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The implications of high-speed rail for Chinese cities: Connectivity and accessibility

Wangtu (Ato) Xu[a,*], Jiangping Zhou[b,*], Linchuan Yang[c,*], Ling Li[d]

[a] Department of Urban Planning, Xiamen University, Xiamen, China
[b] Department of Urban Planning and Design, Faculty of Architecture, The University of Hong Kong, Hong Kong
[c] Department of Real Estate and Construction, Faculty of Architecture, The University of Hong Kong, Hong Kong
[d] Department of Information Technology and Decision Sciences, Old Dominion University, Norfolk, VA 23529, USA.

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ABSTRACT

Based on China's latest national railway network planning proposal, the connectivity and accessibility indices of China's high-speed railway network (CHSRN) in different time periods are computed to evaluate the implications of high-speed rail (HSR) for Chinese cities. An overall index for measuring the connectivity-accessibility of cities on the HSR network is proposed based on three indicators: (a) the Beta index, to reflect the connectivity of the HSR, (b) the number of reachable counties by HSR within the 500-km domain of a city, to reflect the location-based accessibility of the HSR, and (c) the population of the reachable places by HSR within the 500-km domain of a city, to reflect the potential-based accessibility of the HSR. Finally, the differences in the normalized connectivity-accessibility levels of different categories of cities are qualified to measure the impact of China's future national HSR network on the potential development of cities. It is found that "Mid-to-Long-Term Railway Network Plan (Revised in 2016)", if fully realized, would profoundly change the HSR connectivity/accessibility of different cities. Most notably, cities in the Yangtze River Delta would suffer the most whereas cities of the central and western regions would gain the most. This could potentially contribute to, or bring about new changes in, the socioeconomic landscapes in China. The methodological contribution of this paper is twofold. Firstly, an overall index to evaluate the comprehensive connectivity and accessibility levels of the HSR network is designed. Secondly, this paper investigates how to qualify the impact of the future HSR network on different tiers of cities in different time periods according to the change of the overall connectivity/accessibility index.

1. Introduction

Investments in the construction of national transport infrastructure, particularly railways, are closely associated with the socioeconomic development of a country (Chen et al., 2016). For example, the transcontinental railway had remade and even transformed the US in the 19th century. In recent decades, high-speed rails (HSRs) have received increasing attention. This attention is the result of HSRs' numerous favorable and desirable attributes (i.e., hedonic values), such as high speed, high frequency, travel time reliability, and relatively low fare (compared with other transport modes, especially flights); and the spillover effects of these railways. For example, building and maintaining an HSR can generate new job opportunities and facilitate the establishment of a large and considerably integrated market. In populous developing economies such as China and India, HSR could be the most cost-effective

* Corresponding authors.
E-mail addresses: ato1981@xmu.edu.cn (W. (Ato) Xu), zhoujp@hku.hk (J. Zhou), u3003593@connect.hku.hk (L. Yang).

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means of long-distance travel for intercity passengers[1]. The aforementioned desirable attributes and spillover effects mainly explain the reason for the increase in the number of HSR lines being constructed in China and other countries in recent years.

The introduction of HSR will substantially change and even revolutionize the transport mode choice and trip distribution of millions of passengers. Therefore, the analysis of the impact of HSR on cities on the existing railway network is of immense importance. Such impact can be either realized ones or forecasted ones. The current study focuses on the latter and assumes that from the perspectives of connectivity and accessibility, "winners" and "losers" will emerge from the construction or planned construction of HSRs. Thus, we propose an integrated connectivity–accessibility index and define the "winner" as the city that achieves a higher index value than others because of the introduction of new HSR lines, whereas the "loser" is the city with a relatively small change in its index value. Understandably, the winners and losers cannot easily be detected using conventional techniques, such as eyeballing, buffer analysis, and statistical analysis. Instead, they should be investigated from a considerably broad view using sophisticated methods.

Our existing knowledge and online search have enabled us to determine that different strategies have been implemented on winners and losers based on the connectivity and accessibility indices before and after completing a national HSR plan. This study uses China's HSR experience and plans as an example to analyze the winners and losers from HSR constructions or planned constructions in four different time periods between 2007 and 2030. Thus, this research provides a new approach to appraising HSR constructions and plans, compares the time-dependent connectivity and accessibility indices of cities on China's HSR network (CHSRN), discusses the trend of these indices at the city level, and studies how planned constructions influence the connectivity and accessibility indices of different categories of cities and regions. By quantifying future changes in the connectivity and accessibility indices at the city and regional levels in advance, cities and regions could implement proactive measures to respond to such changes. Moreover, this study conducts a performance persistence analysis to reflect the evolution of winners and losers, more specifically, the relationship between past and future performances.

Similar to the current study, Moyano et al. (2018) used cross-sectional data and effectively identified the winner and loser of the city on the Spanish HSR network based on two accessibility indicators (i.e., location- and schedule-based measures). They focused on which HSR stations benefit more from "service provision" compared with "potential accessibility". By contrast, our study uses longitudinal data (which can measure "change") and compares the connectivity–accessibility levels in different periods in China to identify and evaluate the winners and losers. In view of the extensive scale of CHSRN, the mileage of which is approximately 100 times that of the HSR lines in other countries, we further discuss the performance persistence of the winning/losing status of the city on the HSR network based on the results of a nonparametric method.

The main contributions of this study include (1) filling the research lacuna by adding a reliable empirical study of the largest HSR market in terms of connectivity and accessibility; (2) devising a new methodology that can be easily and efficiently employed in other regions to identify the winners and losers emerging from the HSR constructions from the perspectives of connectivity and accessibility; and (3) employing the proposed analytical framework to uncover the change in connectivity–accessibility stemming from the HSR planning in China.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the methodology and related background information. Section 4 details an empirical case of China, in which the connectivity and accessibility indices are used to show how the past and future HSR constructions have influenced or would influence different cities, city categories, and regions. Section 5 provides the discussion and conclusions.

2. Literature review

2.1. Accessibility and connectivity of transport networks

2.1.1. Accessibility of transport networks

Accessibility is an important dimension of transport networks. Numerous approaches and measures have been used to quantify the accessibility of transport networks (Tong et al., 2015; Martínez et al., 2016). The accessibility measures of transport networks can be divided into three categories: location-, potential-, and transport capacity-based.

Location-based accessibility (LBA) focuses on the ease of reaching a node in a transport network. As such, it is also referred to as "local accessibility", "access", and "to-transit accessibility" (Geurs and van Wee, 2004; Matisziw and Grubesic, 2010; Moniruzzaman and Páez, 2012). The calculation of LBA is often based on the average travel time or cost to reach a station on a transport network (Karou and Hull, 2014). In many existing studies, LBA is often perceived as the gravity-based accessibility, which has a few analogues, including the floating catchment area-based accessibility (Luo and Whippo, 2012; McGrail and Humphreys, 2014; Xu et al., 2015), spatial interaction-based accessibility (Saghapour et al., 2016), and cumulative opportunity accessibility (Páez et al., 2012; Yang et al., 2016, 2018; Yang, 2018a).

Potential-based accessibility (PBA) reflects the fullest degree that a transport infrastructure can be used or the possible (or maximum) amount of travel demand that a transport network can serve (Gutiérrez, 2001; Moniruzzaman and Páez, 2012; Páez et al.,

[1] Heated debates have emerged on (1) which mode can better serve the public and meet future travel demands, that is, HSR or magnetic levitation (Maglev) train, and (2) whether HSR can maintain its significance in the future. A few studies (e.g., Lee et al., 2006; Nishijima et al., 2013) have listed a few advantages of the Maglev train over HSR, such as the unmatched advantage in speed, reduction in guide-way construction and maintenance costs, reduction in the greenhouse gas emissions, and improvement of economic viability. Yet, despite over 80 years of development, Maglev transport systems are in operation only in limited areas in three countries, namely, Japan, South Korea, and China, partially because of the huge construction costs involved.