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Operationalizing Jane Jacobs's Urban Design Theory: Empirical Verification from the Great City of Seoul, Korea

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Abstract

Jane Jacobs's *The Death and Life of Great American Cities* (1961) had an enormous influence on urban design theories and practices. This study aims to operationalize Jacobs's conditions for a vital urban life. These are (1) mixed use, (2) small blocks, (3) aged buildings, and (4) a sufficient concentration of buildings. Jacobs suggested that a vital urban life could be sustained by an urban realm that promotes pedestrian activity for various purposes at various times. Employing multilevel binomial models, we empirically verified that Jacobs's conditions for urban diversity play a significant role with regard to pedestrian activity.

Keywords

built environment, Jane Jacobs, urban design, urban diversity

Introduction

Jane Jacobs's *The Death and Life of Great American Cities* (1961) was one of the first books to criticize the dominant planning paradigm of the latter half of the twentieth century, which primarily consisted of large-scale redevelopment and highway construction. She argued that these forms of development were the primary culprits in the loss of a vital urban life that many cities had experienced (Grant 2002; Sternberg 2000). Jacobs noted that if planners wanted to maintain a vital urban life, they should pursue gradual, small-scale, voluntary civil efforts instead of large-scale, capital-supported redevelopment projects (Laurence 2006). In particular, Jacobs insisted that in order to restore, maintain, or promote a vital urban life in large cities, the physical environment should be characterized by diversity at both the district and street levels. Diversity in this sense required four essential conditions: mixed land uses, small blocks, buildings from many different eras, and sufficient building densities (Jacobs 1961). Many scholars have agreed with Jacobs, emphasizing that a vital urban life relies on the active street life that results from high levels of pedestrian traffic. They argued that vibrant, pedestrian-friendly city streets were crucial to the social, functional, and leisure activities of many city residents (Gehl 1987; Hass-Klau et al. 1999; Jacobs 1961; Kim, Choi, and Kim 2013; Mehta 2007; Moudon 1991; Park et al. 2013; Southworth and Ben-Joseph 1996).

Jacobs's urban diversity conditions are important elements in the concepts of traditional neighborhood development (TND) and transit-oriented development (TOD). For instance, three of the seven TOD planning elements (e.g., density, diversity, and design) stem directly from Jacobs's necessary conditions for diversity (Cervero and Kockelman 1997; Ewing and Cervero 2010; Ha, Joo, and Jun 2011). Mixed land use is a critical component of urban diversity because spatial proximity between different land uses increases the potential for social interactions at the street and district levels (Calthorpe 1993; Jacobs 1961; Krier 1992; Kunstler 1994; Duany, Speck, and Lydon 2010). Jacobs's observations and theories of urban vibrancy remain popular and have provided the basis for various books published after her death in 2006 (Alexiou 2006; Flint 2009; Page and Mennel 2011; Soderstrom 2010).

Jacobs (1961) also pointed out that pedestrian activity should not be constrained to certain times of the day, such as rush hour. Rather, vibrant urban areas required a "sidewalk ballet" that occurred throughout the day. In addition, many studies (Forsyth et al. 2008; Frank et al. 2007; Khattak and Rodriguez 2005; Lee and Moudon 2006;

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Moudon et al. 1997) have focused on the relationship between the built environment and pedestrian activity in newer low- or medium-density suburban communities. But Jacobs's four built environment conditions for maintaining a vital urban life in a large urban area have not been empirically tested or verified (Hill 1988; Grant 2010; Sung, Go, and Choi 2013).

This study operationalized Jacobs's observations regarding urban diversity and a vital urban life. In addition, this study addresses the importance of pedestrian activity that occurs at different times of the day. Seoul has a very dense built environment and a well-established public transportation system that is similar to New York, the city where Jacobs lived and observed as she developed her theories. While New York and Seoul differ in some of their physical environment characteristics, as well as in their physical and socioeconomic characteristics, both represent the types of large, dense urban areas that Jacobs addressed when she developed her design theories for a vital urban life. As such, this study contributes to a greater understanding of how Jacobs's theories of a vital urban life contribute to active levels of pedestrian activity.

Jacobs's Urban Diversity and Vital Urban Life

Jane Jacobs states in *The Death and Life of Great American Cities* (1961) that "death" in urban areas is caused by the elimination of pedestrian activity from urban streets due to new highway construction and large-scale urban development projects. Since these were the dominant forms of urban development at the time of her writing, her book triggered controversy and a massive reappraisal of the urban planning practice. Her main point, that the physical environment required diversity, was heavily criticized. In particular, Lewis Mumford (1962) described her theories merely amateur solutions in a book review titled "Mother Jacobs' Home Remedies for Urban Cancer" (Klemek 2007). Despite these criticisms, Jacobs's "amateur solution" significantly influenced the advocacy planning movement and formed much of the theoretical basis for New Urbanism (Laurence 2006).

Jacobs's theories not only influenced urban planning and design practices in the United States but also in Europe and especially in Canada, where they contributed significantly to mixed-use land development practices (Grant 2002; Klemek 2007). An emphasis on diversity within the built environment and on small blocks was listed as crucial to the formation of twenty-four-hour cities in *The Smart Growth Manual* recently drafted by Duany, Speck, and Lydon (2010). Jacobs was careful to note that her theories of urban diversity were intended to apply to large cities such as New York and Chicago. Her observations are not applicable for guiding development in small towns or suburban areas.

For Jacobs, a vital urban life meant a continual "sidewalk ballet" consisting of a streetscape filled with pedestrians at all times of the day. This urban vitality will not be possible if pedestrian activity is restrained to a single purpose during a certain time of day. Rather, streets should experience a "cross-use" of activity related to a range of different purposes, which allow pedestrian activity at all hours of the day. This generates the possibility of diverse face-to-face interactions and a preponderance of "eyes on streets," which increases public safety. To achieve these goals, Jacobs presented four essential diversity requirements for the built environment. First, a district should have two or more primary uses. This means that a mix of land uses is necessary. Districts with more than one primary use will feature pedestrian activity related to different purposes at different times of the day. Jacobs argued that this mix of uses should be maintained across an entire city and across all city streets. The former allows small business establishments to operate in all areas of the city. The latter can increase urban diversity if city streets house a number of diverse shops. Jacobs also emphasized that a land use mix depends on the presence of three population groups: company employees, residents, and visitors.

Second, Jacobs argued that most city blocks should be short in order to create more alternate travel routes and more streets. She argued that superblocks and rectangular blocks produce an urban form that increases travel distances and provides fewer opportunities for cross-use. Jacobs noted that short and close-knit blocks complemented mixed land uses, thereby enhancing urban diversity. Small blocks produce more intersections, and thus slow down vehicles and shorten pedestrians' travel distance. This viewpoint was reflected in the U.S. TOD guidelines (Calthorpe 1993) and in UK compact city development guidelines such as the *Urban Design Compendium* (LDP 2000). Jacobs did not exclusively emphasize that square-shaped grid blocks were ideal, but existing streets in many large cities have already developed along a square grid pattern. As such, this pattern has been the one primarily favored by U.S. TOD and by the United Kingdom for compact city design.

Third, Jacobs argued that the buildings in a district should be mixed with regard to age and form in order to ensure diverse economic activity. A diversity of building types will allow for a diverse range of jobs, including high-, medium-, and moderate-income jobs. Her emphasis on old buildings was a critique of the large-scale buildings and large-scale redevelopments that were popular in Jacobs's New York and elsewhere in the United States in the post–World War II era. These large-scale projects often developed an entire city block at a time and were typically single-use. Jacobs noted that these developments would have difficulty adapting to change over time. As a result, they were at risk of deteriorating into slums. Jacobs argued that districts with buildings from a range of historical eras and with a range of forms could creatively accept new, small-scale construction and economic changes. In addition, diversity of building ages and forms can also promote the coexistence of high- and low-income residents in the same area (Fainstein 2000; Grant 2010; Gordon and Ikeda 2011; King 2013).

Fourth, the built environment should contain a sufficient concentration of buildings to attract people. This applies to both residential and nonresidential urban areas. Jacobs emphasized, however, that the intense use of land alone cannot create urban diversity; the aforementioned three elements must also be met. Jacobs believed that building density would have no effect if the buildings were too standardized in terms of age and form, if the blocks were too long, or if the buildings only served a single use.

In addition to the four diversity requirements, Jacobs emphasized accessibility to neighborhood parks and transport facilities, and border vacuums as additional factors important to walking activity. But these are not necessary conditions for diversity. She argued that the true utility of neighborhood facilities, such as parks, is to encourage and enhance activity throughout the day. For example, neighborhood parks adjacent to single-function residential and business establishments may be intensively used at a certain time of the day but not at other times. This could cause the area to decline and attract crime. To counter this effect, Jacobs emphasized small parks as an alternative. She pointed out that small parks did not create border vacuums, but rather served as nodes to create and coordinate pedestrian activity, and thus promote a vital urban life.

Furthermore, Jacobs observed that arterial-line bus stops or railway stations were similar to small parks in that they interacted with their surrounding physical environment and served as hubs for pedestrian activity. She argued that public transportation systems should consist of arterial lines that connect a city's peripheral areas to downtown so neither will be eroded by excessive private car use. She argued that rather than expanding roads, small-scale blocks should be formed and sidewalks expanded in order to bolster a vital urban life.

Jacobs also noted that border vacuum areas will hamper a vital urban life. Vacuum areas are large-scale, single-use areas or transit facilities. Examples include on-ground railways, wharfs, university campuses, highways, large-scale parking lots, and large-scale parks. Jacobs acknowledged that these areas were necessary, but she also noted the importance of controlling their negative effects on pedestrian activity. Vacuum areas are dead ends for most street users, and by restricting walkability, they hamper a vital urban life. Specifically, the streets adjacent to these borders are often a pedestrian's last destination, and these barriers restrict cross-use. Jacobs argued that public facility buildings also serve as borders, and they should be improved to encourage walking activity. For instance, Jacobs argued that in the case of large-scale parks, the installation of facilities can trigger pedestrian activity near entrance areas and can prevent "the curse of border vacuums." Although she did not suggest that the control of border vacuums was one of the necessary conditions for urban diversity, Jacobs observed that controlling for the negative effects of these borders was important to maintaining urban vitality.

Case Study Area, Data Source and Measurements

Introduction to Seoul

This paper empirically verifies the impact of Jane Jacobs's urban diversity theories for vital urban life using the city of Seoul as a case study. Jacobs argued that these theories will not apply to towns, small cities, or suburban areas, but rather to large American cities like New York. Seoul, with an area of 607 km^2 and a population of 10 million, was selected because it has much in common with the large American cities that Jacobs examined.

Seoul is the capital of South Korea and serves as the economic and industrial hub of the country. The city lies at the center of the Korean Peninsula and is divided into southern and northern sections by the Han River (see Figure 1). Like the rest of the country, Seoul has rapidly urbanized since the 1960s. Beginning in the late 1980s, the city began to develop several large-scale housing projects in order to meet a rapid increase in housing demand. This expansion of high-density development led to increased travel distances and an excessive dependence on private automobiles, which has produced serious traffic congestion.

Seoul is a high-density city that provides and maintains an extensive public transportation system. When the neighboring cities of Gyeonggi and Incheon (which make up the greater Seoul area) are excluded, Seoul has a higher population density than other large cities such as New York and Tokyo (Sung and Oh 2011). Seoul also boasts a well-organized and extensive public transportation system. Since the early 1970s, when Seoul's first urban railway systems opened, the city has invested heavily in passenger rail. As of September 2010, Seoul had several urban rail lines and six multiregion railway lines. The city itself has approximately three hundred railway stations. Because of these continual, large investments, Seoul's public transportation system accounts for 65 percent of all trips taken within the city, a figure that is much higher than that of any other domestic or large foreign city. Moreover, in 2012 Seoul announced a goal of becoming a more pedestrian-friendly city. The city plans to implement car-free streets and transit malls in order to encourage greater pedestrian activity and to discourage private automobile use.

Seoul has a higher residential density and a more expansive public transport system than New York, the city that inspired Jacobs to develop her theories of urban diversity and vitality. As such, Jacobs's theories of urban design, which were highly critical of mid-twentieth-century large-scale redevelopment projects, can have important policy implications for Seoul's redevelopment strategies. This is because Seoul has recently embarked on several large-scale urban redevelopment projects. It is very similar to the large-scale urban redevelopment projects Jacobs criticized for harming urban diversity. At the same time, the new Seoul government

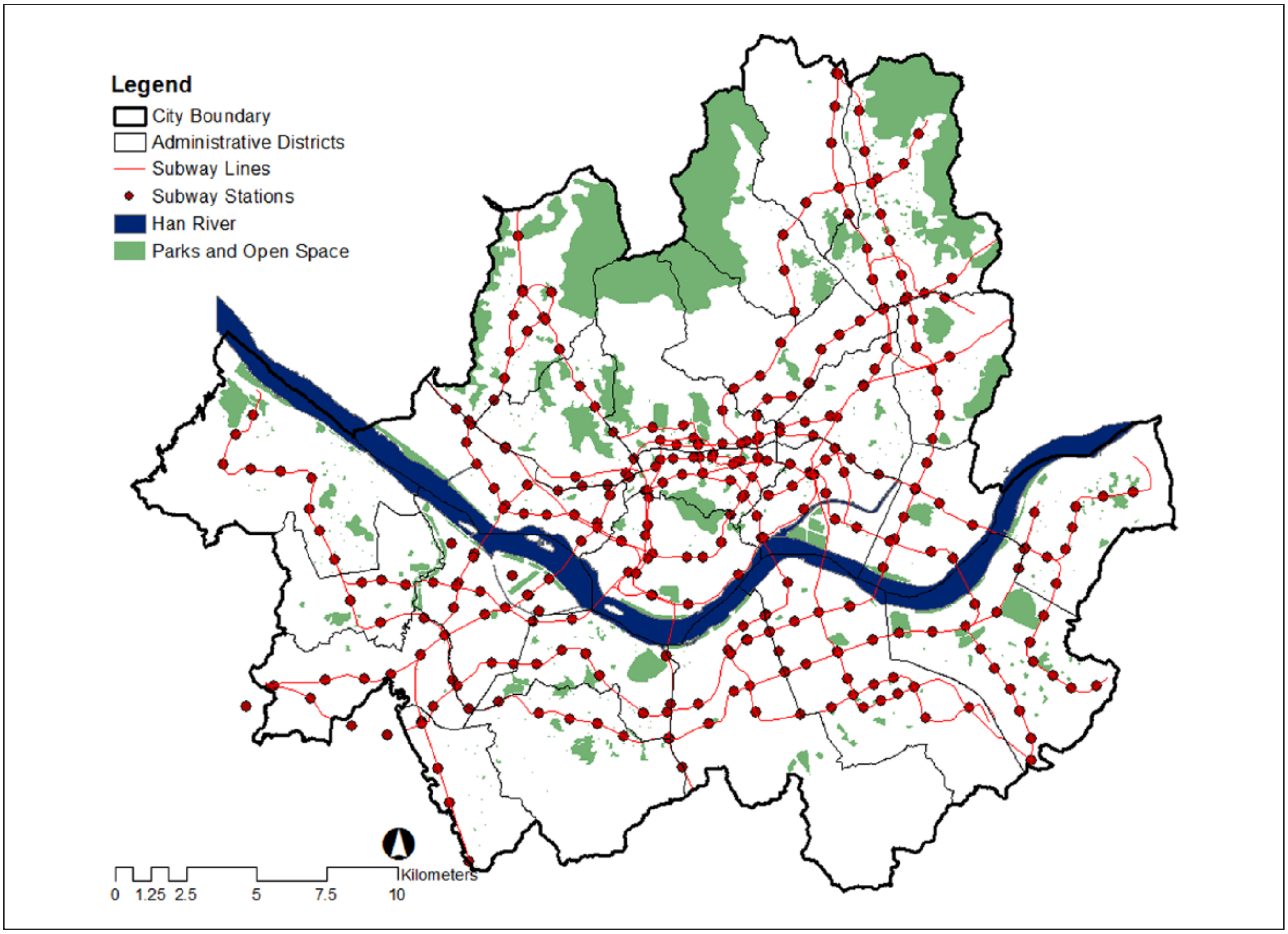

Figure 1. The city of Seoul.

is also attempting to spur urban regeneration in small districts. Since 2000, these smaller projects are progressing alongside mass redevelopment projects, so empirical research on Jacobs's urban diversity and vitality should provide important policy implications for Seoul.

Measuring Jacobs's Urban Diversity and Its Generators

We operationalized Jacobs's urban diversity variables using built environment data obtained for each *dong*, the smallest administrative unit in the city of Seoul. In 2010, Seoul had 424 *dongs*, with one *dong* covering an average area of 14.3 km^2. The total population of all *dongs*, which includes the residential population and the number of people engaging in economic activity, averages 34,768 people. The average population density of each dong is 3,481.3 people per km^2.

The sizes of these administrative units are similar to Jacobs's district concept. Jacobs proposed that the edge of an administrative district should not exceed 2.4 km and that each district should have a minimum population of fifty thousand. In comparison, Seoul's *dongs* are somewhat larger in average area and somewhat smaller in average population. But Jacobs had no strict criteria for a district's size and population, so Seoul's *dongs* are an appropriate unit comparable to a district as defined by Jacobs.

Jacobs (1961) frequently used such phrases as "sidewalk ballet," "street life," and "eyes on the street." Jacobs used these terms to emphasize that urban vitality requires pedestrian activity. She warned that automobiles will destroy vitality by eliminating the presence of pedestrians. Jacobs referred to people who walk as "foot people" and people who use automobiles as "car people" (Jacobs 1993). Alluding to the title of her book, Jacobs noted that foot people brought the urban physical environment to life while car people contributed to its death. Jacobs argued that walking is the preferred transportation mode in a dense and diverse urban area, but a lack of density will force people to travel by private automobile, regardless of their travel purpose (Jacobs 1993).

Thus, it is important to examine how walking, compared to driving, can be influenced by the built environment at the city, district, and street levels with regard to travel mode choice. This study views the choice between walking and driving as the result of built environment, and it measures their corresponding effects. Jacobs also emphasized that cross-use is more important for a vital urban life than the total amount of pedestrian activity. This means that twenty-four-hour street life is a more critical component of a vital urban life than the amount of walking activity at any particular time of day.

This study uses the 2010 Household Travel Survey Data (City of Seoul 2010) to analyze walking and driving activity on weekdays. The survey is conducted every five years to determine travel activity in the Greater Seoul area, which includes the City of Seoul and the surrounding cities and counties. A minimum sampling ratio ranges from 2.4 to 3.6 percent of the population at the smallest administrative level, depending on its size. The spatial unit of sampling, Seoul's *dongs*, is the same as the unit of analysis in this study. Of the total 226,725 surveyed households, 43.3 percent reside in the City of Seoul, this study's area of focus. The focus of this study was home-based trips, as the data shows that 87.2 percent of the total 705,820 trips were either to or from home. We did not include trips made by non-working-age residents (residents aged less than nineteen and beyond sixty-five years), trips that were not walking or driving, and trips that included a transfer to another transportation mode.

Using the survey's raw data, individual travel choices were categorized as either private car use or on foot, and a binomial discrete model for the probability of a resident's choice of walking was constructed. To define the characteristics of twenty-four-hour cross-use, travel was also categorized by the time of day it occurred. These included morning peak time (0600–0900), day time (0900–1800), afternoon peak time (1800–2000), and nighttime (2000–2400). The travel data was merged with the built environment data based on the spatial unit—the dong—where respondents lived. The peak travel times were based on previous studies (Sung, Go, and Choi 2009; Park, Lee, and Cho 2012) that identified hourly variations using the previous editions of the Seoul Household Travel Survey (City of Seoul 2006) and the Seoul Walking Survey (City of Seoul 2010).

The Korean government has produced extensive geographical information databases that provide a range of information about buildings and their parcels, as well as for parks, rivers, railways, and other major facilities. For this study, databases suitable for deriving the features of Seoul's physical environment include the New Address Information Database, the Seoul Land Use Information Database, the Nationwide Firm Statistics Survey Data, and the Population and Housing Census Data. Also, detailed geographical information on roads and intersections was obtained from the Korea Transport Database. Therefore, this study measures Jacobs's diversity indexes for Seoul's physical environments based on the aforementioned geographical information area, and it calculates lot sizes using Arc GIS software.

Unlike previous studies, this study does not use an administrative unit's demographic and socioeconomic characteristics to measure Jacobs's diversity indexes. Instead, physical facility types, sizes, and geographical information are used. Jacobs described a city as containing districts and streets. Thus, this study compiles diversity indexes by using data from the physical urban environment. Sample physical property data that was derived and compiled using Arc GIS is shown in Figure 2, showing two different built environment types and their characteristics. The left side of the figure mostly consists of large high-rise apartment complexes. The urban fabric is very homogeneous in terms of land use and building types. In contrast, the right side of the figure mostly consists of densely developed small buildings, different land uses, and small blocks. Based on Jacobs's urban design theories, the built environment on the right side reflects a diverse urban environment that will encourage more walking activity than the built environment on the left side.

As explained previously, Jacobs (1961) argued that urban vitality depends on four necessary and sufficient conditions and one additional complementary condition. Her argument is summarized as follows: to maintain or restore vitality to an urban area, it is necessary to secure two or more major mixed land uses, short blocks, old buildings, a diversity in building form, a concentration of buildings great enough to attract people, and a control of border vacuums. Table 1 summarizes the statistics for the variables derived from the databases used in this study.

Mixed Land Use. Jacobs (1961, 1993) emphasized the necessary condition of mixed primary uses at the district level. Primary use categories include residential, office, industrial, entertainment, education and recreation, museums, libraries and galleries, etc. (Jacobs 1993: 209). We employed two measurements to determine the relative level of mixed uses. First, we calculated an area-based combination of two or more major uses. Second, we calculated an accessibility-based mixed use measurement. Mixed land use measurements were calculated using two indexes based on a building's use and gross floor area. These were the Land Use Mix (LUM) index and the residential and nonresidential balancing index (RNR index). The LUM index uses an entropy index to denote the relative mix of two or more uses within a single *dong*. Calculations range from 0 to 1, with 1 indicating a *dong* of perfectly balanced land use mixes. This index was originally applied by Cervero (1988) and other scholars, including Frank and Pivo (1994), Cervero and Kockelman (1997), Frank et al. (2006), and Sung, Go, and Choi (2013). From the equation below, P_i is the proportion of building square footage of land use i and n is the number of land uses.

$$LUM = \sum_{i=1}^{n} \frac{\left(P_i * lnP_i\right)}{ln(n)};$$

$$RNR_i = 1 - \left| \frac{Res_i - Non\_Res_i}{Res_i + Non\_Res_i} \right|$$

Figure 2. Comparison of neighborhood built environment in Seoul.

The RNR balancing index calculates the mix of residential uses with nonresidential uses for an administrative district, *dong*. From the equation above, the RNR index ranges from 0 to 1. Like the LUM index, a higher score indicates a district with more balance between residential and nonresidential uses. Specifically, the three defined RNR index categories are residential and nonresidential for daily and nondaily uses, residential and nonresidential uses for daily uses, and residential and nonresidential uses for nondaily uses.

The current Korean Building Construction Act lists twenty-eight categories of building uses. This study recategorized all building uses into five categories based on building use distribution. The five major building use categories are residential, daily neighborhood life, non-daily use, office, and other. Daily neighborhood life uses refer to buildings that residents use for everyday activities. These include small convenience stores, restaurants, medical facilities, and sports facilities. Daily neighborhood life buildings are generally small, although sizes can vary depending on their use, and may range from 300 m^2 to 1,000 m^2. Non-daily-use buildings refer to cultural and meeting facilities, sales and business facilities, medical facilities, education and research facilities, sports facilities, or all facilities with a total floor area larger than daily neighborhood life buildings. For land use mix, we developed land use mix measure (LUM5) for five land use categories in addition to the RNR balancing index of residential and nonresidential daily uses. In addition, we developed a housing mix index for different housing types such as single-family, multifamily, apartment, and others.

Jacobs observed that neighborhoods should serve more than a single purpose. This requires a range of facilities that are commonly used. Based on her observations, we developed distance-based mixed use measures among building uses using GIS. These measures included the average distances between the nearest nondaily use building or office building and all other buildings. A lower average distance between an office building and all other buildings indicates that office buildings are mixed with other building uses.

Block Size and Contact Opportunities. Jacobs presented small block sizes as the second necessary condition for diversity, as they corresponded to increased opportunities for social interaction, particularly at street corners. Specifically, she emphasized that opportunities for interpersonal contact will increase

Table 1. Variables and Summary Statistics.

Variables	Variable Name	Descriptions	Observations	Mean	Standard Deviation	Minimum	Maximum
Dependent variables							
Model A	Walking_all	1 = walking; 0 = driving (all day 7AM–12PM)	170,084	0.471	0.499	0.000	1.000
Model B	Walking_am_pt	1 = walking; 0 = driving (peak time 7AM–9AM)	50,050	0.294	0.456	0.000	1.000
Model C	Walking_daytime	1 = walking; 0 = driving (9AM–6PM)	54,380	0.320	0.466	0.000	1.000
Model D	Walking_pm_pt	1 = walking; 0 = driving (peak time 6PM–8PM)	22,255	0.131	0.337	0.000	1.000
Model E	Walking_night	1 = walking; 0 = driving (8PM–12PM)	17,348	0.102	0.303	0.000	1.000
Independent variables: Level 1 (personal/ household)							
Gender	Gender	1 = female, 0 = male	170,084	0.473	0.499	0.000	1.000
Age	Age	Years old	170,084	45.121	11.212	19.000	65.000
Job type	Job_type1	1 = professional/office jobs; 0 = no job/housewife	170,084	0.291	0.454	0.000	1.000
	Job_type2	1 = other job types; 0 = no job/housewife	170,084	0.376	0.484	0.000	1.000
Num. children	Num_child	Number of children	170,084	0.157	0.446	0.000	4.000
Car ownership	Car_own1	1 = one car per household; 0 = no car	170,084	0.623	0.485	0.000	1.000
	Car_own2	2 = two or more cars per household; 0 = no car	170,084	0.155	0.362	0.000	1.000
Monthly household income	Mhh_inc	1 = <$1,000, 2 = $1,000–$2,000, 3 = $2,000–$3,000, 4 = $3,000–$5,000, 5 = $5,000–$10,000, 6 = ≥$10,000	170,084	3.523	1.181	1.000	6.000
Independent variables: Level 2 (district)							
Mixed land use	LUM5	Entropy index of five categories for land use mix (i.e., residential, daily neighborhood life, nondaily use, office, and others)	170,084	0.412	0.176	0.009	0.962
	R_nres_daily	Balancing index between residential and nonresidential daily uses	170,084	0.120	0.128	0.000	0.926
	Htype_mix	Entropy index of four categories of housing types (i.e., single-family, multifamily, apartment, others)	170,084	0.554	0.256	0.000	0.911
	Mdist_nres_daily	Mean distance of all buildings to the nearest nonresidential daily use building	170,084	37.610	26.997	5.431	240.01
	Mdist_com	Mean distance of all buildings to the nearest commercial use building	170,084	266.435	172.313	9.139	1,519.6
	Mdist_off	Mean distance of all buildings to the nearest office building	170,084	1,418.2	1,142.6	0.000	4,514.0
Small block and contact opportunities	Nden_intersect.	Net density of intersections (number of intersections/net administrative district area)	170,084	0.000	0.000	0.000	0.001
	Ratio_4w_intersect.	Ratio of 4-way intersections (number of 4-way intersections/all intersections)	170,084	0.647	0.072	0.420	1.000
	Mdist_intersect	Mean distance of all buildings to the nearest intersection	170,084	540.0	481.4	86.8	3834.9
Aged building and small enterprises	Bldg_age_mean	Average built year of all buildings	170,084	1,978.5	1.351	1973.2	1983.6
	Bldg_age_sd	Standard deviation for the built years of all buildings	170,084	8.470	3.583	2.830	42.903
	Enterprise_size	Average no. of employees per firm	170,084	5.489	3.457	1.937	24.880
Density and concentration	Nden_pop(a)	Net population density	170,084	0.028	0.011	0.000	0.055
	Nden_emp(b)	Net employment density	170,084	0.011	0.024	0.000	0.566
	Nden_interact(a/b)	Net density interaction (pop/emp)	170,084	4.696	3.513	0.010	21.250
	Nden_nres_daily	Net density of nonresidential daily use floorages	170,084	0.043	0.039	0.000	0.277
	Nden_nres_ndaily	Net density of nonresidential nondaily use floorages	170,084	0.100	0.190	0.000	3.699
	Nden_off	Net density of office use floorages	170,084	0.031	0.068	0.000	1.091
Border vacuums	Ratio_bldgroups	Ratio of number of building groups to number of all buildings	170,084	0.057	0.040	0.000	0.275
	Mdist_railway	Mean distance of all buildings to the nearest on-ground railway	170,084	1,782.6	1,223.1	0.000	4,517.9
	Mdist_expway	Mean distance of all buildings to the nearest expressway	170,084	1,319.4	877.6	114.8	4,365.3
	Mdist_river	Mean distance of all buildings to the nearest river/stream	170,084	753.2	439.5	148.1	2,566.8
	Mdist_station	Mean distance of all buildings to the nearest rail station	170,084	542.8	354.2	117.8	2,849.8
	Mdist_park	Mean distance of all buildings to the nearest park	170,084	371.2	313.6	60.8	2,238.5

Note: Monthly household income is a categorical variable but employed as a continuous variable in the models; net area (m^2) subtracts parks and rivers/streams from each district area; all distance measures are in meters (m).

with the amount of street corners. Density measures of each administrative district, including population and street intersections, were calculated using the district's net area (m^2) while excluding areas such as rivers and natural parks.

The block size indexes include the street intersection density (i.e., the number of intersections/net administrative district area), the ratio of four-way intersections to the total number of intersections (i.e., number of four-way intersections/total number of intersections), and the average distance of all buildings to the nearest intersection. The street intersection density has been widely used as a proxy variable to represent average block size in a designated area (Ewing and Cervero 2010; Ewing and Bartholomew 2013; Sung, Go, and Choi 2013). A high street intersection density indicates an area with smaller blocks. Lastly, we included the mean distance of all buildings to the nearest intersection. A smaller mean distance indicates increased opportunities for street-level social interactions. Jacobs criticized the existences of large-scale rectangular blocks, since they prevented people from interacting at street corners.

Aged Buildings and Small Enterprises. Jacobs emphasized the need for older buildings. These buildings encourage the proliferation of small and diverse enterprises, which produces more vigorous streets and city districts. This study measured the diversity of building ages in each administrative district using the mean and standard deviation of the year all buildings in an administrative district were built. The average age of buildings reflects the level of building age for a district's building stock, and the standard deviation of the building age reflects the level of heterogeneity in terms of a district's building age. Specifically, a larger mean for the year building built reflects a district with newer buildings. A greater standard deviation of building ages reflects a greater diversity between old and new buildings within a district.

Jacobs also noted that aged buildings are very important for small-size enterprises, because ordinary and low-value old buildings are often more affordable to small businesses. We thus developed a variable for the average enterprise size within each district using the average number of employees per firm.

Density and Concentration. Jacobs's fourth diversity condition called for a sufficient concentration of buildings to attract people. She observed that both residential and nonresidential urban land should be intensively used. Therefore, we employed two concentration measures, one for people and one for buildings. First, population and employment density measures were calculated by dividing the number of people and employees by each administrative district's net area, respectively. In addition, an interaction term between the two measures was calculated by dividing population density by employment density. If the interaction term is positive and significant, it indicates that walking is chosen more than driving, as the district's population density is relatively higher than employment density.

The building density within an administrative district was calculated by dividing the total floor area of all buildings for each use type by the district's net area. We included the net density variables of floorages for nonresidential daily neighborhood use buildings, nonresidential nondaily neighborhood use buildings, and office use buildings.

Border Vacuums. Jacobs described "the curse of border vacuums" as one of the major obstacles to urban vitality. Border vacuums can be defined as either large or lengthy built environment features such as heavy rail tracks, large parks, highways, rivers, or large-scale single-use buildings. In order to identify the impact of these vacuums, we calculated the average distance from a district's buildings to all bordering facilities. Bordering facilities included large-scale developments of two or more buildings, heavy rail tracks, urban and regional expressways, rivers and streams, rail stations, and parks. According to Jacobs, these features can either separate neighboring areas or create a hub that connects them. For instance, proximity to nearby expressways may create a barrier that discourages pedestrian activity. However, a large park can create a hub of pedestrian activity if it is efficiently managed.

Methodology

The multilevel binomial logistic model, also known as a random-effects logistic model, was used to evaluate the relationship between walking and operationalized built environmental measures for Jacobs's urban diversity. The binominal logistic model is a discrete model with values of either 0 or 1. The choice to travel by private car is classified as 0 and the choice of travel by walking is classified as 1. The explanatory variables used herein are not only Jacobs's diversity indexes in both district-level neighborhood units and accessibility-based distance units but also the individual-level demographic and socioeconomic properties. This is because travel modes are chosen not only according to an individual's surrounding physical environment but also according to an individual's preferences and attitudes. Here, the individual-level explanatory variables are classified as control variables to more accurately estimate the effects of Jacobs's diversity indexes. The final selected individual-level explanatory variables were the gender, age, job type, number of preschoolers per household, car ownership, and monthly household income. The job types were categorized into nonworkers such as homemakers and jobless people, professionals and administrative office workers, and technical and sales people. Car ownership was categorized into no car, one car per household, and two or more cars per household. Individual demographic and socioeconomic properties, such as gender, job type, and car ownership, were treated as dummy variables.

In order to include the diverse hierarchical data of individuals and administrative districts in one model, a multilevel bionomical logistic model was constructed. If the administrative district *dong*-level data are dealt with at the same level as individuals' demographic and socioeconomic data, an ecological fallacy may occur (Rabe-Hesketh and Skrondal 2008; Hox 2010). This is called the Robinson effect, and refers to the error in interpreting the district-level aggregated data at the individual level. Here, the model was categorized into individuals (level 1) and district-level neighborhoods (level 2), resulting in a two-level model.

Using the 2010 Household Travel Survey Data for the City of Seoul, we developed five dependent variables that include the total numbers of home-based walking trips and home-based driving trips during a designated time interval (i.e., morning peak time, day time, afternoon peak time, and nighttime). Models were created in which each of these five dependent variables is explained by identical independent variables. Table 1 shows the variable names and their descriptive statistics. The data used in the analysis consisted of 170,084 total trips, 50,050 morning peak time trips, 54,380 daytime trips, 22,255 afternoon peak time trips, and 17,348 nighttime trips. Regarding the specification for final models, we have tested a series of models with different combinations of independent variables after testing multicollinearity issues. Since the multilevel binomial logistic model does not report an R-squared value, we selected final models based on goodness of fit using the Akaike information criterion (AIC) and the Bayesian information criterion (BIC).

Analysis Results and Interpretations

Table 2 shows the association between the probability for choosing walking over private cars and Jacobs's urban diversity indexes. Overall, the individual demographic and socioeconomic properties, namely, the control variables, were statistically significant in each time interval model. In addition, the coefficients' directions were consistent. Specifically, female, younger people and nonemployed people chose to travel by walking more than by private car. Also, walking was chosen more by households with fewer preschoolers, by people with fewer cars, and by people with lower income.

Jacobs described built environment diversity in American cities, particularly in New York in the mid-twentieth century, as the driving force behind urban vibrancy. Table 2 proves that Jacobs's urban diversity elements such as mixed land use, small block sizes, aged buildings and small enterprises, building density, and a control of border vacuums could be important factors that influence people to choose walking over driving in Seoul. The empirical verification of Jacobs's urban design theory of the physical environment showed that although some built environment variables for urban diversity were not consistently significant across all models, her viewpoint is generally valid. Our interpretations of the results for each design element are provided below.

Mixed Land Use

Our analysis of the results indicates that the land use mix for the five land use categories and for the land use balancing index between residential and non-residential daily uses did not show statistically significant associations for the choice of walking over driving. However, the housing mix index for housing types shows statistically significant and positive associations, indicating an association between the diversity of housing types and walking. This finding indicates that a diversity of housing types at the neighborhood level may increase the probability of choosing walking over driving. Low-rise housing types have a greater possibility for increasing the mix of uses. In particular, this can be done at the ground floor, where nonresidential daily living uses such as restaurant and general stores can be installed to promote walking activity among residents.

The distance-based proxy variables for mixed uses indicate that the proximity to commercial buildings is significant for encouraging walking activity across four of the models, although proximity to office uses does not show a significant association with walking. Proximity to nonresidential daily-use buildings shows only a weak significance for walking in Model B. This finding indicates that proximity to commercial uses is more important than proximity to office uses when promoting walking over driving. The other distance measures for border vacuums, such as the proximity to rail stations and large parks, have positive effects for walking choice. This indicates that proximity to public facilities such as rail stations and parks will influence people to choose walking over driving.

Block Size and Contact Opportunities

The analysis of short, small-scale blocks suggested that Jacobs's theoretical approach is generally true. In particular, although street intersection densities did not show consistent results for all models, the net intersection density variable shows a weak association with walking probability in Model B. The ratio of four-way intersections to all intersections was not statistically significant, except for a negative association with walking choice for nighttime travel in Model E.

Jacobs believed that the lot size and street-level interaction opportunities—which are expressed by the average distance from a building entrance to street corners—can increase walking activity. This analysis showed that, generally, a shorter distance from a building to a street corner will increase the likelihood of walking.

Aged Buildings and Small Enterprises

The analysis results showed that among Jacobs's physical diversity planning elements, the existence of old buildings played a significant role in encouraging "foot" people over "car" people. All models except Model B showed a

Table 2. Analysis Results of Multilevel Binomial Logistic Model.

Variable Description	Model A (All-Day)		Model B (Morning Peak Time)		Model C (Nonpeak Day time)		Model D (Afternoon Peak Time)		Model E (Night time)	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Level 1 (personal/household)										
Gender	1.462***	103.76	1.437***	56.21	1.244***	45.52	1.687***	43.75	1.130***	26.95
Age	−0.024***	−40.76	−0.026***	−23.52	−0.023***	−22.11	−0.013***	−7.26	−0.027***	−14.82
Job type										
Job_type1	−1.594***	−89.19	−1.751***	−51.65	−1.368***	−39.35	−1.416***	−24.70	−1.806***	−28.94
Job_type2	−1.000***	−59.96	−1.034***	−31.35	−0.859***	−30.18	−0.960***	−17.09	−1.026***	−16.89
Num. child	−0.487***	−33.16	−0.510***	−18.37	−0.451***	−18.95	−0.423***	−9.56	−0.629***	−12.21
Car ownership										
Car_own1	−1.466***	−88.37	−1.549***	−50.92	−1.468***	−44.79	−1.515***	−34.20	−1.429***	−28.57
Car_own2	−2.706***	−108.55	−2.839***	−59.79	−2.782***	−64.03	−2.589***	−37.02	−2.478***	−32.75
Mhh_inc	−0.195***	−32.24	−0.194***	−17.00	−0.234***	−22.27	−0.142***	−8.36	−0.152***	−8.12
Level 2 (district)										
Mixed land use										
LUM5	0.224	1.46	0.118	0.71	0.368*	1.85	0.139	0.66	0.210	0.85
R_nres_daily	−0.369	−1.19	−0.186	−0.56	−0.657	−1.63	−0.124	−0.29	0.006	0.01
Htype_mix	0.360***	3.05	0.186	1.47	0.485***	3.24	0.368**	2.26	0.323*	1.72
Mdist_nres_daily(ln)	−0.063	−1.44	−0.080*	−1.72	0.015	0.27	−0.081	−1.36	−0.022	−0.32
Mdist_com(ln)	−0.157 ***	−4.51	−0.137 ***	−3.68	−0.185 ***	−4.16	−0.111 **	−2.35	−0.173 ***	−3.15
Mdist_off	4.7E-06	0.27	1.2E-05	0.68	4.7E-06	0.21	4.5E-07	0.02	1.2E-05	0.46
Small block and contact opportunities										
Nden_intersect.	242.877	1.04	467.679*	1.89	439.410	1.48	45.029	0.14	191.037	0.53
Ratio_4w_intersect.	−0.049	−0.19	0.079	0.28	−0.195	−0.59	0.432	1.22	−0.770 *	−1.87
Mdist_intersect	−1.0E-04**	−2.36	−1.4E-04***	−3.00	−6.0E-05	−1.13	−8.8E-05	−1.54	−2.7E-05	−0.42
Aged building and small enterprises										
Bldg_age_mean	−0.040**	−2.42	−0.020	−1.14	−0.041**	−1.96	−0.074***	−3.25	−0.063**	−2.35
Bldg_age_sd	−0.001	−0.12	−0.001	−0.19	−0.002	−0.34	−0.004	−0.52	−0.009	−1.01
Enterprise_size	−0.013	−1.39	−0.020**	−2.05	−0.008	−0.71	0.001	0.07	−0.001	−0.09
Density and concentration										
Nden_pop(a)	0.082	0.03	−2.540	−0.86	5.478	1.56	1.970	0.53	5.928	1.37
Nden_emp(b)	0.719	1.09	1.269*	1.80	0.466	0.50	−0.817	−0.89	1.677*	1.70
Nden_interact(a/b)	−0.014*	−1.67	−0.018**	−1.99	−0.009	−0.84	−0.015	−1.28	−0.028**	−2.07
Nden_nres_daily	0.620	0.67	0.631	0.63	0.497	0.41	2.168*	1.73	−1.529	−1.01
Nden_nres_ndaily	0.217***	2.68	0.230**	2.53	0.210*	1.88	0.255**	2.13	0.092	0.66
Nden_off	0.901***	2.79	0.987***	2.66	0.810*	1.78	0.571	1.23	0.783	1.40
Border vacuums										
Ratio_bldgroups	−1.042 *	−1.89	−0.147	−0.25	−1.183 *	−1.69	−0.767	−1.02	−2.536 ***	−2.86
Mdist_railway	2.1E-07	0.01	3.4E-06	0.20	−2.7E-05	−1.30	1.9E-05	0.85	1.9E-05	0.73
Mdist_expway	5.5E-05**	2.39	7.5E-05***	3.07	6.7E-05**	2.30	−5.4E-06	−0.18	9.7E-06	0.27
Mdist_river	1.2E-05	0.27	−8.1E-06	−0.17	2.0E-05	0.34	1.0E-04*	1.69	4.6E-06	0.07
Mdist_station	−1.7E-04***	−2.88	−1.6E-04**	−2.54	−1.1E-04	−1.50	−1.8E-04**	−2.30	−1.3E-04	−1.38
Mdist_park	−2.1E-04***	−3.52	−1.4E-04**	−2.18	−2.8E-04***	−3.80	−7.9E-05	−0.96	−1.3E-04	−1.40

(continued)

Table 2. (continued)

	Model A (All-Day)		Model B (Morning Peak Time)		Model C (Nonpeak Day time)		Model D (Afternoon Peak Time)		Model E (Night time)	
Variable Description	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Constant	83.579**	2.56	44.350	1.26	85.620**	2.07	149.297***	3.32	129.036**	2.46
Model statistics										
Number of observations (level 1)	170,084		50,050		54,380		22,255		17,348	
Number of groups (level 2)	424		424		424		424		424	
Observations per group										
Minimum	24		8		4		2		3	
Average	401.1		118		128.3		52.5		40.9	
Maximum	1214		336		416		170		134	
Wald $\chi^2(32)$	40506.32***		12070.72***		10426.47***		5009.68***		3806.84***	
Log likelihood	−81582.59		−23420.19		−26820.818		−10624.64		−8725.4651	
Sigma_u	0.3330		0.2892		0.3862		0.3145		0.3854	
Rho	0.0326		0.0248		0.0434		0.0292		0.0432	
Likelihood-ratio test of rho=0 chibar2	1843.87***		221.03***		680.41***		94.91***		119.75***	
AIC	163233.2		46908.39		53709.64		21317.28		17518.93	
BIC	163574.7		47208.29		54012.36		21589.63		17782.81	

Note. Reference group consists of unemployed females (or housewives) with no car; monthly household income is a categorical variable but employed as a continuous variable in the models; net area is calculated to subtract the area of parks and rivers/streams from each district area. AIC = Akaike information criterion; BIC = Bayesian information criterion.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

statistically significant association between the presence of aged buildings and walking. In other words, a greater number of aged buildings will increase the probability of people choosing walking over driving. The standard deviation of a district's building age, which denotes the relative heterogeneity of a district's buildings with regards to age, was not statistically significant in any model.

Jacobs also observed that a diversity of building types and ages supports a more dynamic urban economy. According to her observation, aged buildings are more likely to be small, making them a good fit for small enterprises. In the models, firms' employment size was used as a proxy variable for firm size. However, we can only confirm that her argument holds true in Model B, during morning peak travel time. That is, a higher number of employees per firm in a district decreased the probability of people choosing walking over driving during the morning peak travel time.

Density and Concentration

Jacobs (1961) indicated that a concentration of buildings will attract people and promote urban life. Our analysis results demonstrated that Jacobs's observations of urban life could be operationalized when they are represented by physical environment measures, not as direct measures of the population. The density measure for population was not significant in any model. In contrast, employment net density showed significant associations with walking in Model B (morning peak time) and Model E (nighttime). Dividing the population density interaction variable by the employment density produced negatively significant associations in Models A, B, and E, indicating that employment density has a positive association with walking when population density is held constant.

Regarding concentration measures by the land use type, the analysis of the building-unit density for nondaily and office use showed that they have a significant, positive role in choosing walking over driving. The concentration measure for nondaily use was significant in all models except for the nighttime travel model (Model E), while the measure for office use in the Model A, B and C was significant. The analysis of non-daily-life-use office building density supported Jacobs's argument in that they suggest that in cities similar to Seoul, a high density of special-use buildings is more important than overall building density when it comes to encouraging people to choose walking over driving.

Border Vacuums

Most analysis results supported the conclusion that borders such as arterial roads, large-scale parks, on-ground railway tracks, and large-scale building developments discourage walking activity and harm a vital urban life. Large-scale building developments showed a negative association with walking in all models except Model D. Particularly, the negative association was very strong and significant in Model E (nighttime). In other words, people who live in a district with large-scale building developments are more likely to choose driving over walking during nighttime. Our analyses confirmed that proximity to expressway, rail stations, and parks showed significant associations with walking. Particularly, proximity to expressways showed a positively significant association with walking in Models A, B, and C, indicating that expressways often act as border vacuums. In contrast, proximity to rail stations or parks tended to induce walking activity. Measures for on-ground railway tracks and rivers/streams did not show statistically significant results.

Cross-Use

This study also focused on twenty-four-hour cross-use activities because Jacobs emphasized that multiple uses throughout the day are more important than overall walking activity with regards to a vital urban life. In the travel models for different times of the day (Models B, C, D, and E), some of the explanatory variables were not statistically significant, presumably because travel activities by a certain time of day are closely related to an administrative district's physical environment and thus occur in connection with particular travel purposes. Although we found consistent as well as inconsistent factors for choosing walking over driving across the five models by different times of a day, none of Jacobs's physical environmental variables showed statistically unexpected opposite associations with walking. Our results showed that the time of the day played a significant role in promoting walking activities, which suggests potential possibility of twenty-four-hour cross-use streets.

Conclusion

Despite greatly influencing urban planning and urban design in the United States and elsewhere, many of the theories that Jacobs articulated in *The Death and Life of Great American Cities* (1961) have been criticized for their nonverifiability. This study found that Jacobs's urban design theories, which were based on observations of New York City in the latter half of the twentieth century, provided important theoretical viewpoints and implications for promoting a vital urban life in contemporary Seoul. While the findings suggest that a somewhat cautious approach is required in the application of Jacobs's theories to Seoul, this study found empirical evidence that the built environment characteristics espoused by Jacobs, such as mixed uses, small block sizes, and high building concentrations, can play a significant role in sustaining urban diversity.

A vital urban life, as embodied in cross-use, requires conditions such as land use diversity with access to diverse facilities, aged buildings, and a relatively high building density. Land use policies should consider the importance of land use diversity as well as good accessibility to facilities in order to encourage high levels of walking activity and contributed to a more vital urban life. This study also identified that the mix of housing types and the good accessibility to commercial use have positive association with walking over driving. This finding indicates that the urban design policies in Seoul should be changed from single-use superblocks of large-scale apartment complexes to mixed land use and mixed housing types. In addition, proximity to public facilities such as rail stations and parks show that cross-use by pedestrians could be enhanced if public facilities are located close to buildings.

Next, the existence of aged buildings promotes the possibility of neighborhood cross-use by encouraging walking. Analysis of the average age of all buildings showed that the existence of newer buildings encouraged travelers to choose driving over walking. Jacobs argued that the existence of old buildings enhances the urban economy, by providing suitable office space for small firms. Recently, Seoul initiated several urban regeneration projects to preserve old buildings, considering them as community assets for local economic vitalization. Finally, both employment density and development density for nonresidential daily use, nonresidential nondaily use, and office use are favorable for encouraging the cross-use of streets and a more vital urban life.

This study is significant because it helps bridge the gap between Jacobs's theories of a vital urban life and the planning practice. In particular, we confirmed Jacobs's claims that mixed use, old buildings, high building concentrations, and border vacuums contribute to a vital urban life. In addition, we found that distance-based measures could be more useful than area-based ones when analyzing the effect of built environment on walking activity in large cities.

As Jacobs indicated, urban planning and design issues in large cities should not be viewed as problems of simplicity or disorganized complexity that depend on simple statistical analyses and probability theories. Although our study did not completely address the issue of organized complexity for choosing walking over driving in Seoul, it suggested theoretical and methodological approaches to understanding the role of organized complexity with regard to walking. In other words, we successfully operationalized Jane Jacobs's key argument of organized complexity theory using not only multidimensional variables and interaction variables for each condition, we also specified four time frames of morning peak time, nonpeak daytime, afternoon peak time, and nighttime to measure walking activity. Our study confirmed that the physical environment measures based on Jacobs's urban design theories were interconnected and had different impacts within different contexts in terms of the physical environment and at different times of the day. However, there are still questionable issues to be addressed to put her design theory into practice. Future research should address the degrees of mixed land use, block size, and concentration that generate urban vibrancy in the different context of urban environment.

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