic potential, and daily accessibility indicators to evaluate the accessibility impacts of a new high-speed link along the Madrid-Barcelona-French border; the authors considered two scenarios (the year 2005 "with" and "without" the new line) to reflect on the potential impacts. They concluded that the new line would reduce accessibility inequalities in cities on a European scale, but will increase accessibility inequalities at the national scale. Willigers and Floor (2007) employed potential accessibility indicators to explore the accessibility impacts of HSR in the Netherlands, the author argued that the accessibility effect is greater for business travel than for commuting. Martínez Sánchez-Mateos and Givoni (2012) used travel time by rail to London to measure potential accessibility impact of a new HSR line in the UK; the authors argued that the accessibility benefits from the HSR line were relatively limited in terms of geographic spread; travel time savings were mainly gained in cities at the end of the line, while the cities in the 'middle' of the line experienced relatively minor improvements in accessibility. Monzón et al. (2013) proposed a spatial impact analysis technology based on GIS to assess the accessibility improvement caused by HSR in Spain from the perspective of efficiency and fairness. In a study by Cao et al. (2013), weighted average travel times and travel costs, contour measures, and potential accessibility were employed as indicators to analyse the accessibility impacts of China's HSR network on 49 cities (most are provincial capital cities), with the emphasis on mid-to-long distance passenger transport. In a case study in the Appalachian region, Chandra and Vadali (2014) conducted a systemized analysis on the accessibility impact of the proposed America 2050 HSR plan; the author used travel time to a county from all other counties to evaluate the accessibility change by comparing the 2002 base period (the "no-build" year) and the future year of 2035 (the "build" year). Based on train timetables, Shaw et al. (2014) used travel time, travel costs, and travel distance to assess HSR impacts on the accessibility of various cities across China. Jiao et al. (2014) used a weighted average travel time, daily accessibility, and potential values to analyse the impact of the present and planned HSR networks on the accessibility of 333 prefecture-level cities and four municipalities in China; they found that the HSR network improved the accessibility of cities across the nation but also increased the inequality of accessibility between the eastern, central, and western regions of China.

Previous studies have demonstrated that accessibility measures are widely accepted in evaluating the impact of HSR at different levels. Nevertheless, some HSR stations are located in the inner city and simultaneously undertake the task of HSR and conventional trains. On the one hand, the accessibility of those stations is not only affected by HSR but also by the comprehensive transport system, consisting of conventional trains, road networks, and other traffic modes. Previous studies have focused on the HSR line itself and have neglected the comprehensive influence of multiple transport modes on the accessibility of HSR stations. On the other hand, due to the introduction of HSR, the frequency with which some conventional trains operate has decreased, while the running times of the rest have been adjusted. Little attention has been paid to this aspect of change. This paper hopes to address these issues. Based on previous accessibility impact studies, we choose the shortest travel times, accessible regions, service populations, and population potential as the accessibility indicators; through a comparison of these indicators under different station scenarios, we attempt to estimate the contributions of the advent of HSR, conventional railway route adjustment, and road network improvement to HSR stations accessibility changes.

3. Study area

The study area in this paper includes one HSR station, Tanggu Railway Station, and one accessible region, the Bohai Rim Area (Fig. 1). Tanggu Railway Station is located in the Tianjin Binhai New Area, which is a state-level development area and the first national pilot

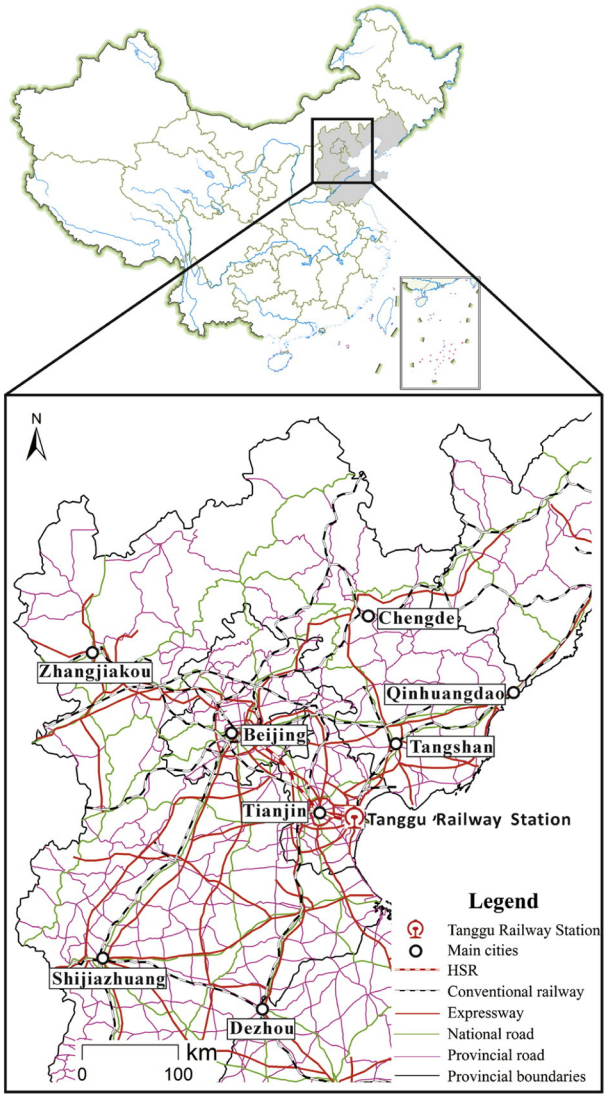

Fig. 1. Location map of Tanggu Railway Station and Bohai Rim Area.