https://doi.org/10.22645/udi.2020.12.30.063
도시과학 제9권 제2호 2020. 12. 63 - 68쪽

Impacts of Local Land Use on Individual Modal Choice

Yang, Hee Jin*

Abstract In recent years, the planning of livable communities has emerged as a new paradigm. The concept of livable communities is related to both the spatial balance of working, playing, and living and the promotion of green modes of transportation, such as walking and biking. This study uses a disaggregate travel survey conducted by the Seoul Metropolitan Area in 2006. I applied a multi-level random intercept logit model to estimate the effects of land-use characteristics on the choice of green modes, holding a traveler's socio-demographic characteristics constant. The empirical results show that higher density and more mixed land-use development encourages people to walk and bike even when individuals have the same socio-economic characteristics. This paper demonstrates that land-use planning by itself can play a role in the creation of livable cities and the decline of greenhouse gas production.

Key Words walk and bike, modal choice, mixed land use, density, multi-level random intercept logit model

1. Introduction

Sprawling patterns of urban development have led to high levels of automobile use (Handy et al., 2005). It has been blamed for traffic congestion and environmental harm, and economic inefficiency, which led to considerations of travel-demand management (Rajamani et al., 2003; Sung and Choo, 2010). Meanwhile, the planning of livable communities has recently emerged as a new paradigm, related to Smart Growth and New Urbanism. The concept of livable communities covers the spatial balance of working, playing, and living and the promotion of non-automobile-based travel.

To plan livable communities through land use change, however, necessitates more understanding of individual travel patterns in relation to regional properties. Yet, much of the previous literature accounting for green modal choices does not control for individual factors affecting modal choices, but has only analyzed regional differences. Modal choice behaviors should be understood both in relation to individual properties and in terms of local circumstances. Therefore, we need to shed light on the simultaneous impacts of individual properties and local characteristics on modal choice.

The purpose of this study is to empirically estimate how land use affects the modal choices of individuals. The focus of our analysis is neighborhood environments that increase walking and biking. This paper is organized as follows: In section 2, we present a literature review on individual modal choice and urban form measures, such as composite indices for mixed land use and accessibility. In section 3, we detail our research method, variables and data analysis, and in section 4, our findings are interpreted. Section 5 highlights our conclusions.

2. Previous Studies

2.1 Modal Choice

The link between local land use and travel behavior has long been of interest to the field

* Incheon Studies Institute, 교신저자 (hjyang@inu.ac.kr)

of urban planning. Cervero (1996) explored how the presence of retail activities in neighborhoods influenced the commuting choices of residents. The resesarch revealed that commuting distances tend to be shorter in dense and mixed-use neighborhoods. Handy and Clifton (2001) and Handy et al. (2002) also explored the relationship between the built environment and human behaviors. They concluded that pedestrian friendly environment through mixed-land use and street design could enhance the likelihood of walking and biking.

Boarnet and Crane (2000) pointed out the endogenous issues connecting urban design characteristics and travel behavior because people choose locations based on individual preferences. By analyzing individual-level data, the research suggested that persons living in regions with more commercial land use have shorter non-work trip distances. Although the empirical evidences investigating the relationship between neighborhood characteristics and travel choices have been accumulating, the caulsal relationship is still vague(Handy et al., 2005).

2.2 Measuring Land Use Characteristics

Conventional gravity model has used only automobile impedance. Levinson and Kumar (1993) presented multi-modal trip distribution functions, which were developed for each of the seven modes for work and non-work purposes. Their method is advantageous rather than a conventional gravity model by accounting for modal changes.

The planning elements for the compact city were defined as density, diversity, design, and accessibility(Sung and Choo, 2010). The compact city development was identified as a positive impact on modal choices but a negative impact on an inner-travel ratio, refereed to as low level of self-suffiency.

Land use characteristics were estimated as mixed land use, accessibility, residential density, and the presence of cul-de-sacs (Rajamani et al., 2003). With controlling for household and individual demographics, they suggested that mixed land uses and higher residential densities encourage walking for non-work travel. However, a large number of cul-de-sacs discourages pedestrians.

3. Analytical Framework

3.1 Measures of Local Land Use

Land-use characteristics considered here include population density, diversity of service industries, and accessibility to jobs. The first measure of local land use is population density, which is incorporated to examine the effects of compact urban development. This variable is defined as the residential population per unit area at the local level of dong (the smallest administrative region in Korea).

Population density:

$$Pop_i = \frac{residential\,population}{area}$$

The second measure is a diversity index of tertiary service employees in order to measure the effects of mixed-use development as stated in New Urbanism. Entropy index is applied to each industrial employment at the level of dong.

Service industry diversity:

$$Ent_i = \frac{-\sum_{i=1}^{n} p_i \ln(p_i)}{\ln(n)}$$

where p_i is a ratio of each tertiary industry employee, and n is the number of service industries. In this case, n=11.

The third measure of local land use is the job accessibility by walking and biking. Levinson and Kumar (1996) presented a methodology for measuring accessibility by each travel mode. The accessibility is defined using the equation below:

Job accessibility:

$$\text{Ai} = \sum_{j=1}^{J} f(C_{ij}) \times Emp_j$$

where A_i is the regional accessibility index of region i, $f(C_{ij})$ is the friction factor between zone i and j by walk-and-bike mode,

Emp_j is the employment in zone j, J is the total number of regions (522 dongs) in Seoul.

The next equation shows the impedance function of a work-trip gravity model. The dependent variable is the number of trips by green modes divided by the total number of trips (possible trip ends), to which natural log transformations were applied. Travel time and its transformations (t^2, $\sqrt{t}$ was considered) served as independent variables in the same manner as Levinson (1998). Each five-minute travel time cohort was analyzed as a separate observation. It helps ensure higher R^2 values.

For walk and bike trips (R^2=0.89):

$$f(C_{ij}) = \exp(4.841 - 0.1195 + 0.00042t^2)$$

Table 1. Top-10 Rank of Job Accessibility Estimated

Rank	Dong	Accessibility index
1	Kangnam-gu Yeoksam1-dong	572,608,360
2	Youngdengpo-gu Yeoudo-dong	491,447,898
3	Jongro-gu Jongro 1234 dong	269,555,887
4	Kangnam-gu Samsung2-dong	255,841,847
5	Kuro-gu, Kuro3-dong	243,207,511
6	Seocho-gu Seocho3-dong	242,782,671
7	Kangnam-gu Nonhyun1-dong	159,050,034
8	Kangnam-gu Yeoksam2-dong	155,128,331
9	Jung-gu Myeong-dong	145,664,634
10	Jung-gu Hoehyun-dong	139,239,204

3.2 Data and Variablees

The data comes from a 2006 individual travel survey conducted by the Seoul Metropolitan Area, which contains individual properties such as age, income, and number of preschool children. The spatial extent of the analysis is limited to Seoul city due to the accessibility of local land-use data. After excluding observations with missing information on any variables used in this analysis, the final sample consists of 50,422 individuals. Those who used the green modes are 8,707 individuals, accounting for 37.10%.

Table 2. Modal Choice in Each Trip Purpose

	walk/ bike	bus/ subway	car	Total	
commute	3265	10235	5466	18966	(18.63)
	(17.22)	(53.96)	(28.82)	(100.00)	
go to school	8645	4278	607	13530	(13.29)
	(63.90)	(31.62)	(4.49)	(100.00)	
shop & leisure	6797	7994	3135	17926	(17.61)
	(37.92)	(44.59)	(17.49)	(100.00)	
Total	18707	22507	9208	50422	(100.00)
	(37.10)	(44.64)	(18.26)	(100.00)	
				chi-sq :	13619.4 ***

The dependent variable is the individual choice of travel mode coded as 1 in case of walking or biking and as 0 in cases of automobile usage (cars, buses, or the subway). The independent variables include two types of variables: the first is the observed individual variables and the second is the added local characteristic variables of each departure. Every metric variable is centered by grand mean.

The definitions of variables used in the hierarchical model are presented in Table 3. Age is in years measured at the time of the survey of 2006. Dumsex is coded as 1 if the traveler is male and as 0 if the traveler is female. Hkidnum is the number of preschool children in the house. Duminc is the monthly household income of Korean won and the reference variable is lower than 200 million won. Dumpur represents trip purposes, which are categorized as commuting, going to school, and shopping and leisure. The characteristics of origin include the three variables mentioned previously.

Table 3. Variables and Descriptions

Variables		Description
Dependent	modal choice	walk and bike(=1), others(=0)
1-level indpendent variables	age	average age(=32.537), min(=5), max(=101)
	dumsex	male(=1), female(=0)
	hkidnum	number of preschool children average hkidnum(=0.182), min(=0), max(=4)
	duminc	monthly income of household duminc1(lower than 200m), duminc2(between 200m and 500m), duminc3(more than 500m)
	dumpur	trip purposes dumpur1(commute), dumpur2(school), dumpur3(shop and leisure)
2-level independent variables	pop	population density of origin npop = pop - average pop (grand centering)
	entropy	entropy index of tertiary service industry of origin nentropy = entropy - average entropy (grand centering)
	acjob	Accessibility index estimated of origin nacjob = acjob - average acjob(grand centering)

4. Empirical Results

Results of the analysis are shown in Table 4. Models were calibrated using the GLIMMIX procedure in SAS. The results have been obtained after taking into account unobserved local specific random effects. The random effects in Table 4 can be understood by assuming a unique effect for each local group, in addition to the fixed intercept.

Model 1 is the intercept-only model, or an empty model. When local difference is controlled, individual probability of choosing a green mode is 0.361 (=1/(1+exp(0.5701))) on average. The residual variance is about 22.8% (=0.2926/(0.2926+0.9910)), which means local characteristics can explain that amount. According to this result, we can confirm that regional differences significantly affect individual modal choices.

In Model 2, we have included ten covariates, with seven at the individual level and three at the local level. Model fitness is determined by deviance because Glimmix macro chooses Restricted Pseudo-Likelihood. Thus, the deviance difference between Model 1 and 2, 14140.4(=124441.1-110300.7), means that adding variables of individual properties increases fitness for models. The parameters of variables can be interpreted in the same way as those from the standard logit model.

Estimation results show that, everything else being equal, males less tend to choose green modes by 11.88% (=100- exp(-0.1265)*100), while females make fewer automobile trips. Persons older than the average age of 33 make more automobile trips, as do persons with higher incomes. Also, it confirms that even though individual attributes like income are the same, local land use planning can affect individual modal choice significantly.

This model takes into consideration both under-dispersion when extra-dispersion is substantially smaller than 1, and over-dispersion when extra-dispersion is substantially greater than 1. Since under-dispersion or over-dispersion can lead to unreliable estimates of standard error, Model 3 sets the dispersion to 1. The results show that apart from control, the intercepts of fixed effect and random effect do not differ greatly from Model 2; therefore, the implication is the same with the previous results that the planning strategies for higher density and more mixed land use encourage the choices of waking and biking.

5. Conclusion

Green modes of transportation, such as walking and biking, are getting more attention because they are eco-friendly, use fewer energy resources, and promote good physical health. To plan livable neighborhoods, towns, and regions, we need more understanding of the role of land use and more specific model calculations with a regional properties variable. But the previous studies did not control for individual factors affecting modal choices.

This study analyzed whether land use properties affect individual modal choices when the person's attributes are controlled. To begin with, three types of local land use characteristics were quantified. And the multi-level random intercept binary logit model was employed to separate regional effects since individual survey data was hierarchically

Table 4. Random Coefficient Binary Logit Models

		Model1			Model2			Model3		
Parameter		Estimate		S.E	Estimate		S.E	Estimate		S.E
Fixed Effects										
	Intercept	-0.5701	***	(0.025)	-1.2398	***	(0.034)	-1.2409	***	(0.033)
1-level										
	nage				-0.0336	***	(0.001)	-0.0336	***	(0.001)
	dumsex				-0.1265	***	(0.015)	-0.1266	***	(0.015)
	duminc2				-0.2414	***	(0.017)	-0.2415	***	(0.017)
	duminc3				-0.4622	***	(0.028)	-0.4618	***	(0.027)
	nhkidnum				0.0151		(0.016)	0.0151		(0.016)
	dumpur2				1.3590	***	(0.031)	1.3600	***	(0.030)
	dumpur3				0.9449	***	(0.027)	0.9453	***	(0.026)
2-level										
	npop				0.0148	***	(0.002)	0.0148	***	(0.002)
	nentropy				0.4828	**	(0.208)	0.4830	**	(0.208)
	najob				-0.0027	***	(0.000)	-0.0027	***	(0.001)
Random Effects										
1-level	Intercept	0.9910	***	(0.004)	1.0616	***	(0.005)	1.0000	.	(0.000)
2-level	Intercept	0.2926	***	(0.020)	0.1952	***	(0.015)	0.1978	***	(0.015)
N		50422.0			50422.0			50422.0		
Deviance		124441.1			110300.7			110289.9		
-2logL		448841.2			476055.0			476450.5		

clustered into regions.

This primarily confirms that even though individual factors like income, age, and sex are the same, local land-use planning can affect individual modal choices significantly. In concrete terms, planning strategies for higher density and more mixed land use encourage people to walk and bike. However, local accessibility to jobs, on average, has negative effects on the choice of green modes of transportation.

REFERENCES

Boarnet, M. and Crane, R. (2001). "The Influence of Land Use on Travel Behavior: Specification and Estimation Strategies." Transportation Research part A: Policy and Practice 35(9): 823-845.

Cervero, R. (1996). "Mixed Land Uses and Commuting: Evidence from the American Housing Survey." Transportation Research Part A: Policy and Practice 30(5): 361-377.

Guo, G. and Zhao, H. (2000). "Multi-level Modeling for Binary Data." Annual Review of Sociology 26(1): 441-462.

Handy, S., Boarnet, M., Ewing, R., and Killingsworth, R. (2002). "How the Built Environment Affects Physical Activity." American Journal of Preventive Medicine 23(2S): 64-73.

Handy, S., Cao, X., and Mokhtarian, P. (2005). "Correlation or Causality Between the Built Environment and Travel Behavior? Evidence from Northern California." Transportation Research Part D: Transport and Environment 10(6): 427-444.

Handy, S. and Clifton, K. (2001). "Local Shopping as a Strategy for Reducing Automobile Travel." Transportation 28(4): 317-346.

Lee, S. and Jo, J. (2004). "Determinants and Regional Disparities of Environmental Agriculture." Agricultural Economics 27(1): 41-61.

Lee, S. and Lim, K. (2000). "Implications of Multi-level Model in Disciplinary Practices of

Social Sciences.“ Journal of Korean Regional Development 12(3): 213-227.
Levinson, D. (1998). “Accessibility and the Journey to Work.“ Journal of Transport Geography 6(1): 11-21.
Levinson, D. and Kumar, A. (1994). “A Multi-modal Trip Distribution Model.“ Transportation Research Record 1466: 124-131.
Rajamani, J., Bhat, C., Handy, S., Knaap, G., and Song, Y. (2003). “Assessing Impact of Urban Form Measures on Non-work Trip Mode Choice After Controlling for Demographic and Level-of-service Effects.“ Transportation Research Record: Journal of the Transportation Research Board 1831(1): 158-165.
Sung, H. and Choo, S. (2010). “The Effects of Compact City Development at the Living Area of Neighborhood Level on Modal Split and Self-Sufficiency.“ Korean Planning Associations 45(1): 155-169.

논문투고일 2020년 06월 01일
논문심사일 2020년 12월 19일
논문게재일 2020년 12월 30일