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The effects of spatial accessibility and centrality to land use on walking in Seoul, Korea

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ABSTRACT

The debate on pedestrian-friendly urban structures has increased interest in the connections among land use, accessibility, and pedestrian volume. Most econometric models have focused on the individual and separate effects of density, land-use patterns, and street connectivity on the spatial variation of walking. This study investigates the effects of spatial accessibility and centrality by land-use types on pedestrian presence in Seoul in 2009. The model employs four newly developed accessibility indices and identifies the differentiated effects of land-use accessibility and centrality on pedestrian volume, controlling for street features, location and transportation characteristics, and neighborhood land-use attributes. The model results confirm that the effects of land-use accessibility and centrality vary with the spatial distribution of pedestrians. This analysis highlights the importance of investigating accessibility effects by land-use volume. Indeed, policies on pedestrian-friendly urban structures should consider local contexts as well as the complex relationship between land-use accessibility and walking.

1. Introduction

As we experience climate change and a lower quality of life in auto-oriented cities, smart growth and new urbanism are dominating urban paradigms, reshaping urban spatial structures worldwide. Naturally, urban planning, policy, and design aim to create cities that have a low auto-use, high pedestrian-friendly urban form. Walkable cities have certain advantages such as fewer auto trips, more street activity for local retail outlets and the community, and robust health for citizens. Thus, we need to understand the determinants of walking activities to encourage the creation of pedestrian-friendly urban structures.

Many studies have focused on the main determinants of walking: socioeconomic features, the built environment, and street layout. These studies specifically suggest that population and employment density, land-use patterns, and land-use mix determine the pedestrian volume in cities. Within a specific area, higher population density has been shown to be associated with more walking (Agrawal & Schimek, 2007). However, other conditions are also required. For instance, high-density development, mixed-use areas, and comfortable public transit services influence the link between population density and walking behavior (Cervero & Kockelman, 1997; Holtzclaw, 1994). Proponents of smart growth and new urbanism have even suggested that higher density development converts auto usage into public transit travel and walking (Lopez-Zetina, Lee, & Friis, 2005). Boarnet and Crane (2001), by contrast, maintained that a higher density and a greater mixture of land development fail to reduce long-distance vehicle travel. A number of studies have also confirmed that increased retail land use near residential areas generates more walking choices. Thus, mixed-use residential and retail environments increase walking as a transportation mode (Cervero, 1996; Ewing, 1995; Frank & Pivo, 1994). The key finding of previous studies is that accessible locations for walkers are associated with diverse land use and a convenient street layout.

On the contrary, street-focused studies maintain that street conditions and connectivity generate walking alternatives. Early studies of street effects focused on the influence of topological and physical settings on walking choices (Crane & Crepeau, 1998; Ewing & Cervero, 2001). Many authors have confirmed that street density and its link with cul-de-sacs affect walking behaviors (Cervero & Kockelman, 1997; Lee & Moudon, 2006; Song & Knaap, 2004). A wider focus on overall street fabric and connections has also promoted studies of catchment area and space syntax approaches, finding that walking is more likely to be concentrated near key destinations and along corridors between origins and destinations (Handy, Paterson, & Butler, 2003; Hess, Moudon, Snyder, & Stanilov, 1999). Among measurements of space syntax, integration and choice attract increased walking (Hillier, 1996; Peponis & Wineman, 2002). One study of the effects of space syntax features showed that pedestrians prefer more accessible

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streets to those with shorter paths. In addition, local contexts change the connection between space syntax features and walking volume (Baran, Rodriguez, & Khattak, 2008).

In summary, while the findings of previous studies have confirmed that population density, land-use patterns, and street layout determine the spatial variations of walking, research has not thus far tested the hypothesis that different access to land use based on the characteristics of a street network affects the spatial distribution of pedestrian presence. This statement is testable in a sophisticated framework because most walkers are sensitive to the integrated urban setting of varied land use and street layout.

The present study intends to bridge this gap in the body of knowledge on this topic by testing the various effects of spatial accessibility and centrality by land-use type on walking volume in Seoul, Korea. In particular, this study compares the effects of spatial accessibility and centrality discussed in previous studies. However, as previous studies have focused on how spatial accessibility and centrality separately affect walking, we have less understanding about how their effects differ. To improve our knowledge of the linked impacts of land-use density and street network layout, this study thus applies popular and widely used spatial accessibility and centrality indices to identify their different effects on walking under one research framework.

The remainder of the paper is organized as follows. The first section introduces the local contexts of the study area and data sources used for the empirical tests. The second section describes the motivation behind measuring spatial accessibility and centrality as well as presents and defines the variables and multilevel regression models deployed. The third section discusses and interprets the results of the regression analyses. In the final section, the study summarizes the results and suggests policy implications.

2. Study context and data sources

Seoul is a highly dense city with high land-use mix and a well-organized public transit system. The population density of Seoul was 17,466 people per km^2 in 2010, almost twice that of New York and 3.6 times that of London (Urban Information Network, 2010). Seoul operates nine subway lines at a total distance of 316.8 km with more than 290 stations and 11,200 bus stops with dedicated bus lanes, high service quality, and a convenient fare system. The total sidewalk length measured 2523 km^2 in 2009 (Seoul Institute, 2014).

The Seoul Metropolitan Government (SMG) has constantly strived to make Seoul a more livable, pedestrian-friendly, and sustainable city. In particular, since 2004, it has implemented innovative policies such as replacing the freeway with the *Cheonggyecheon* urban stream,[1] reforming public transit services, and expanding green spaces to promote pedestrian- and public transit-oriented urban structures (Kang, 2009). In 2012, the SMG further integrated pedestrian-friendly urban settings into the public transit system and introduced car-free streets and transit malls to promote walking. Thus, micro-level pedestrian survey and land-use data in Seoul provide a great opportunity to test the link between relative access to diverse land use and pedestrian volume.

We compiled data from a number of key sources, namely (1) location-based pedestrian volume data; (2) street maps; (3) Korean census tract (*Jipgyegu*) boundary maps[2]; (4) major transit stations and route maps; (5) bus stop maps; (6) building maps and built volume by land use[3]; and (7) a population and employment density map. In terms of point (1), the SMG counted the number of pedestrians at 9848 survey spots across Seoul in 2009 and matched these data with street-level information such as the width of sidewalks, furniture on sidewalks, types of streets, and nearby road types (Seoul Metropolitan Government, 2010). Fig. 1 indicates the spatial patterns of walkers on weekdays across Seoul (the average walking patterns on Saturdays were similar). To clarify these spatial patterns, this study represents average walking volume in Seoul's census tract units by summing the walking volume of each survey spot. As shown by the figure, a large number of walkers are concentrated in the CBD, sub-CBDs, and places near main roads.

3. Methodology

3.1. Motivation behind measuring spatial accessibility and centrality

Previous studies have ignored the combined effects of land use and street conditions. Recent works examining the built environment and street design have thus captured the attention of urban planners and designers. Intuitively, pedestrians consider urban settings containing the built environment and street layout (Ozbil, Peponis, & Stone, 2011). For example, more people tend to walk along well-connected streets with a higher density of commercial and retail spaces (Peponis, Hadjinikolaou, Livieratos, & Fatouros, 1989). Still, we have little knowledge on how land-use accessibility generates spatial variations in pedestrian volume.

The accessibility and network centrality approaches open up new perspectives on the complex connection between land use and street features. While accessibility measures the ease of reaching destinations along streets or road networks, network centrality identifies the relative importance of nodes in a network (Geurs & van Wee, 2004; Hansen, 1959; Newman, 2010). Key studies of accessibility and its effects have verified that higher accessibility to jobs and land use generates higher housing prices and fewer vehicle miles (Cervero, 2005; Osland & Thorsen, 2008; Srour, Kockelman, & Dunn, 2002). In particular, higher accessibility to retail outlets and universities confers higher premiums on residential property values (Adair, McGreal, Smyth, Cooper, & Ryley, 2000; Franklin & Waddell, 2003; Song & Sohn, 2007). Empirical studies of network centrality have mainly suggested that higher "Closeness" and "Betweenness" are associated with higher housing prices and rent, population density, and commuting (Barthélemy & Flammini, 2009; Chiaradia, Hillier, Schwander, & Barnes, 2013). Other studies have used the network centrality concept to measure the complex flow of commuting in spatial networks (Caschili & De Montis, 2013; Reggiani, Bucci, & Russo, 2011). However, few studies have investigated how accessibility to land use changes walking behavior in metropolitan areas.

To compare the different effects of spatial accessibility and centrality to land use on walking, this study applies the Gravity Index, Betweenness, Straightness, and Closeness. The popular use of such measures in previous studies justifies selecting these indices. The Gravity Index is one of the most popular and applied indices to evaluate spatial accessibility (Cervero, 2005; Handy & Niemeier,

[1] *Cheonggyecheon* is the corridor-type stream in the urban core of Seoul that replaced a freeway in 2005. After taking office in 2002, Mayor Lee initiated the project of converting the elevated freeway into an urban greenway to provide a pedestrian-friendly park along the stream.

[2] Similar to census tracts in the United States, *Jipgyegu* is defined as the smallest statistical and spatial units for collecting socioeconomic data. Statistics Korea designates these units to be relatively homogeneous with respect to their demographic attributes, economic status, and living conditions. Each unit has an average of about 500 inhabitants and Seoul had 16,471 units in 2010 (Statistics Korea, 2014). The database of Korean census tracts for 2010 provides information on boundary maps, population, and employment.

[3] The Seoul Building Registry of 2009 is the key source for building location and built volume by land use.