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The impacts of high-speed rail extensions on accessibility and spatial equity changes in South Korea from 2004 to 2018

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ABSTRACT

The construction of South Korean High-Speed Rail (HSR) or Korea Train eXpress (KTX) has been evolving in phases since its first operation in 2004. This development raises concerns whether the benefits from the extended HSR network would again be limited to the initial HSR corridors and will deepen the inequalities in accessibility with the rising issue of uneven regional development of the country. This paper measures the accessibility of each stage of HSR network extension and evaluates its spatial distribution, variation, and changes using weighted averaged travel time and potential accessibility indicators. The results of this study find different accessibility impacts from each stage of HSR extension. Although travel-time reduction and increased attractions have been widened in more cities by each HSR extension, the spatial equity is degenerated by the extension in 2010/2011 as the improvement of accessibility has been concentrated in cities along the primary HSR corridor near the already-advantageous Seoul capital area. In contrast, the future HSR extension in 2018 will enhance equitable accessibility to the isolated regions such as the northeast and the southwest regions of the country. However, the relative degree of accessibility improvement will not be large enough for increasing the spatial equity of accessibility without more extended HSR networks between provinces.

1. Introduction

With operating speeds ranging between 250 and 350 km/h—twice that of the current ground transportation of automobiles or conventional trains, high-speed rail (HSR) operation brings entirely different impacts in the transportation system of a country. This increased speed reduces travel times and reorganizes the spatial interaction, unity, and competitiveness between cities and surrounding metropolitan regions (Forslund and Johansson, 1995; Martin, 1997; Vickerman et al., 1999; Martin et al., 2004). The degree of benefits enhanced by the HSR transport infrastructures in cities is commonly represented by accessibility (Gutiérrez, 2001; Cao et al., 2013)—a term generally defined as the potential opportunity for spatial interaction among spatially separated human activities promoted by transportation (Hansen, 1959). Improving accessibility is a common goal in almost all transportation plans (Handy and Niemeier, 1997), and hence, the construction of the HSR network is justified.

Benefits received from the HSR system are not evenly distributed across the country (Monzón et al., 2013). Considering construction costs and the large number of passengers required to sustain its service, there is no choice, but to focus on densely populated areas and HSR systems first must be constructed in the most economically efficient corridors. Direct effects from the HSR service are naturally limited to certain cities having HSR stations within this corridor, which foster further changes in land use and economic growth around this corridor and may eventually transform into a "regional core" (Martin, 1997). On the contrary, cities not served by HSR may suffer from relative disadvantages because of the relative loss of travel time to other cities (Vickerman, 1997; Ureña et al., 2009; Monzón et al., 2013). Although cities without HSR may receive some advantage indirectly from the network effect of being connected with HSR, these benefits are usually limited (Garmendia et al., 2012). Thus, the isolation from the initial HSR network may intensify spatial disparities of interactions among cities.

Providing equality in access from HSR transportation services is gaining popularity in transport-policy documents, and further HSR network extensions are in practice to increase network efficiency and reduce the unequal accessibility distribution to the periphery (Bruinsma and Rietveld, 1993; Gutiérrez et al., 1996; Martin, 1997). Pursuing network efficiency, however, can be reversely interpreted as creating disadvantaged areas that are far from the

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HSR network. Acceptable levels of equal access can be guaranteed while ensuring maximum economic benefits from the HSR network if improvement of the HSR infrastructure focuses on closing the gap. Therefore, the comparison of disparities and benefits from the construction of a current HSR network and future HSR networks can be an important process to identify the areas where improvement of the HSR infrastructure is necessary (Gutiérrez, 2001; Monzón et al., 2013).

In this context, the purpose of this study is to examine the disparity of accessibility as an indicator of benefits that cities have received or will receive from the Korean High-Speed Rail or Korea Train eXpress (KTX) at different stages of extensions: stage-1 (S1) (year 2004), stage-2 (S2) (year 2010/2011), and stage-3 (S3) (year 2018) using a multi-modal ground transportation networks. There is a paucity of research examining changes in accessibility and equity issues using proper accessibility measures from HSR networks (e.g., Monzón et al., 2013; Jiao et al., 2014; Marti-Henneberg, 2015), especially focusing on South Korean HSR. Limited research exists evaluating the effects of the first stage of HSR operation in 2004 (Chang and Lee, 2008), and this work was principally from the perspective of advantages of network efficiency. Chung and Lee (2011) used factor analysis to verify the relationship of socioeconomic and accessibility changes based on the average travel time to all destinations. Comparing the absolute travel-time changes between cities is an easy way to show the benefits of accessibility, but it does not reflect the importance of the travel time between two places—a crucial consideration to measure accessibility. Park and Ha (2006) and Chang and Lee (2008) conducted a disaggregated survey data analysis and represented the characteristics of passengers, degree of satisfaction, and major complaints of the HSR service. To our knowledge, no research has focused on the impacts of the HSR extensions in South Korea since S2 by using accessibility measures, especially addressing the issues of spatial equity using multimodal transportation network.

2. Review on accessibility measures and impacts of HSR

2.1. Accessibility measures

The concept and measurement of accessibility is an important implication for urban transportation researchers and planners because it evaluates the impact of transportation systems on travel and land-use patterns. Accessibility, therefore, has been used in various aspects such as location choice, travel demand forecasting, and appraisal of land-use changes (Handy and Niemeier, 1997). The concept of accessibility pursues practical applications in policy-making processes, yet the measurement of accessibility is more central to transportation research (Páez et al., 2012). Measures of accessibility are crucial for understanding the benefits of a transportation system through changes in proximity and supremacy of access from destinations and can be examined in terms of either population or economic status (Weber, 2012; Weber and Sultana, 2013).

Thorough reviews of accessibility measures exist (Geurs and van Wee, 2004; Páez et al., 2012), so we limit our discussion on accessibility measures relevant to the importance and interpretation of our study. Several types of accessibility measures exist for different uses, but two components that commonly influence accessibility measurements are: (1) ease of access, and (2) attractiveness of location (Páez et al., 2012). Since improving locational position of cities or regions is among the most important economic aspect for the constructions of HSR, location-based accessibility measures are most appropriate to evaluate the impact of this transportation infrastructure (Givoni, 2006; Martin, 1997; Gutiérrez, 2001; Chang and Lee, 2008; López et al., 2008; Monzón et al., 2013). These measures analyze accessibility at locations that are typically macro scale and describe the level of accessibility to spatially distributed activities, which include the land use and transportation components at locations (Geurs and van Wee, 2004).

The most widely used locational-based measures include distance or connectivity measure and gravity-based or potential accessibility (PA) measure. Distance measure evaluates degree of connectivity between locations by using distance; and the lowest total distance at the location is considered to have highest accessibility to all other locations. Using the same concept as distance measure, weighted average travel time (WATT) measure emphasizes the relationship between regions by calculating travel time (instead of distance) of a location to all other destinations considering the size of destinations. The size of the destination is used as weight in order to value the importance of the minimal travel time routes (Gutiérrez, 2001; Cao et al., 2013). The mathematical expression is as follows:

$$T_i = \frac{\sum_j M_j \cdot t_{ij}}{\sum_j M_j}, \quad (1)$$

where T_i is the accessibility of location i, t_{ij} is the travel time to destination j, and M_j is the size of j. Generally, the minimal travel time is used for t_{ij}, and the number of population or gross product is used for M_j (in our case it is the total population of each city). This indicator focuses on the shortest travel time rather than the shortest distance. The data of population or gross product at locations are to value the importance of the travel time route. The interpretation of this indicator is simple: the reduced value of T_i after the operation of the new HSR means a travel time saving of location i; and the lowest average travel time at the location is considered to have highest accessibility to all other locations.

Since WATT accessibility measure focuses only the travel-time benefits, not the economic potential at the location, another widely used accessibility indicator is potential accessibility (PA), which is a gravity-based measure using distance decay affects. PA measure focuses on the nearness of opportunity of economic activities in a location (Hansen, 1959; Gutiérrez, 2001; Martin et al., 2004; López et al., 2008; Cao et al., 2013; Monzón et al., 2013) with the assumption that the nearer and bigger a destination to a location, the higher its market potential. It is a gravity-based measure determined by the volume of the size of destinations divided by the travel time between them. The expression is as follows:

$$P_i = \sum_j \frac{M_j}{t_{ij}^{\alpha}}, \quad (2)$$

where P_i is the PA of location i, t_{ij} is the travel time between locations i and j, M_j is the size of destination j (in our case it is the total population of each city), and α is a distance friction parameter. In this study, the value of α is used as 1. The use of a higher value of α has the problem of excessive reflection of adjacent destinations, so we use 1 as a parameter because it has been used by other researchers dealing with the similar measure at a national scale (Gutiérrez, 2001; Cao et al., 2013). The result is interpreted as the chances of economic potential of each city caused by the new HSR extensions. Higher values indicate higher potential adjacency of opportunities.

2.2. Efficiency impacts of HSR

Despite the uncertainty of the relationship between connectivity and economic growth (Martin, 1997; Pol, 2003; Givoni, 2006; Gutiérrez et al., 2010; Monzón et al., 2013), the efficiency impact of the network remains an important criterion for assessing the