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An Analysis of the Relationship between Land Use and Weekend Travel: Focusing on the Internal Capture of Trips

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Received: 17 December 2017; Accepted: 3 February 2018; Published: 6 February 2018

Abstract: Weekend travel has not been duly considered in academics and practice regarding its relationship with land use. A lack of consideration is notable in terms of how land use internalizes weekend travel. Thus, by separating the internal and external travel of the traffic analysis zone, this study analyzes the land use effect on weekend travel in comparison with that on weekday travel. Two structural equation models, each of which is specified for weekday and weekend travel, construct the same sample and their results become comparable. At the travel variable level, the models find consistent results: Stronger effects are made on internal travel than on external travel and particularly, on trip frequency than on travel time. This implies that compact land use causes a stronger addition of internal trips and a less strong reduction of external trips, that is, changes in destinations rather than in total travel time. At the factor level, unlike the weekday model in which the sociodemographic factor exerts a stronger effect, the weekend model presents that land use more strongly affects travel patterns. This magnitude difference is explained by the different flexibility of compulsory weekday travel and discretionary weekend travel in relation to the choice of trip destination and frequency.

Keywords: weekend travel; land use; internal trips; traffic analysis zone; structural equation modeling; Seoul

1. Introduction

Defined as travel on Saturdays and Sundays that are not holidays and vacations [1,2], weekend travel mostly has non-commuting purposes such as sightseeing, social, recreational and sports activities [3]. In its unstructured and irregular nature [4], weekend travel considerably differs from weekday travel in terms of the distribution of peak hours and variety of destinations [5]. (Actually, weekend travel, especially summer weekend travel, may be generated for visiting a second home. In this case, it can also have a clear structure and regular nature.) In practice, however, the different characteristics of weekend travel have not been duly reflected in the construction of transportation systems and design of transportation policies and plans [6–8]. Also in academics, few have dealt with weekend travel [9,10] probably because weekday travel traditionally accounted for most travel needs and further, travel data were constructed centered on weekday travel [11]. (A lack of information and concern about weekend travel is somewhat attributed back to the variety of its purposes, distances and spatial and temporal distributions [11].)

However, weekend travel can no longer be underrated, considering people's growing interest in leisure travel (or work–leisure balance), most of which takes place on weekends. In fact, from the late 2000s, studies began to analyze weekend travel (e.g., [12]). However, very few studied how weekend travel, unlike weekday travel, is affected by compact land use and in this regard, a study equipped with weekend travel data has been recommended for a comprehensive understanding the land use–travel relationship [3,13].

This study aims to analyze the relationship between land use and weekend travel in comparison with weekday travel. In addition to the land use factor, the individual factor will be used to analyze travel patterns. (Due to data limitations, this study will measure the individual factor only with sociodemographic variables, not with attitudinal variables although attitudes have often been reported to strongly affect travel patterns [14–16].) Specifically, the hypothesis of the study is: As compared with the effect of the reference factor of sociodemographics, the land use effect is stronger on weekends than on weekdays.

This study will evaluate the factor of travel behavior with travel time and trip frequencies together. Indeed, compact land use would change trip frequency, trip destination (trip length) and trip time whose variation is led by traffic flow (congestion) changes (then, this does not necessitate changes in trip frequencies and destinations). Ewing and Cervero's meta-analysis [17] found that the magnitude of the land use–travel relationship hinges partially on the travel measure itself. They reported that land use has a smaller effect on trip frequency than on total travel distance (as a composite measure). According to Gim [18], if compact land use reduces total travel distance without a significant reduction of trip frequency, then, this means that only trip length is reduced (due to a shorter physical distance between the origin and destination of a trip), that is, the primary outcome of compact land use is the choice of alternative destinations. In fact, several studies [19,20] argued that the true effect of compact developments is not to reduce travel but to encourage trip-chaining (instead of isolated trips) and/or internal trips whose destinations are within the local area. According to a review by Ewing and Cervero [19], however, trip-chaining and internal trips have not been sufficiently investigated. They argued that between the two, even more is unknown about the internal capture of trips and accordingly asked for research on trip internalization.

In this sense, with a case of Seoul, this study attempts to evaluate travel time and trip frequency by separating the internal and external trips of the traffic analysis zone (TAZ). (The TAZ may be arbitrary in size and arrangement and people have no concern for them when making trips [21]. According to Greenwald [22], however, the intra-TAZ trip is a valid substitute for the local trip and this TAZ approach is beneficial in the travel demand modeling process [23]. Most studies on trip localization (e.g., [13,22–26]) have accordingly employed the TAZ as the unit of observation.) Regarding the TAZ in Korea, it is defined by the homogeneity of trip generation and attraction and socioeconomic characteristics including income class and job type [18]; as of 2006, Seoul has 522 TAZs in its area of 233.673 mile^2. The TAZ was also used as the sampling cluster for the 2006 Korean Household Travel Survey (KHTS) whose data were used for empirical analysis of this study. (The KHTS coded the locations of the trip origin and destination on the TAZ scale.)

Regarding the analytical method, this study employs structural equation modeling (SEM) as it can address two major barriers to research on the land use–travel relationship [14]: (1) spatial multicollinearity (SM) and (2) residential self-selection (RSS). SM refers to correlations between land use independent variables. In case of SM (e.g., correlation between population density and road intersection density), the no multicollinearity assumption is violated if the variables are analyzed together [27,28]. A conventional technique (e.g., regression analysis) addresses this issue by combining the correlated variables into a factor or removing some of them. Then, it becomes difficult to evaluate the significance and magnitude of the initially considered variables. By contrast, SEM preserves the original forms of the variables: Its measurement model firstly specifies the relationship between a factor and its variables and the relationship is kept intact in the full SEM model. Thus, one can estimate in the original set of the variables which one better represents the effects of compact land use.

RSS becomes an issue because people's individual characteristics (e.g., sociodemographics) may determine the choice of a residential area in a compact/sprawling land use manner, which subsequently affects their travel patterns. Then, the sociodemographics–land use–travel relationship makes the magnitude of the land use–travel relationship overestimated. Meanwhile, land use would also affect sociodemographics (e.g., automobile ownership) and another consideration is that the land use–sociodemographics–travel relationship is possible. Since multiple relationships can be specified in one SEM model, this study will estimate the land use–travel and sociodemographics–travel relationships while specifying the sociodemographics–land use relationship. In particular, considering that it may go one way or the other, this study will specify a correlation path for the sociodemographics–land use relationship.

In short, this study uses SEM because (1′) it can compare all variables in their original forms and identify what more important variables are, which is a traditional research topic for transportation planners who aim to design an effective policy measure [6,29] and (2′) by controlling for RSS, it can accurately estimate the magnitude of the land use effect; the current literature requests studies on the magnitude beyond the statistical significance [30].

To empirically examine the land use–weekend travel relationship, this study extracts travel data from the weekend survey of the KHTS. For comparison purposes, it also analyzes weekday travel using data from the KHTS main (weekday) survey. A feature of this study is that its sample consists of those who responded to both surveys and thus, a direct comparison is made possible between the results of the weekend travel model and those of the weekday model. The data of the KHTS are also used to measure sociodemographic variables. Lastly, land use variables are evaluated with GIS (geographic information systems) datasets.

2. Literature Review

2.1. Relationship of Land Use with Total Travel Measures on Weekdays and on Weekends

Studies on the land use–travel relationship have reached a consensus on its statistical significance [31]. A current discussion is centered on its magnitude [14,18,30,32,33], that is, whether travel variations are enough to justify land use interventions while its notable change takes a considerable time [34]. Some studies argued that the magnitude of one land use variable may be small but its combined effect with other land use variables through SM would be substantial [33,35–37]. Others highlighted the fact that the empirical land use–travel relationship is week [9,19] or meaningless due to inconsistent results on the relationship [34,38,39]. Furthermore, they argued that land use does not exert an effect per se but individual characteristics work as an antecedent (i.e., according to RSS). Then, if the RSS effect is controlled for, the true land use effect may be weaker than previously reported [40]. Actually, recent studies attentively addressed the RSS issue by employing techniques that estimate and control for the selection bias (e.g., sample selection models, propensity score matching and SEM). Most of them found that the true land use effect is larger than the spurious RSS effect [15,33] and thus, Næss [41] concluded that the issue is a "(t)empest in a teapot" (p. 57). In contrast, according to Mokhtarian and van Herick's review [30] on those studies that appropriately controlled for the selection bias, the spurious RSS effect could account for more than half of the total land use effect. Anyhow, almost all studies that considered SM and RSS up to a certain degree analyzed weekday travel data. We lack knowledge on how land use affects weekend travel.

While the land use–travel relationship has been studied focusing on weekday travel, some of the studies extended their findings to discuss how weekend (leisure) travel possibly occurs. One possibility is that compact land use for encouraging internal trips on weekdays causes a balloon effect on weekends and increases weekend travel distance/time [29]. Specifically, reduced mobility in weekday commuting—for example, compact land use limits the chance of accessing green spaces—could bring about weekend *compensatory travel*, that is, long-distance (i.e., external) leisure travel for the purpose of making up for the mobility reduction. However, empirical studies reported that the compensatory travel does not occur [42] or as opposed to the possibility, suburban long-distance commuters tend to travel a long distance also for leisure [43]. Similarly, Gim [15,44] argued that among commuting, shopping and leisure travel, leisure travel is the most sensitive to land use variations.

With respect to empirical research on weekend travel in particular, descriptive studies have continued until the mid-1990s: They presented travel patterns by the day of the week and how weekend travel differs by the purpose, mode and number of household members [45,46]. To consider land use, studies sampled a couple of areas with different land use and described variations among the areas in trip length, total travel distance and other travel patterns on weekends [45]. Later, studies began to inferentially analyze the differences between weekday and weekend travel patterns [5,47].

However, few of the inferential weekend travel studies considered land use as a determinant of travel behavior. Instead, regarding physical activities, Bhat and Srinivasan [48] examined the land use effect on weekend out-of-home activities. They found that land use variables are insignificant altogether and suspected that the insignificance could be explained by RSS. As related to this particular study, Lee et al. [12] constructed two Tobit models, each of which was specified to explain weekday and weekend total travel time, using land use variables. In the weekday model, household density, commercial district density, rail station proximity significantly reduced travel time but in the weekend model, no land use variables were significant. Unlike Lee et al. [12], first, this study does not filter out collinear variables but through SEM, analyzes all original variables and presents the magnitude of the land use factor as a whole. Second, not only total travel time but this study also analyzes trip frequencies and both measures of travel are separately evaluated according to whether it is TAZ internal or external travel. Then, this study can see what is affected by compact land use: It may be traffic congestion/flow (i.e., trip time, only), trip length (i.e., destination), or trip frequency. Third, this study uses the same sample of respondents, not two different samples, for the weekday and weekend travel models in order to directly compare their results: Otherwise, differences in the results may be attributed to differences between the samples rather than the weekday–weekend differences.

2.2. Relationship of Land Use with Destination Selection (Trip Internalization)

To the argument that the land use effect on travel measures (e.g., trip frequency and travel distance/time) is inconsistent or only modest, an alternative response is that the essential role of compact land use is not to reduce travel but to internalize it within the local area [19], which promotes walk and bike instead of automobile travel. According to Handy and Clifton [20], the way that compact land use reduces automobile dependency is to locate destinations within a walkable/bikable distance. In this case, external travel is replaced by internal travel. Thus, this study analyzes whether compact developments are associated with destination changes (i.e., increases in TAZ internal travel and decreases in external travel) and how the magnitude of the association differs between weekdays and weekends.

Up until the mid-2000s, few have studied the land use–travel relationship in relation to trip internalization [22]. An exception is Ewing et al. [49]: They analyzed a sample of 20 communities in South Florida and found that community internal trips are partially accounted for by land use mix and regional accessibility. In fact, the trip internalization approach is connected with the concept of jobs–housing balance [22], which was proposed and empirically validated by Cervero [50]. In later studies, the effectiveness of the concept has been both supported [51–53] and rejected [54,55]. Anyway, as Greenwald [22] indicated, most studies investigated the effect of jobs–housing balance on commuting time/distance and commuting VMT (vehicle miles traveled)/VHT (vehicle hours traveled). That is, the concept has not been duly examined with regard to trip distribution or trip internalization/externalization.

In Austin, Texas, Zhang et al. [26] identified 42 mixed land use districts through expert interviews and descriptively—not *inferentially*—compared them with 450 conventional TAZs. The districts had a 40% higher internal trip rate (7.4% of the total trips). In Shiraz, Iran, Soltani and Ivaki [25] analyzed how interzonal trip generation is differentiated at the TAZ level—not at the *individual* level—by five principal components (land use diversity, density, suburbanization, connectivity and accessibility to public transport) and by TAZ-level sociodemographic variables. Among the land use components, land use diversity and road connectivity were not significant and it was suspected that the two components might affect *intrazonal* trip generation, instead. As a way of examining an individual's destination choices in Erie County, New York, Sadek et al. [24] set two skyline buffers around each TAZ (they carried 33% and 66% of the total TAZs in the county, respectively) and generated four types of destinations: same TAZ as the trip origin, TAZs within the inner buffer (but not the trip origin), TAZs between the inner and outer buffers and TAZs outside the outer buffer. Four destination-based binary logit models found that in relation to home-origin commuting, land use diversity positively affects the choices of the same and inner-most TAZs. Regarding home-origin shopping travel, land use entropy and transit availability affected the choices. In Montreal, Canada, Manaugh and El-Geneidy [13] analyzed how regional accessibility and local accessibility contribute to trip internalization, which was evaluated by a local trip index (a composite measure of activity space internalization and total travel distance). A regression model found that both of the regional and local accessibilities are significant while the local measure has a higher magnitude.

Compared to previous studies, this study *inferentially* investigates trip internalization at the level of *individual* travelers by evaluating *both internal and external* trips. More importantly, none of the above studies on trip internalization used weekend travel data. Indeed, Manaugh and El-Geneidy [13] acknowledged that "(t)he primary limitation of this research is the use of a single-day travel survey . . . (and a) multi-day survey, particularly one that includes weekends, could add much" (p. 25). This particular study answers this call.

3. Data

3.1. Korean Household Travel Survey: Measuring Travel and Sociodemographic Characteristics

Among three types of research variables, TAZ-level land use was evaluated with GIS datasets (to be discussed later) and individual-level travel and sociodemographic characteristics with 2006 KHTS. By processing the KHTS, this study defined "home-origin travel" with internal trip frequency, external trip frequency, internal travel time and external travel time while "destination choice-related sociodemographics" were evaluated with the numbers of automobiles, children and members in the household and the individual's birth year and gender. In fact, these five are among the most frequently used sociodemographic variables [14,56]. In theory, they are related to transportation needs and mobility and expected to account for variations in travel behavior [57] although automobile ownership is considered a more important travel determinant [58–60].

First conducted in 1996 and then in 2002, the KHTS began to include the weekend survey (in addition to the main, weekday survey) in 2006. (The 2010 and 2016 KHTSs also had the weekend survey but a respondent was given a separate ID for each of the weekday and weekend surveys; thus, it is impossible to construct the same sample for the weekday and weekend models). By law, the weekday survey is conducted on the last Thursday of October and the weekday survey on the following Saturday and Sunday, arguably a usual weekend in South Korea [61]. From the data of the 2006 KHTS, this study excluded one case whose gender was unknown and used responses from 1744 residents in Seoul. Figure 1 shows the geographical distribution of the final sample. (Data are fully available online: https://drive.google.com/open?id=0B7BjwkPI35r1VGJDUFBkTDBBMkE.)

3.2. Geographic Information Systems: Measuring Land Use Characteristics

As with travel behavior for which only home-origin trips were counted, this study evaluated land use in the origin TAZ, using six variables (as reflective indicators) to represent "compact developments": daytime population density (daytime population = nighttime (registered or de jure) population + inbound commuters − outbound commuters), nighttime population density, road connectivity (density of road intersections within a 0.5-mile straight-line buffer from the TAZ boundary), land use balance—Shannon entropy measured within the buffer = $-\sum 4(p_i \times \ln(p_i))/\ln(4)$, where p_i = areal share of land use i among the following four land uses: housing, work, commercial and leisure—bus availability (density of bus stops in the 0.5-mile buffered area) and metro availability (density of metro stations in the buffered area).

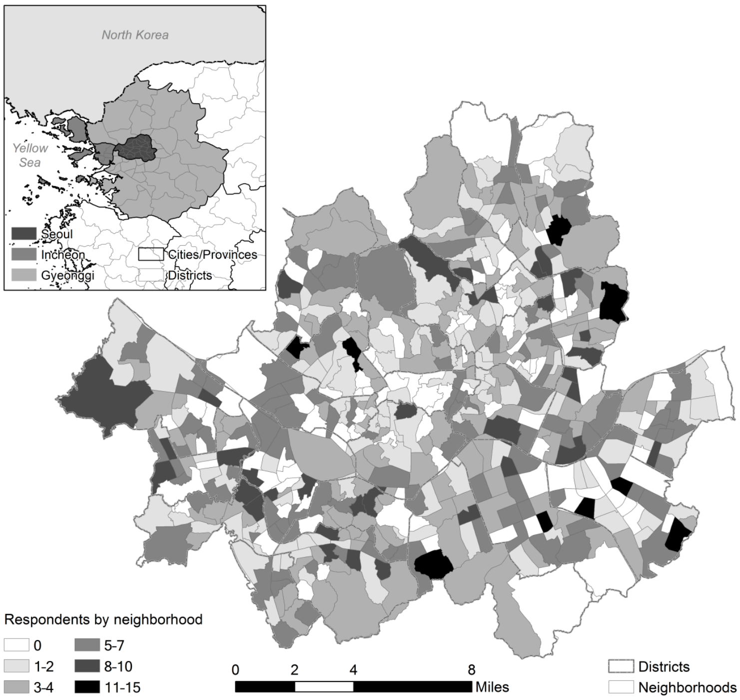

Figure 1. Sample distribution (n = 1744). Note: The upper-left inset shows the coverage of the 2006 KHTS, the Korean Capital Region (Seoul Special City, Incheon Metropolitan City and Gyeonggi Province). The coverage became the entire country from the following 2010 KHTS while before 2006 (i.e., for the 1996 and 2002 KHTSs), it was limited to Seoul.

Population density, land use balance and road connectivity have long been used to define land use: They are representative measures of 3D's [17,19,62], that is, density, diversity and design [63]. Notably, this study categorized population density into daytime and nighttime densities as recommended by Gim [64]. While the former better represents activity density, the latter was also considered as typically used in the literature [14,65,66]. Also, bus/metro availability (transit depot density) or proximity (distance to the nearest depot) is usually added to the 3D's [17,19,54,62,67]. (According to Frank and Engelke [68], road connectivity and transit availability/proximity stand for "transportation systems" as opposed to the other "built environmental" variables.) Between the availability and proximity measures, this study employed the former since it has been reported to more significantly affect travel behavior [69,70].

To measure the land use variables for the representative year of 2006, this study obtained secondary data from public sources: Korean Ministry of the Interior (numerical data on populations), Highway Management System ("street centerlines" GIS dataset for road connectivity), the Seoul Institute (processed GIS dataset, "land characteristics," for land use balance), Bus Management System (GPS location information on bus stops) and New Address System (metro facility GIS data).

4. Results

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics of the sampled respondents (n = 1744). On average, trip frequency and travel time are more on weekends and in this sense, the sample well reflects the travel characteristics of those living in Seoul [61]. Most sociodemographics are also representative of the life situation characteristics of typical Seoul residents but mid-aged people and those with fewer children in their households are slightly oversampled. Nonetheless, most importantly, variations in research variables are enough for inferential statistics.

Table 1. Descriptive statistics.

	Mean	S.D.	Min	Max		Mean	S.D.	Min	Max
Daytime pop. density (pop1_d)	67,873.983 persons/mile^2	51,322.493	97.261	411,117.750	Road connectivity (cnn_d)	893.471 intersections/mile^2	520.396	22.767	2361.104
Nighttime pop. density (pop2_d)	69,141.585 persons/mile^2	33,183.271	16.955	197,880.479	Bus availability (avl_bus_d)	130.033 bus stops/mile^2	58.210	6.147	272.728
Land use balance (ent)	0.587	0.156	0.184	0.981	Metro availability (avl_met_d)	1.393 metro stations/mile^2	0.879	0	4.892
	Mean	**S.D.**	**Min**	**Max**		**Mean**	**S.D.**	**Min**	**Max**
Weekday int. trip freq. (df_internal)	0.538 trips	0.990	0	5	Birth year (m_birth)	1968.634	16.460	1926	2000
Weekday ext. trip freq. (df_external)	2.001 trips	1.116	0	9	Household size (h_size)	3.779	0.991	1	7
Weekday int. travel time (dt_internal)	8.862 min	18.669	0	150	Children (h_child)	0.096	0.336	0	2
Weekday ext. travel time (dt_external)	76.527 min	66.489	0	545	Automobiles (h_autom1)	0.853	0.561	0	4
Weekend int. trip freq. (ef_internal)	0.611 trips	1.183	0	10			f	%	
Weekend ext. trip freq. (ef_external)	3.198 trips	1.880	0	11	Gender (m_gender)	Male (=0)	766	43.9	
Weekend int. travel time (et_internal)	18.350 min	48.054	0	395		Female (=1)	978	56.1	
Weekend ext. travel time (et_external)	166.170 min	150.269	0	1230					

4.2. Structural Equation Modeling

The initial models specified the sociodemographic and land use factors to independently affect travel behavior (see Figure 2). SEM refines the initial model based on either the re-specification or the competition approach [71]. According to the re-specification approach, SEM eliminates insignificant paths and adds those that provide a better model fit (also called covariance fit) to the given data [44,56]. Almost all SEM studies on travel behavior—including this particular one—used the former approach [72]; an exception is Gim's in-press paper [54]. Notably, the more the initial model is updated for statistical significance and overall model fit, the further it moves away from the theory-testing purpose of SEM [71]. (Accordingly, strictly for the original confirmatory purpose, researchers are advised to adopt the competition approach: Through this approach, multiple models are constructed and among them, one that best handles the issue at hand is selected.) In this sense, the model should be carefully modified not to harm its original structure [44,73]. For example, compared to correlation paths within the same factor, regression paths (or correlation paths across different factors) may considerably alter the structure; they are also theoretically less acceptable.

In this study, the final models were identified by removing all paths that are insignificant at the 90% confidence level and then, by adding paths one by one in descending order of the MI (modification index). For the path addition, this study set the minimum MI to 10 and considered only correlations between the residuals of the indicator variables in the same factor. As shown in Table 2, all goodness-of-fit indices strongly support the final models.

While the re-specification approach of SEM allows for correlation paths for a higher model fit, those between residuals are among the best justified paths [74] and frequently added in travel behavior studies [72]. The correlation between residuals denotes that the variances unaccounted for by the two indicator variables of the residuals are correlated. For instance, in the final weekday model, the correlation between the residuals of automobile ownership and birth year means that the automobile–age correlation is present, controlling for their common factor, sociodemographics (i.e., it is a proportion of the automobile–age correlation that is not explained by the sociodemographic factor); thus, the residual correlation can be understood as the partial correlation between automobile ownership and age and it is a sign for the existence of another factor on the two indicators in addition to sociodemographics.

Table 2. Model fit.

Indices		χ^2	d.f.	*p*	GFI	AGFI	CFI	SRMR	RMSEA	AIC
Cutoffs				Insignificant †	>0.9	>0.9	>0.9	<0.08	<0.08	The smaller, the better.
Weekday model	Initial	1447.627	88	0.000	0.903	0.868	0.806	0.080	0.094	1511.627
	Final	247.520	56	0.000	0.978	0.965	0.971	0.049	0.044	317.520
Weekend model	Initial	1590.146	88	0.000	0.899	0.862	0.688	0.087	0.099	1654.146
	Final	339.530	58	0.000	0.971	0.954	0.936	0.059	0.053	405.530

† χ^2 is almost always significant if $n > 200$ (n for this study =1744).

Different from correlation paths between residuals, those between exogenous variables/factors are always required in initial SEM models: in this study, the path of LS ↔ LU (correlation between sociodemographics and land use). At the same time, the path was specified to see if RSS is present. As shown in Figure 2, the LS ↔ LU path was significant in the weekday model and insignificant in the weekend model. This suggests that a particular sociodemographic group of people select residential areas considering their weekday travel, not weekend travel, and/or land use of the areas affects the group' sociodemographics (e.g., number of automobiles).

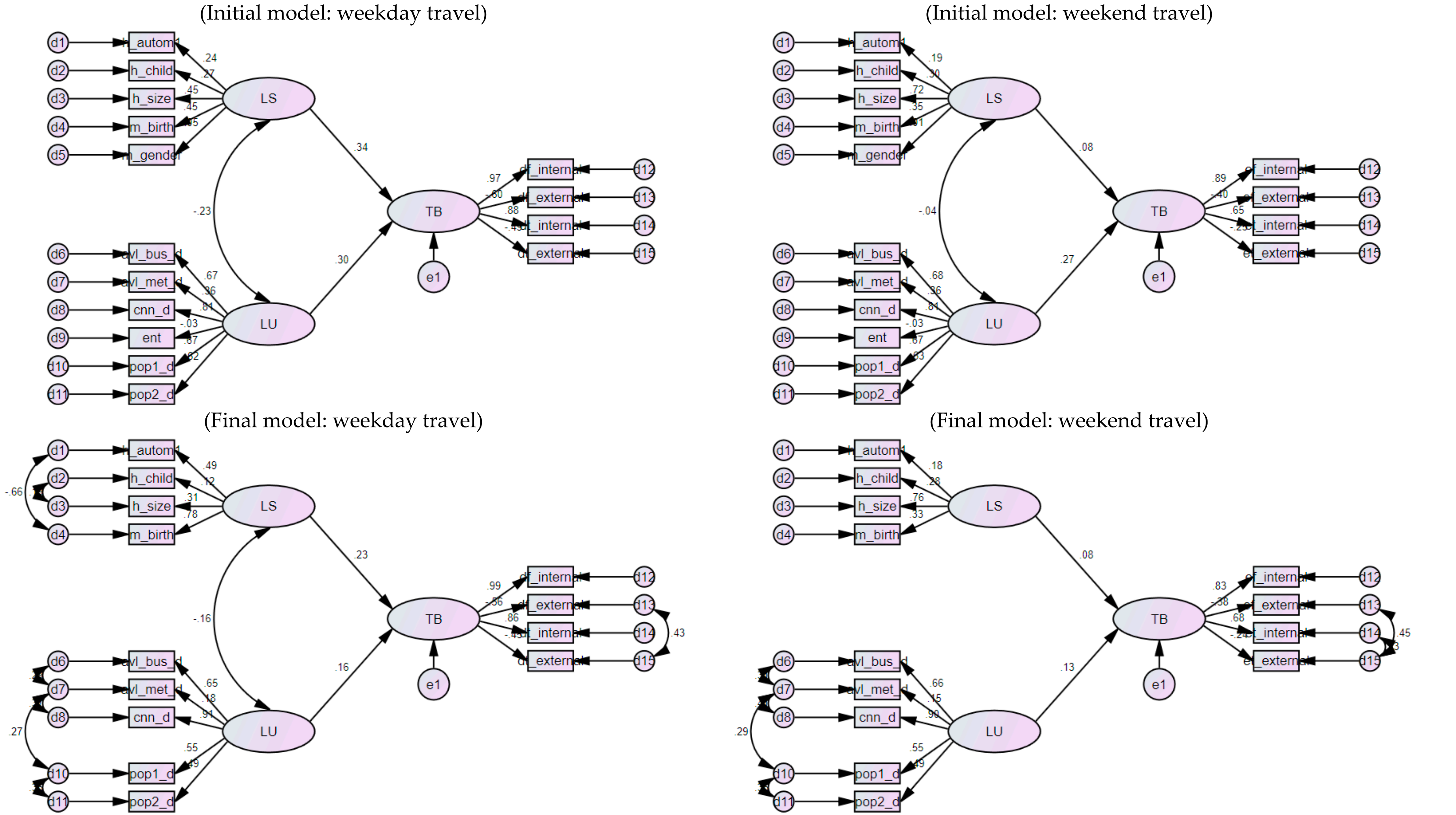

Figure 2. Structural Equation Models. Note: LS = sociodemographic factor; LU = land use factor; TB = travel behavior factor; for variable names, see Table 1; as automatically generated by an SEM program called Amos, the above path coefficients and all other statistics are presented in Tables 3 and 4.

Table 3. Path coefficients: weekday travel.

			Initial Model				Final Model			
			Coef.	**S.E.**	***p***	**Std. coef.**	**Coef.**	**S.E.**	***p***	**Std. coef.**
Regression paths										
df_internal	←	TB	1 (Fixed)			0.970	1 (Fixed)			0.991
df_external	←	TB	−0.673	0.024	0.000	−0.599	−0.634	0.025	0.000	−0.564
dt_internal	←	TB	16.950	0.339	0.000	0.882	16.250	0.394	0.000	0.857
dt_external	←	TB	−32.489	1.487	0.000	−0.489	−30.275	1.548	0.000	−0.453
h_autom1	←	LS	0.306	0.054	0.000	0.245	0.892	0.257	0.001	0.490
h_child	←	LS	0.204	0.033	0.000	0.273	0.135	0.028	0.000	0.124
h_size	←	LS	1 (Fixed)			0.453	1 (Fixed)			0.311
m_birth	←	LS	16.485	2.262	0.000	0.449	41.633	11.313	0.000	0.779
m_gender	←	LS	−0.057	0.040	0.153	−0.051	(Excluded)			
avl_bus_d	←	LU	130.209	8.460	0.000	0.672	239.817	34.534	0.000	0.653
avl_met_d	←	LU	1 (Fixed)			0.359	1 (Fixed)			0.181
cnn_d	←	LU	1399.007	86.804	0.000	0.808	2980.413	434.089	0.000	0.908
ent	←	LU	−0.017	0.014	0.211	−0.033	(Excluded)			
pop1_d	←	LU	114,976.126	7465.997	0.000	0.673	175,043.754	25,350.499	0.000	0.546
pop2_d	←	LU	68,809.872	4598.052	0.000	0.623	104,967.242	15,468.982	0.000	0.495
TB	←	LS	0.777	0.115	0.000	0.344	0.737	0.103	0.000	0.228
TB	←	LU	1 (Fixed)			0.297	1 (Fixed)			0.157
Correlation paths										
LS	↔	LU	−0.032	0.007	0.000	−0.234	−0.008	0.003	0.009	−0.160
d4	↔	d1	(Not specified)				−3.321	0.951	0.000	−0.658
d3	↔	d2	(Not specified)				0.059	0.008	0.000	0.189
d7	↔	d6	(Not specified)				10.615	1.244	0.000	0.287
d8	↔	d7	(Not specified)				67.550	11.915	0.000	0.370
d10	↔	d7	(Not specified)				9821.119	914.153	0.000	0.275
d10	↔	d11	(Not specified)				437,056,299.406	35,711,465.373	0.000	0.361
d13	↔	d15	(Not specified)				23.599	1.485	0.000	0.428

Note: LS = sociodemographic factor; LU = land use factor; TB = travel behavior factor; for details of the variables and residuals, see Table 1 and Figure 2.

Table 4. Path coefficients: weekend travel.

			Initial Model				Final Model			
			Coef.	**S.E.**	**p**	**Std. coef.**	**Coef.**	**S.E.**	**p**	**Std. coef.**
Regression paths										
ef_internal	←	TB	1 (Fixed)			0.888	1 (Fixed)			0.828
ef_external	←	TB	−0.678	0.052	0.000	−0.398	−0.713	0.062	0.000	−0.376
et_internal	←	TB	28.518	1.744	0.000	0.646	33.165	2.534	0.000	0.682
et_external	←	TB	−33.197	3.782	0.000	−0.245	−36.830	4.820	0.000	−0.243
h_autom1	←	LS	0.153	0.034	0.000	0.193	0.133	0.032	0.000	0.180
h_child	←	LS	0.141	0.026	0.000	0.297	0.126	0.026	0.000	0.284
h_size	←	LS	1 (Fixed)			0.715	1 (Fixed)			0.764
m_birth	←	LS	8.055	1.483	0.000	0.347	7.156	1.438	0.000	0.329
m_gender	←	LS	−0.007	0.022	0.768	−0.009	(Excluded)			
avl_bus_d	←	LU	129.355	8.403	0.000	0.676	287.252	51.767	0.000	0.660
avl_met_d	←	LU	1 (Fixed)			0.364	1 (Fixed)			0.152
cnn_d	←	LU	1377.226	85.648	0.000	0.806	3488.548	635.082	0.000	0.897
ent	←	LU	−0.016	0.014	0.249	−0.031	(Excluded)			
pop1_d	←	LU	113,290.666	7376.280	0.000	0.672	207,516.847	37,448.860	0.000	0.546
pop2_d	←	LU	68,177.109	4558.206	0.000	0.625	124,024.510	22,576.136	0.000	0.493

Table 4. *Cont.*

			Initial Model				Final Model			
			Coef.	**S.E.**	**p**	**Std. coef.**	**Coef.**	**S.E.**	**p**	**Std. coef.**
TB	←	LS	0.133	0.057	0.020	0.084	0.103	0.048	0.033	0.079
TB	←	LU	1 (Fixed)			0.273	1 (Fixed)			0.133
					Correlation paths					
LS	↔	LU	−0.009	0.008	0.240	−0.042	(Excluded)			
d7	↔	d6	(Not specified)				11.485	1.288	0.000	0.312
d8	↔	d7	(Not specified)				78.728	12.448	0.000	0.407
d10	↔	d7	(Not specified)				10,268.186	936.338	0.000	0.286
d10	↔	d11	(Not specified)				430,762,517.919	35,907,337.867	0.000	0.356
d13	↔	d15	(Not specified)				115.029	7.408	0.000	0.451
d14	↔	d15	(Not specified)				1190.448	135.548	0.000	0.230

Note: LS = sociodemographic factor; LU = land use factor; TB = travel behavior factor; for details of the variables and residuals, see Table 1 and Figure 2.

Regarding the indicators of the travel behavior (TB) factor, consistent results were found on weekdays and weekends: Effects were stronger on internal travel than on external travel and particularly, on frequency than on time (internal trip frequency > internal travel time > external trip frequency > external travel time).

First, the presence of a stronger effect on internal than external travel supports an argument of a literature review [24]: Land use more strongly affects internal travel. Compared to the review, this study further found that internal travel is more sensitive not only to land use but also to sociodemographics. Therefore, the larger variation of internal travel may be attributed to itself (not land use or sociodemographics), that is, possibly because it is often discretionary/non-mandatory (e.g., leisure and social) travel as highly flexible while most of external travel is compulsory/mandatory (e.g., commuting) [75].

Second, the finding of a stronger effect on trip frequency than on travel time implies that with respect to internal travel, trip frequency is added rather than trip time (travel time = trip frequency × trip time). That is, (if land use alters either trip frequency or the destination) people in compact TAZs are likely to travel to the same destination more frequently. (This interpretation is valid on the basis of the assumption that along with the physical distance to the destination, the trip speed stays the same (trip time = trip length/trip speed). On the contrary, it is possible that people actually have traveled a shorter/longer distance in their TAZs but at the same time, the speed went down/up. This counter-instance is highly unlikely). Also regarding external travel, trip frequency was reduced as opposed to the relatively constant trip time. This also suggests that (although less than the absolute (trip frequency and travel time) increase of internal travel as shifted from external travel) people went to the same destination less frequently. (This implication is also based on the consistent speed assumption, that is, it does not hold true if outside the TAZ, people traveled a shorter/longer distance but the speed also decreased/increased.)

All in all, the effects of compact land use would be expressed mainly as an increase in the frequency of internal trips and a reduction of that of external trips. Considering that short-length internal trips are expected to change more strongly, the *fixed travel time budget theory* may be supported, that is, people's total travel time would not substantially change just because they live in compact/sprawled TAZs. Meanwhile, if the internal trip increase and external trip reduction occur by the same mode (e.g., automobile), then, the suggested effect of the compact development (i.e., less dependency on the automobile) could not be realized. However, walk and bike are common means of internal travel and motorized modes are used for a large proportion of external travel, so the compact development would be effective in reducing automobile dependency [76].

Indeed, supporting the above expectation, Handy and Clifton [20] found that the choice of the intra/interzonal trip and that of the travel mode is made simultaneously, that is, for example, people decide between walking to an internal destination and driving to an external destination. Likewise, in Greenwald's study [22], internal trips were 5.67 times more likely to be made by walk than by automobile. Boarnet and Crane [77] also argued that below a certain distance, walking/biking is preferred. In a similar vein, Sadek et al. [24] found that smart growth-related land use variables (e.g., land use diversity) affects intrazonal travel by encouraging walking or discouraging automobile travel. A more recent study by Bhatta and Larsen [23] also highlighted that "because (intrazonal trips) are shorter trips generally, it is widely believed that intrazonal trips are mostly nonmotorized trips such as walking and cycling" (p. 13). Then, they confirmed this belief through logistic regression analysis on mode choice.

Regarding the indicators of the sociodemographic (LS) factor, their contributions to the factor differed between weekdays and weekends: in the order of their magnitudes, birth year–automobiles–household size–children in the weekday model and household size–birth year–children–automobiles in the weekend model. That is, in terms of weekend travel decision-making, life-cycle characteristics related to marriage, birth and education better reflect travelers' sociodemographics. Actually, previous studies regarded automobile ownership as an important travel determinant [44,78] but according to this study, the finding applies only to weekday travel.

As for the last land use (LU) indicators, their standardized coefficients were consistent in the weekday and weekend models: in descending order, road connectivity, bus availability, daytime population density, nighttime population density and metro availability (land use balance was insignificant in both models). First, the result that compact land use is best explained by road connectivity echoes the finding of previous studies [37,44,54].

Second, this study supports Soltani and Ivaki's argument [25] that transit availability significantly affects trip internalization/externalization. Not only the significance but by separating transit availability into bus- and metro-related variables, this study further showed that bus availability has a higher magnitude than transit availability in increasing internal travel and reducing external travel. This finding is intuitively acceptable insomuch as buses are used for internal travel as well as for external travel. As in Table 1, a TAZ has multiple bus stops and buses can be taken for internal travel but because it usually has one metro station, metro can be hardly used for internal travel. Third, as with transit availability, this study separated population density measures into daytime and nighttime densities. The daytime density was found to be more important and it is also plausible since a majority of trips are made in the daytime.

Last, land use balance was insignificant in both of the weekday and weekend models. In fact, previous studies have delivered mixed outcomes in terms of its significance. In a study by Sadek et al. [24], land use balance significantly affected the choice of the destination in the trip origin TAZ and the next closest TAZs. Along with this study, however, other studies argued that land use balance does not have a meaningful effect. For instance, Soltani and Ivaki [25] presented that land use diversity has no significant effect on interzonal travel. Also, Greenwald [22] found that the effect of land use balance/jobs–housing balance on trip internalization is insignificant or virtually zero albeit significant. Handy and Clifton [20] reported similar results: Adding local shopping facilities in a TAZ is not effective in reducing automobile travel distance and actually, in such a TAZ, residents' total driving time is rather longer since they tend to choose more distant stores.

The most important finding of this study is that at the factor level, the weekday and weekend models differed in the relative magnitudes of the land use and sociodemographic effects on travel behavior. The weekday model supported the consistent argument of previous studies based on weekday travel data: Sociodemographics exert a stronger effect [40]. While most of the studies were concerned with trip frequency, mode choice and travel distance, Manaugh and El-Geneidy's study [13] on trip internalization also concluded that household sociodemographics is more strongly associated with the internalization than is land use (accessibilities). Actually, they used weekday data, only and called for analysis of weekend data. The finding of this study indicates that their conclusion applies only to weekdays: On weekends, land use has a greater effect on trip internalization.

The stronger land use effect on weekend travel is possibly because while most weekday travel is embarked on for compulsory/mandatory purposes (e.g., commute and business), weekend travel is mostly discretionary/non-mandatory travel (e.g., for leisure and social) [3]. Discretionary travel is more flexible in terms of the choice of trip destination and frequency [18]. For example, even in compact TAZs, people can barely change their trip destination/frequency when commuting to workplace/school but for weekend non-work travel, they are possibly more willing to go to alternative destinations in their TAZs for more times.

5. Summary

Weekend travel differs from weekday travel but few have investigated its characteristics, particularly with regard to the effect that land use has on weekend travel. Thus, this study aimed at analyzing the land use effect on weekend travel as well as on weekday travel through SEM, focusing on destination choice or trip internalization, a topic that has been barely studied in relation to weekend travel. In two SEM models that were specified for weekday and weekend travel, respectively, the travel factor was evaluated with travel time and trip frequencies and both measures of travel were separately measured according to whether it is TAZ internal or external travel. Data for testing the models were extracted from the weekday and weekend surveys of the 2006 KHTS. Specifically, this study sampled only those who responded to both surveys because otherwise, differences between the results of the models could be due to those between the samples, not between weekdays and weekends.

At the variable level, the weekday and weekend SEM models consistently presented that travel variations are larger in internal travel than in external travel and particularly, in trip frequency than in travel time. As such, this study found that the main effects of compact land use are a stronger increase in the frequency of internal trips and a less strong decrease in that of external trips. In consideration of the magnitude difference—short-time internal trips are expected to change more strongly—this finding might support the fixed travel time budget theory. Regarding land use variables, the two models also consistently showed that in descending order, compact land use is well represented by road connectivity, bus availability, daytime population density, nighttime population density and metro availability. This finding implies that stronger effects are made by transportation system characteristics that are related to internal travel (pedestrian-friendly road networks and local bus systems).

Unlike the variable level, the two models presented differing results at the factor level: Compared to sociodemographics, land use had a weaker effect on weekday travel but a stronger one on weekend travel. In this sense, the hypothesis of this study, "the land use effect is stronger on weekends than on weekdays," is accepted. The magnitude difference can be explained by the different flexibility of weekday and weekend travel. That is, most weekday travel has compulsory purposes such as commute and business for which trip destination and frequency cannot be easily changed. By contrast, weekend travel is usually discretionary purposes of travel that are more flexible, including leisure and social activities. As such, a theoretical implication of the results of the hypothesis testing is that while the compact city concept is believed to facilitate the trip internalization according to the shortened distance to the trip destination, the effectiveness of the concept depends on whether the destination itself can be replaced by a local alternative.

This study contributed to the literature (1) by empirically confirming the hypothesis that compact land use affects travel patterns by shifting external trips to internal trips rather than by reducing travel. (2) A further contribution is the finding that such a land use effect is stronger on weekend travel than on weekday travel. The first finding suggests that if centered on trip internalization rather than on travel reduction, the estimated land use effect may be stronger than previously reported and this would encourage planners to consider land use interventions for changing travel patterns. Insomuch as the importance and proportion of weekend travel is becoming larger, the second finding (2)—the land use effect is stronger on weekends—may further justify the interventions. Lastly, a limitation of this study is that despite their reported importance, it could not analyze attitudinal variables. Thus, future studies are recommended to include them in analytical models to more accurately estimate the land use effect.

Acknowledgments: This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (No. 2017R1C1B1007433).

Conflicts of Interest: The author declares no conflict of interest.

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