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Accessibility impact of future high speed rail corridor on the piedmont Atlantic megaregion

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ABSTRACT

This study evaluates the accessibility impact of future high speed rail (HSR) corridor on the Piedmont Atlantic Megaregion (PAM) in the United States. A geographic information system (GIS) tool is used to conduct the accessibility assessment. The door-to-door approach is adopted to evaluate the multimodal (including roadways and HSR) travel time. Three accessibility indicators are selected, including the weighted average travel time (WATT), daily accessibility (DA), and potential accessibility (PA). The selected accessibility indicators are calculated by using the estimated travel time at the geographical level. The average accessibility scores of the counties in the PAM during peak and off-peak hours are estimated and compared. The results indicate that the building of the HSR corridor within the PAM will improve the accessibility at the megaregional level. However, the coefficient of variation results indicate that the inequality will also increase due to the new HSR corridor. The relationships between megaregional accessibility scores (i.e., WATT) and HSR services (such as headway and speed) are explored. Several policy implications are drawn in terms of enhancing the megaregional accessibility.

1. Introduction

The U.S. population is projected to reach 400 million in 2050 (Ross and Woo, 2011). The increasing population and the continually expanding metropolitan regions create a new scale of geography which is commonly known as megaregion. As a new geographic unit, megaregion plays an important role in interlocking economic systems, sharing natural resources, and linking people together. Typically, the geographic scale of a megaregion is consistent with its longer distance trips appropriate for High-speed rail (HSR) (Ross and Woo, 2012). HSR corridor (and network) can be used to provide a fastest mean of mass ground transportation and alleviate congestion on roadway networks (Campos and de Rus, 2009). In addition, HSR can compete with air travel for its faster passenger loading and unloading times (Levinson, 2012). HSR system planning studies at the megaregional level have been carried out by researchers (e.g., Ross and Woo, 2012) and organizations (e.g., America 2050, 2011) in the United States.

Compared with traditional transportation modes (such as cars, air, and conventional railway), HSR not only provides a shorter travel time, more safety, and lower cost, but also reduces the emission of greenhouse gases. The mobility and interactions among people in different regions and different economic activities can be promoted since the space-time distance is shorted by HSR. Due to the benefits of HSR services, the European counties, Korea, and China are continuing to support HSR projects. One of the most direct benefits of HSR is the improvement in accessibility (Sánchez-Mateos and Givoni, 2012; Wang et al., 2016; Zhang et al., 2016). The improved accessibility results in numerical benefits among different regions, including the expansion of markets and spatial agglomeration of industries (Lakshmanan, 2011; Chandra and Vadali, 2014), inducing shifts in the travel dynamics of householders, and restructuring new economic patterns (Tierney, 2012).

Accessibility is defined as the potential to reach spatially distributed opportunities for employment, recreational, and social interactions (Páez et al., 2012). The concept of accessibility has been widely adopted in the fields of land-use, transportation planning, and geography (Geurs and van Wee, 2004; Holl, 2007; Cao et al., 2013). Accessibility analyses have also been used in HSR planning during the past decades (Hou and Li, 2011; Kotavaara et al., 2011; Gutiérrez et al., 2011; Pérez et al., 2011; Koopmans et al., 2012; Cao et al., 2013; Jiao et al., 2014; Wang et al., 2016), which include evaluating the accessibility at a HSR station (Zhang et al., 2016), corridor (Gutiérrez, 2001;

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Sánchez-Mateos and Givoni, 2012), and network (Cao et al., 2013; Monzón et al., 2013; Chandra and Vadali, 2014). For example, Gutiérrez (2001) evaluated the accessibility impact of the high speed Madrid–Barcelona–French border train line. By using different accessibility indicators, the European value added by the TEN-T projects was appraised by Gutiérrez et al. (2011). Cao et al. (2013) conducted accessibility analysis for quantifying the impact of HSR network in China. Chandra and Vadali (2014) analysed the potential accessibility changes from 2002 to 2035 with respect to six key industry sectors around the HSR stations in the Appalachian Region in the United States. Zhang et al. (2016) employed accessibility analysis to compare the shortest travel times, accessible regions, and service populations at Tanggu Railway Station in China.

The purpose of this research is to evaluate the accessibility impact of the future HSR corridor on the PAM. By using the door-to-door approach, travel times during peak and off-peak periods between any pair of cities are estimated. Three accessibility indicators are employed to measure the accessibility impact. Such evaluation results will provide support for decision-making on the operation and planning of future HSR corridor in the PAM. Several policy suggestions to enhance accessibility in the PAM are also made. The remainder of this paper is organized as follows. Section 2 describes the methodology used in this study. Section 3 provides an overview of the PAM. Section 4 presents the methods used to estimate the multimodal travel times and calculate the accessibility impact. The numerical results (including the validation of the travel time, comparisons of the accessibility indicators, and drawing policy implications) are discussed in Section 5. Section 6 presents the conclusions and outlook for future research.

2. Methodology

2.1. Approach for travel time measurement

As a common performance indicator for measuring accessibility, travel time has been frequently used (Salonen and Toivonen, 2013; Wang et al., 2016). In some studies, travel time at every stage of a journey between origin and destination is taken into account when calculating the total travel time from origin to destination (Lei and Church, 2010; Benenson et al., 2011). The door-to-door approach, which was initially developed by Salonen and Toivonen (2013), is adopted to estimate every stage's travel time in a journey in this study.

The door-to-door approach is illustrated by Fig. 1. Two scenarios are presented: one traveling by car and the other by HSR. Under the first scenario, in which one chooses car, the travel time includes (1) walking from origin to parking space; (2) driving from the parking space to the destination point; (3) looking for a parking space at the destination point; (4) walking from the parking space to destination (Benenson et al., 2011). By HSR, the total travel time is also divided into four parts: (1) driving (or taking transit) from origin to HSR station; (2) total transferring time at the HSR station, including the walking time to the station, waiting time at the station, and relevant transfer penalties in travel time (if any). It should be pointed out that the waiting time is highly relevant to the HSR headway. In this study, the average waiting time at the HSR station is assumed to be half the headway (Lei and Church, 2010); (3) Traveling from origin HSR station to destination HSR station; (4) driving (or taking transit) from HSR station to destination.

The total travel time taken under the two scenarios by using the door-to-door approach can be estimated by the following two equations, respectively:

Traveling by car:

$$T_{od}^{car} = T_{OP} + T_{PP} + T_{PD} \tag{1}$$

Traveling by HSR:

$$T_{od}^{HSR} = T_{OS} + T_{SS} + T_{SD} + T_{transfer} \tag{2}$$

where $T_{tranfer}$is the total transfer time at HSR stations, which can be calculated by $T_{tranfer} = T_{walking} + T_{waiting} + T_{other}$. $T_{walking}$is the total walking time at the station, $T_{waiting}$is the average waiting time at the HSR station, and $T_{other}$is other penalty time. Note that it is assumed that the penalty time is not involved in this study, i.e., $T_{other} = 0$.

Based on Eqs. (1) and (2), the travel time T_{od} of the journey from origin o to destination d is the shortest travel time among different modes (e.g., car, HSR, air, and conventional rail), which is defined as:

$$T_{od} = \min(T_{od}^{car}, \ldots, T_{od}^{HSR}) \tag{3}$$

where $T_{od}{}^{car}$ and $T_{od}{}^{HSR}$ are the travel time by car and HSR, respectively

2.2. Accessibility indicators

To evaluate the accessibility impact of a new infrastructure, different indicators have been selected by different researchers. Typically, the accessibility indicators can be divided into three categories: cumulative opportunities, gravity-based, and utility-based (Wang et al., 2016; Zhang et al., 2016). Each indicator highlights different effects, and each one provides a different point of view on the impact of accessibility. According to López et al.'s (2008) suggestion, more than one indicator should be computed. After estimating the travel time from origin to destination by using the door-to-door approach, three classical accessibility indicators which are computed on the basis of travel time are used in this study, including the weighted average travel time (WATT), daily accessibility (DA), and potential accessibility (PA).

2.2.1. WATT indicator

WATT is the average weighted travel time from a given location i to other locations that are connected to location i. The mathematical expression of WATT is presented as follows:

$$WATT_i = \frac{\sum_{j=1}^{n} T_{ij} M_j}{\sum_{j=1}^{n} M_j} \tag{4}$$

where $WATT_i$ is the weighted average travel time of location i, $T_{ij}$is the travel time between locations from location i to city j (i.e., the physical address of the city government), n is the number of selected cities in the study area, and M_j refers to the value of accessibility measurement of destination city j, which can be computed by Eq. (5) (Wang et al.,

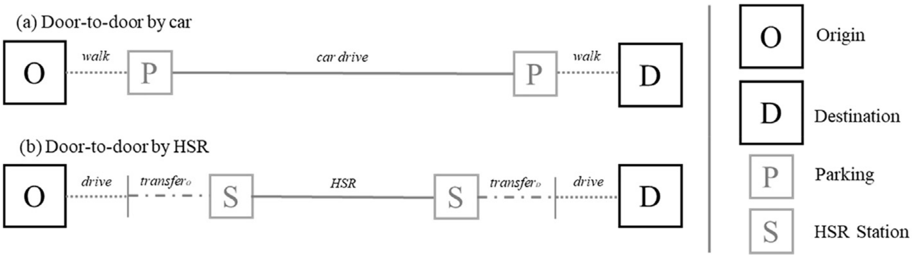

Fig. 1. Schematic diagram of the door-to-door approach.