Journal of Transport Geography 45 (2015) 1–11

Contents lists available at ScienceDirect

Journal of Transport Geography

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

A GIS-based spatial statistical approach to modeling job accessibility by transportation mode: case study of Columbus, Ohio

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ARTICLE INFO

Keywords:
Spatial statistics
GIS application
Transportation planning
Transportation equity
Job accessibility

ABSTRACT

Improving job accessibility based on transport connectivity helps to address equity issues. Spatial autocorrelation (SA) is also a focus of interest in transportation planning, but has been neglected in analyzing job accessibility in metropolitan areas. In this study, GIS-based job accessibilities by walking, transit, and car are computed for the metropolitan area of Columbus, Ohio, and three transport-based spatial autoregressive (SAR) models are estimated to account for the SA of job accessibility among neighboring block groups, while controlling for built-environment and socioeconomic factors. SA intensities and extents are compared in order to better understand local spatial clusters of job accessibility across the region. Direct and indirect spillover effects due to an investment change in transportation facilities are estimated and provide important transportation planning information. The results also show that walking-accessed jobs are primarily related to physical settings (e.g., land uses) at the local level. Locations with a higher share of zero-vehicle housing units have better job accessibility by transit. There is a spatial mismatch between Asian population clusters and transit-accessed jobs, possibly because of the car-oriented residential clusters around Honda of America Manufacturing in suburban areas. More importantly, locations with a higher share of single-parent households are at a disadvantage in overall job accessibility. Due to its complex transportation needs, a society friendly to single parents should spatially integrate accessible jobs with other needed activities via land-use and transportation planning. Alternatively, car-ownership programs and non-spatial social supports also might be effective to help secure job opportunities and perform daily life activities.

1. Introduction

Assessing accessibility to individual activities in metropolitan areas has been a long-standing interest in transportation geography (Chen et al., 2014; Karou and Hull, 2014; Le Vine et al., 2013; Lin et al., 2014; Martínez and Viegas, 2013). Transportation equity affects people's economic and social opportunities (Handy and Niemeier, 1997; Litman, 2002; Niemeier, 1997). Therefore, improving transport accessibility increasingly is used to cope with social inequality, particularly for socially disadvantaged groups (Sanchez et al., 2003). Job accessibility by transportation mode is a key theme among transportation equity issues (Cheng and Bertolini, 2013; Grengs, 2012; Holzer et al., 2003). The spatial patterns of jobs accessed by different transportation means result from a set of socioeconomic and built-environment factors (Bullard, 2003; Geurs and van Wee, 2004; Handy and Niemeier, 1997; Litman, 2002; Lubin and Deka, 2012). Therefore, it is important to understand more clearly the spatial relationships between transport-accessed jobs and these metropolitan factors (Bullard and Johnson, 1997; Klein, 2007). Spatial statistics increasingly are used to examine spatial autocorrelation (SA) in transportation planning (Goetzke, 2008; Wang et al., 2015). Therefore, this study tests the hypothesis that transport-accessed jobs in a given district spatially interact with those of neighboring districts, due to similar physical and socioeconomic conditions (Bolduc et al., 1997; LeSage and Pace, 2009). The SA intensity and extent may also vary across different transport-based job accessibilities. Therefore, transportation policies designed to enhance job accessibility should consider not only the direct effects of infrastructure investments but also the spillover effects when the SA is significant.

Job accessibilities by three different transportation modes (walking, transit, and car) are calculated for the metropolitan area of Columbus, Ohio. The census block group is selected as the

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http://dx.doi.org/10.1016/j.jtrangeo.2015.03.015
0966-6923/

geographical unit. Three spatial autoregressive (SAR) models for the three transportation modes are estimated to account for the SA of job accessibilities among neighboring block groups, while controlling for built-environment and socioeconomic factors. Accounting for SA, which has been infrequent in past research, should result in interesting insights when comparing different SA intensities and extents. Built-environment features include bus-stop density, street-junction density, distance from the city center, population density, and commercial and industrial uses. Socioeconomic factors are represented by race, single-parent households, zero-vehicle housing units, education, and owner-occupied housing units. The spatial patterns of these factors are compared to those of transport-accessed jobs to assess possible spatial mismatch.

The remainder of the paper is organized as follows. Section 2 provides background information. GIS-based calculations and the modeling methodology are discussed in Section 3. The GIS results are described in Section 4, while Section 5 presents the spatial statistical results. Section 6 summarizes the findings and outlines areas for future research.

2. Background

2.1. Social equity and accessibility

Transportation plays a pivotal role in shaping human interactions, economic mobility, and urban sustainability; therefore, transportation planning has significant impacts on social equity (Bullard, 2003; Delmelle and Casas, 2012; Klein, 2007; Litman, 2002; Sanchez, 1999). Social equity broadly refers to equally distributed social benefits and costs, which can be significantly affected by transportation accessibility. For instance, Kaplan et al. (2014) proposed using transit accessibility for assessing transport equity, and the results showed that lower-equity areas are linked to low transit connectivity, human interactions, and economic opportunities. In their study, accessibility is defined as the ability and ease of reaching activities, opportunities, services, and goods. Golub and Martens (2014) also reported that all neighborhoods in the San Francisco Bay Area suffer from a lack of car and transit accessibility, and showed that transportation investment can help reduce access poverty. Lack of fair and appropriate transport accessibility might result in a spatial mismatch between social groups and social benefits (Blumenberg and Shiki, 2003). Such spatial differences in accessibility could be across geographical areas, population groups, and time. Delbosc and Currie (2011), for example, used Lorenz curves to assess public transport equity across different age, income, and vehicle ownership groups.

Accessibility has been an essential measure for assessing cumulative opportunities reached by transport within a distance band (Castiglione et al., 2006; Delmelle and Casas, 2012; Fan et al., 2012; Handy and Niemeier, 1997; Litman, 2002; Niemeier, 1997; Páez et al., 2010, 2012). Job accessibility, a proxy for economic mobility, is an important equity focus. Numerous job accessibility concepts are comprehensively reviewed, together with their calculations, in Cheng and Bertolini (2013), Le Vine et al. (2013), Chen et al. (2014), Lin et al. (2014), Golub and Martens (2014), Karou and Hull (2014), where potential jobs within a certain travel time/distance and transportation impedance are the two factors used to assess job accessibility. Sanchez (1999) calculated labor participations for each block group subject to a certain walking distance from transit stops in Portland and Atlanta. In the case of transportation impedance, the lack of network connectivity between residential locations and employment workplaces results in low job accessibility (Ihlanfeldt, 1994; Sanchez, 1999). Moreover, Sanchez (1999), Lubin and Deka (2012) both reported the positive role of equitable transit in improving job accessibility for socially disadvantaged groups. Their research also found that some critical barriers still affect meeting the basic needs of these groups in terms of safety, reliability, affordability, and availability.

2.2. Spatial analysis of job accessibility

There are two streams of research on the spatial relationships between job accessibility and built-environment and socioeconomic factors: graphical comparisons and the metropolitan structure and statistical regression modeling. Job accessibility, together with the associated transport connectivity, is graphically presented and compared to the metropolitan distributions of race, income, age, gender, single-parent households, car ownership, and household size (Chen et al., 2014; Cheng and Bertolini, 2013; Golub and Martens, 2014; Karou and Hull, 2014; Le Vine et al., 2013; Lin et al., 2014). A drawback of this approach is that the results do not provide comprehensive spatial relationships between job accessibility and the factors of interest. Using a spatial statistical approach to account for the effects of built environment features, Sung et al. (2014) found that land-use patterns and the transportation system intrinsically define the urban framework and, thus, influence transport accessibility. Páez et al. (2010) also reported that social exclusion regarding food accessibility is affected significantly by household income and car ownership. Fan et al. (2012) found that job accessibility is improved significantly by implementing light-rail systems, particularly in areas with high shares of Latinos, Asians, college graduates, and zero-vehicle residents. Foth et al. (2013) reported that most socially disadvantaged census tracts in Toronto have better job accessibility due to lower transit travel times and, therefore, concluded that Toronto has an equitable transit system.

Global spatial trends in metropolitan areas can be compared using ordinary regression models, but local spatial autocorrelation (SA) may remain in the residuals. Agglomeration economies generally refer to location-specific effects, which can help us understand SA effects (McCann, 2001; Park and von Rabenau, 2011). Agglomeration economies have been widely used to account for the urban structure and different city sizes through three economies-of-scale mechanisms: information spillovers, non-traded local inputs, and local labor pools (McCann, 2001). The concept of agglomeration can also be used to analyze the simultaneous effects of regional attributes on quality of life (Park and von Rabenau, 2011; Roback, 1982). Park and von Rabenau (2011) used a spatial autoregressive (SAR) simultaneous equation model to account for the effect of agglomeration factors on amenity, and calculated direct and spillover effects. It is worth noting that location-specific effects may decay rapidly with distance, at a scale smaller than a city (Duranton and Overman, 2005; Fu, 2007; Park and von Rabenau, 2011; Van Soest et al., 2006). Using the concept of agglomeration, the basic assumption is that the job accessibility of a given district is related not only to built-environment and socioeconomic factors, but also to the accessibilities of neighboring districts. Sung et al. (2014) demonstrated the existence of SA in accessibility in Seoul and its metropolitan area, using spatial error (SEM) models. In this study, SA intensities do not vary among different accessibility catchments. Conceptually, a transportation-facility investment in a given district can increase job accessibility not only for that district but also for neighboring districts, due to the spillover effects of improved local transport connectivity.

3. Methodology

3.1. Job accessibility calculations by transportation modes

The cumulative-opportunity approach, a location-based accessibility measure, has been widely used in accessibility studies