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The S + 5Ds: Spatial access to pedestrian environments and walking in Seoul, Korea

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ABSTRACT

Previous studies have confirmed that pedestrian environments affect walkers' behaviors in terms of density, diversity, design, destination accessibility, and distance to transit. However, street configuration connects walkers with other built environments. Few studies have yet determined the effects on walking volume by measuring street configurations combined with other walking environments. Thus, by capturing spatial accessibility and centrality to pedestrian environments, this study determines how street configuration, combined with pedestrian environments, affects pedestrian mobility. Our multilevel regression models verify the positive effects of higher access to primary destinations, such as neighborhood retail stores, schools, cultural facilities, and available public transit along the local street network on walking volume. Furthermore, while areas with a higher volume of pedestrian accidents and nonresidential land use are the main venues for walkers, access to residential density and parks has negative or no effects on pedestrian mobility. Finally, the effects of spatial access to pedestrian environments varies with multiple neighborhood scales. The key findings imply the significance of spatial access to pedestrian environments on walking volume. Thus, policies to create pedestrian-friendly neighborhoods should consider the relationship between spatial access to pedestrian environments and walking behaviors.

1. Introduction

As auto-oriented cities face climate change, urban sprawl, traffic congestion, air pollution, and lower quality of life, creating walkable neighborhoods has been the core principle of sustainable and livable cities. Thus, many relevant studies have long been concerned with which urban settings create pedestrian-friendly cities and how the urban spatial structure should be reformed. Specifically, the diverse benefits of walkable cities justify identifying the determinants of walking choice and suggesting policy implications. These benefits include reducing the effects of climate change, pollution, and noise, enhancing public health and local economic performance, and higher social cohesion (Talen & Koschinsky, 2013).

Previous studies have examined the determinants of walking behavior, the specific role of streets in walkable urban settings, and the interconnected effects of streets and other built environments on pedestrian mobility. Many studies have sought the main determinants of walking, including population and employment density, land use diversity, accessibility to destinations, and access to public transits and have verified that a higher density of residents, a higher diversity of land use, and easier access to land uses are strongly associated with higher pedestrian volume (Agrawal & Schimek, 2007). Higher density means that more people live in a specific neighborhood. Dense neighborhoods tend to be safer due to more “eyes on the street” and more accessible services (Loo & Chow, 2006). A mix of residential, commercial, office, and other spaces is positively correlated with walking and cycling, as the local diversity of daily destinations promotes walking between destinations and lower automobile use (Koh & Wong, 2013; Manaugh & Kreider, 2013). Furthermore, easy access to the central business district (CBD), work, and retail stores decreases car use and increases the propensity to walk (Cervero, 2006). Finally, increased access to public transit creates a favorable urban setting that increases walking volume (Bento, Cropper, Mobarak, & Vinha, 2003; Rajamani, Bhat, Handy, Knaap, & Song, 2003). These pedestrian environments have been conceptualized as the 5Ds; namely density, diversity of land use, and design including safety and amenity (the 3Ds), and destination accessibility and distance to transit (the 2Ds) (Cervero & Kockelman, 1997; Ewing & Cervero, 2010).

While previous studies have considered the various determinants of pedestrian-friendly environments, newer research has focused on the specific effects of street networks on walking mobility. The fundamental perspective is that streets are not equivalent to other built environments in terms of urban spatial structure. Design components comprise features such as street environments, amenity, safety, and street density.

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Among street features, the density of street connections used as a proxy for street block size increases the propensity for walking (Jacobs, 1961). Street-focused empirical models have verified that street setting and network connection play different roles in promoting walking behaviors. Mainly, studies of topological and physical settings have found that higher street density and well-linked networks are positively associated with walking choices (Crane & Crepeau, 1998; Song & Knaap, 2004). Quantitative measurement of street networks by catchment area and Space Syntax methods have expanded the perspectives on street networks. The empirical models have discovered that pedestrians tend to concentrate along frequent-use corridors to reach their destinations (Handy, Paterson, & Butler, 2003). Specifically, higher integration and choice of street networks measured by Spatial Syntax methods are positively associated with attracting more walkers along shorter paths (Hillier, 1996; Peponis & Wineman, 2002). Since local features of street networks alter the link between street design and pedestrian volume, the street density, connectivity, and block size of given areas have been used to explain and predict variations in walking behavior (Baran, Rodríguez, & Khattak, 2008).

Recent studies with more advanced perspectives have focused on the combined features of street layout and other built environments to generate variations in walking and cycling (Vale, Saraiva, & Pereira, 2015). The blended features of walking environments substantially affect pedestrian volume and choice. This new framework allows both street layout and other built environments to be considered as a single factor to explain and predict local walking behaviors. First, walking behavior tends to respond to accessibility, both implicitly and explicitly, including density, diversity, distance to destination, and route characteristics. Thus, diverse methods to measure accessibility utilize the relevant information of socioeconomic features, land use patterns, and street features (Dong, Ben-Akiva, Bowman, & Walker, 2006; El-Geneidy & Levinson, 2011; Miller, 2005). More advanced measurements, walkability, and the pedestrian environment index comprise the combined measurement of several built environments (Peiravian, Derrible, & Ijaz, 2014). Second, concurrently measuring both street configuration and other pedestrian environments generates more reliable factors affecting pedestrian mobility. Intuitively, built environments combined with street layout tend to influence walking behavior (Ozbil, Peponis, & Stone, 2011). Third, built environments of destinations along walkable street networks are substantially associated with pedestrians' spatial patterns. Specifically, higher access to commercial than to residential and office use are strongly correlated with walking volume (Kang, 2015). Thus, we need to consider two key factors of pedestrian environments, destinations and neighborhood scale, to capture more reliably the connection between spatial access to built environments and walking behaviors (Kang, 2017).

To date, however, the effects of built environments have not adequately explained or predicted urban walking behavior. Furthermore, most studies have neglected the fact that street layout is not identical to other built environments in terms of walking choice. Rather, street configuration connects walkers with other factors related to pedestrian behaviors. Further, we have less understanding of the neighborhood scales from which effects occur. The accumulation of empirical tests on pedestrian environments and street-focused studies support new insights into how the combination of street configuration and other built environments affects variation in walking volume over multiple spatial scope. Thus, this study raises the unexplored research question of how the combined features of street configuration and other pedestrian environments affect walking volume. We expect this new approach to expand the existing discussion and provide more insight for academic and professional communities. This study also examines whether the research framework of Western studies can be generalized to East Asian cities. Particularly, the use of Seoul as a case allows us to investigate unexplored questions and hypotheses due to its diverse geographical information.

Referring to previous studies and considering local contexts, we have established key hypotheses on the effects of spatial access to diverse built environments on walking volume. First, as previous studies have confirmed, the 5Ds combined with street configuration differently affect walking choice and behaviors. We expect destination accessibility, access to transit, and nonresidential land use diversity along the specific street layout to be positively associated with walking volume, while diversity of overall land use, residential density, access to parks, and pedestrian accidents will confer negative or no effects. In terms of public transit, we expect that access to bus-stops will be more associated with pedestrian volume than access to metro stations, because pedestrians tend to gather near bus-stops to transfer to metro transit (Kitamura, Mokhtarian, & Laidet, 1997; Targa & Clifton, 2005). Furthermore, many studies have verified that easier access to daily destination, mixing nonresidential land use, and access to public transit affect pedestrian volume (Handy, Cao, & Mokhtarian, 2006; Lee & Moudon, 2006). However, the existing literature has verified the inconsistent relation between resident density and diversity of overall land use and pedestrian presence (Cervero, Sarmiento, Jacoby, Gomez, & Neiman, 2009; Frank, Kavage, Greenwald, Chapman, & Bradley, 2009; Zhang, 2004). As walkers and traffic accidents tend to concentrate at specific spots, we expect a positive association between them (Mueller, Rivara, Lii, & Weiss, 1990; Rothman et al., 2014). Second, the effects on variations in pedestrian volume of spatial accessibility and centrality metrics combined with given built environments (such as Reach, Gravity Index, Betweenness, Straightness, and Closeness to pedestrian environments) vary with neighborhood scales. Comparing the metrics of accessibility and centrality provides the specific pattern of relation between pedestrian environment and walking, among other associations (Kang, 2016; Wang, Antipova, & Porta, 2011; Xiao, Webster, & Orford, 2016). This study anticipates that walkers are highly attracted to higher destination accessibility, access to transit, and nonresidential land use diversity along easily reachable, highly accessible, directly-routed, and highly dense street networks. However, locations with highly detoured passing tend to decrease walking presence, as Kang (2015) has confirmed. Third, the neighborhood scales of the effects suggest specific implications for more effective urban design. Thus, many previous studies have attempted to capture impact zones (Kang, 2017; Sarkar et al., 2015). We expect that neighborhood scales of the effects will vary with spatial access to diverse built environments.

The remainder of this study consists of four sections. The first describes the features of the study case and data for the empirical models. The second provides background regarding measuring spatial access to pedestrian environments, variables for the empirical tests, and the multilevel regression models. Specifically, the Background section provides more detailed information. The third section interprets key findings from the empirical models. The fourth discusses the implications of the core results. The final section summarizes this study and suggests the further studies.

2. Methods

2.1. Study case and data sources

Seoul is the largest urban area and capital of South Korea. It is characterized by high population density and mixed land use (housing, retail, offices, manufacturing and warehouses, and other uses) that are well-served by public transit. In terms of pedestrian environments, the length of the sidewalk in Seoul in 2011 was 2789 km (10.25 km^2), with 169 pedestrian overpasses and 88 pedestrian underpasses (Seoul Institute, 2017). Since the 1990s, the Seoul Metropolitan Government (SMG) has attempted to create livable, pedestrian-friendly, and sustainable urban settings to deal with traffic congestion and environmental pollution. The SMG has two policy directions: creating pedestrian-friendly streets and converting car space into pedestrian space. From 2012 to 2015, the SMG supported actions to improve districts and