REGARDING THE EFFECT OF THE BUILT ENVIRONMENT AND INDIVIDUAL PREFERENCES ON TRAVEL BEHAVIOR: A CASE STUDY OF THE KANTO REGION, JAPAN

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ABSTRACT

This study analyses the relations between the built environment, individual preferences –as measurements of residential self-selection– and travel behavior in the Kanto Area, Japan. A negative binomial regression model and a Tobit regression model were built to analyze trip frequency by mode and travelled distances respectively. Findings suggest that even after controlling for modal access preference for residential location, the built environment affects to a certain extent travel behavior; higher densities were negatively associated with car trip frequency, and higher land use mix and closeness to transit stations were positively associated with transit and non motorized trip frequency. Findings also suggest that although built environment characteristics around home location might explain trip frequency by mode, built environment features at the city level might account better for travel distances than features at the local level.

Keywords: travel behavior, land use mix, built environment, individual preferences, self-selection, non-work travel, negative binomial regression, Tobit regression, Japan

INTRODUCTION

Background and objectives

In recent years the concepts of smart growth, compact cities and new urbanism have penetrated the sustainability discourse under the premise that high density, mixed use cities might significantly reduce car use and improve both the livability of cities and the health of its inhabitants. The underlying implication is that the built environment exerts a strong enough influence on individuals and households to effectively change their behavior. A considerable body of evidence, particularly in the literature from the United States, suggests an association between high density mixed developments with less and shorter car trips and more trips by alternative means when compared to its low density homogeneous land use counterparts (Khattak & Rodriguez, 2005; Cervero & Kockelman, 1997; Cervero & Radisch, 1996; and Friedman et al., 1994). The evidence however, remains inconclusive.

Kitamura et al. (1997) found that although the built environment exerts an effect on behavior to a certain extent, socio-demographics and attitudinal variables are more strongly associated with travel behavior, particularly with trip frequency. Furthermore; the direction of the effect of the built environment on behavior might not be as clear as generally assumed, as individuals might choose their residential location based on their desire to meet their transport preference (Boarnet & Crane, 2001), an issue known as residential self selection. In other words, individual preferences not controlled for in previous studies might actually explain to a larger extent travel behavior; therefore, if there is in fact an effect of individual attitudes and preferences on behavior, then failure to account for these factors would result in biased and inconsistent estimators on the real effect of the built environment on travel behavior.

Concerning attitudes research in Japan, researchers have mostly focused in travel feedback programs that seek to change individual attitudes towards car use by raising awareness on alternative means, environmental and health issues and the public good (see Nakazato et al., 2006,and Suzuki et al., 2006); however, to our knowledge the preference issue, from a self-selection perspective in Japan remains rather unexplored when compared to western countries.

This study will thus attempt to shed some light on the relations between the built environment, individual preferences and travel behavior in the Japanese case. Additionally, given the inherently different characteristics of the urban space configuration of Japanese cities when compared to their European and North American counterparts, this study seeks to provide grounds for international comparison.

Literature review

A great many deal of studies have attempted to clarify the relationship between the built environment and travel behavior, as well as assess the magnitude of this effect. Several studies in the United States compared compact, high land use mix neighborhoods with low mix, low density ones, and found that residents living in the former ones exhibited a higher rate of transit use and walk trips, particularly for non-work trips (Friedman et al.,1994; Cervero and Radisch; 1996), and that higher densities and land use mixes might support car trip degeneration (Cervero & Kockelman,1997).

Population density, as an indicator of intensity of use of land has been consistently associated with lower levels of car use and higher levels of alternative modes. This effect might be however highly localized (Greenwald & Boarnet, 2001); and whether it exerts a big enough influence to effectively alter behaviour, in particular car use reduction is not very clear (Boarnet & Crane, 2001); findings by Handy and Clifton (2001) and Guo et al. (2007) suggest that, at least in the United States, this might not be the case.

Certainly, in spite of statistical associations found between the built environment and travel behavior, the evidence is still inconclusive and in some cases contradictory; a study by Guo et al.(2007) points out to positive associations between land use mix around home location with motorized maintenance trips for one parent households, as well as negative associations between residential density and number of non-motorized discretionary trips.

Following Kitamura et al. (1997), more recent studies have attempted to control for individual attitudes and preferences in order to avoid omission bias in the estimation of the effect of the built environment on travel behavior. Bagley & Mokhtarian (2002) found no significant effect on travel behavior from neighborhood built environment characteristics after accounting for residential self selection. Different evidence was provided by Cao et al. (2006), who found in a study of neighborhoods in Austin, Texas, that although residential self selection largely explains pedestrian shopping trips, the pedestrian environment at origin is important for strolling walking trips, and land use at origin and destination is related to utilitarian walk trips. Similar findings by Handy et al.(2006) suggest that after accounting for self-selection, built environment characteristics, particularly closeness to destination might encourage walking.

Regarding the omission bias, Chatman(2009) argued that if well self-selection might case an incorrect estimation of the real effect of the built environment, the resulting bias does not make the coefficients insignficant, but might reduce the magnitude of the effect. Chatman concluded that even individuals who did not seek for walk or transit accessible neighborhoods might still be responsive to the built environment where they live.

Concerning the literature on Japan, a study in western Japan by Sun et al.(2009) suggested that while trip numbers are better predicted by life-cycle stage of the household, land use mix and density are likely more significant determinants of travel modes. Fujii et al. (2009) found, in a study on potential reductions of car use that individual perceived ability of cutting driving by half was positively associated with density levels and transit level of service, but negatively associated with distance to habitual destinations –indepdendent of transit LOS- and strength of car use preference.

Some studies in the medical field have also found associations between neighborhoods and physical activity such as walking and biking. Similar to studies conducted in North America and Australia (see: Leslie et al., 2005, and Humpel et al., 2004), Lee et al. (2007) studied two regions that were classified as high walkable and low walkable based on its built environment features and found evidence that residential density, mixed land use and street connectivity positively influenced walking time. Inoue et al.(2010) also found a positive association between perceptions of high residential density and land use mix diversity, as well as good aesthetics and walking facilites with higher levels neighborhood walking. On the other hand, Kondo et al. (2009) found no significant associations between walking time for transport and objectively or subjectively measured built environment features such as land use mix diversity, population density and other more dissagreate factors such as street connectivity and aesthetics.

As with the western literature, the evidence is still inconclusive, and while some of the divergence in the reported results in the literature point out to methodological differences, specifically, sensitivity of empirical results to modeling choices (Greenwald & Boarnet, 2001), it also highlights the need for additional studies to further clarify the relation between the built environment and travel behavior after controlling for individual preferences.

RESEARCH METHODOLOGY

Data and study variables

Data from the 4th Nationwide Person Trip Survey conducted in 2005 by the Ministry of Land Infrastructure, Transport and Tourism of Japan was used, focusing on those cities surveyed within the Kanto Region, which include the Tokyo 23 special wards, Ome and Inagi city in the Tokyo Metropolitan area, Saitama and Tokorozawa in Saitama Prefecture, Chiba and Matsudo in Chiba Prefecture and Yokohama and Kawasaki in Kanagawa Prefecture (see figure 1). Each city was selected to serve as a representative of different characteristics of cities within the region. One day travel data for both a weekday and a weekend were collected via a travel diary, and data from a separate attitude questionnaire conducted along with the person trip survey was used to gather data on modal accessibility preference at the time of the respondent's last move. Additionally, data from the Tokyo 2050 project at the University of Tokyo, which categorized land uses in the Tokyo Metropolitan Region, was used to gather land use characteristics of the study area (Ai, 2012).

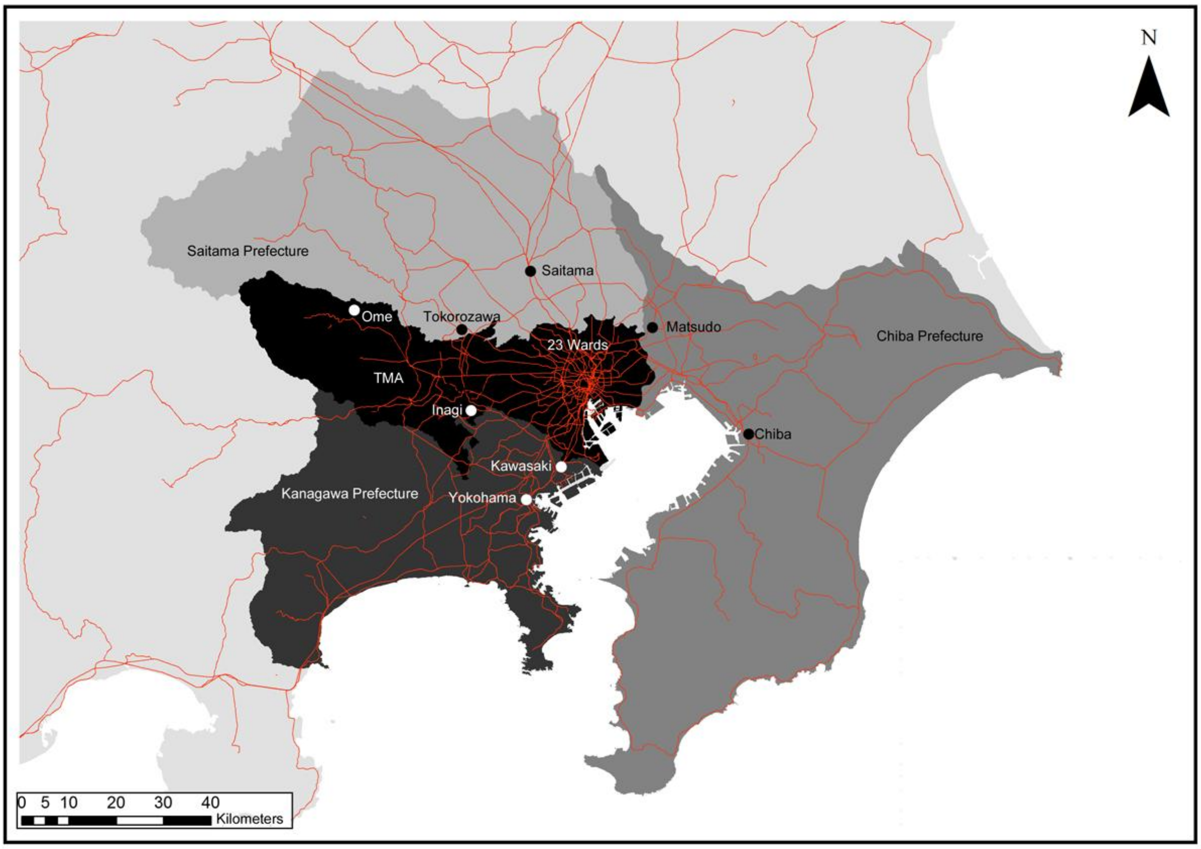

Figure 1. Map of the study area and the regional rail network

Table 1 summarizes the general characteristics of the study area. The regional average population density stands at 6,660 inhabitants per square kilometer; however, it is important to note that 97% of residents in the area live in so called Densely Inhabited Districts (DID)[1], which average a population density of 9,342 inhabitants per square kilometer.

Table 1. General characteristics of the study area

Prefecture	City	Area (km^2)	Population	Density (Person/km^2)	DID Area (km^2)	DID* Population	DID Density (Person/km^2)
Saitama	Saitama	217.49	1,176,314	5,408.6	115.59	1,080,130	9344.5
Saitama	Tokorozawa	71.99	336,100	4,668.7	31.16	296,476	9514.6
Chiba	Chiba	272.08	924,319	3,397.2	118.24	830,383	7022.9
Chiba	Matsudo	61.33	472,579	7,705.5	46.15	453,045	9816.8
TMA	23 Wards	621.35	8,489,653	13,663.2	621.35	8,489,653	13663.2
TMA	Ome	103.26	142,354	1,378.6	17.53	109,974	6273.5
TMA	Inagi	17.97	76,492	4,256.6	7.48	63,129	8439.7
Kanagawa	Yohokama	437.38	3,579,628	8,184.3	347.52	3,487,816	10036.3
Kanagawa	Kawasaki	142.70	1,327,011	9,299.3	132.03	1,316,910	9974.3

*TMA: Tokyo Metropolitan Area. Source: Japan National Census 2005
**DID: Densely Inhabited District

[1] MLIT defines a Densely Inhabited District as a group of continous districts where population density is higher than 4,000 inhabitants per square kilometer and has a total population of more than 5,000 inhabitants. (Ministry of Land, Infrastructure and Transport of Japan , 2007)

Dependent Variables

Six dependent variables were used in this study to describe individual travel behavior: Number of non-work trips by private vehicle, number of non-work trips by public transport, and number of non-work non-motorized trips and its respective travelled distances. Work trips were excluded from the analysis given that behavioral changes of commuting behavior are affected in a much larger extent by factors other than the built environment, hence out of the scope of this analysis. Non-work trips include activities such as shopping, eating out, leisure activities[2] and maintenance tasks.

In the two day period that the person trip survey accounts for, non-work trips accounted for 65% of all trips, out of which car trips accounted for 45%, non-motorized trips for 38% and public transport trips for 16% of the total. The assignment criteria for segmented trips were based on a representative mode hierarchy where mode assignment priority was given first to public transport followed by private vehicle trips, and finally non-motorized trips. For example, if the i_{th} individual used all three modes to reach its destination, the trip is registered as a public transport trip, if he or she used car and non-motorized modes the trip is then registered as a car trip, and so on. Return home trips were excluded from the analysis; in that sense, it seems reasonable to interpret the number of trips by mode as the number of individual activities reached by a given transport mode.

On average non-work trips accounted for 53.3% of total car distances, 49.7% of transit distances and 54% of non-motorized ones, averaging 52% over all modes. The highest average distance for non-work trips was observed for transit with 9.11 kilometers, followed by 7.32 kilometers by car and 1.03 kilometers in non-motorized means.

Independent variables

The scale for built environment variables used in this study was defined at the district level, as an aggregation of several local districts (in Japanese Aza or Cho) in order to match the aggregation level of location data in the person trip survey data. The average area of these tracts is 1.20 square kilometers, and its standard deviation is 0.885 squared kilometers, with 86% of the tracts being no larger than 2.0 square kilometers. Measured built environment variables include: Gross density at residential location, land use mix index at residential location, average distance to closest train station and three city size dummy variables.

As illustrated in figure 2, higher population densities are agglomerated around the train lines spreading outwards from the center of Tokyo, a very characteristic feature of the urban development of the region. The highest densities are recorded in the 23 special wards area of the Tokyo Metropolitan Area at 13,663 inhabitants per square kilometer. Besides being

[2] Leisure activities that fall beyond the scope of everyday activties such as vacations and sightseeing are excluded.

related to intensity of land use and transit access, higher densities also are associated with higher congestions levels, and less parking availability which in might act as disincentives towards car use (Chatman, 2009).

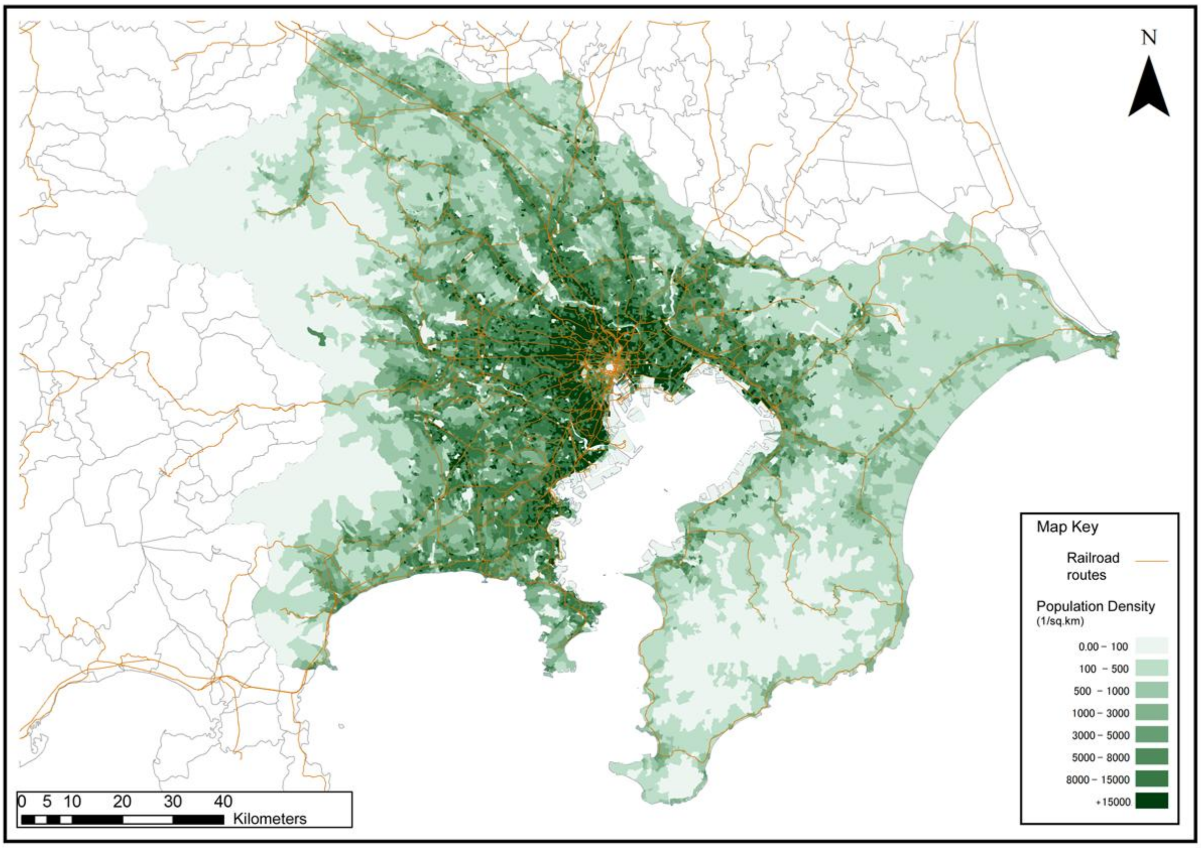

Figure 2. Population density map of the study area

Land use mix was determined using the following entropy index (see: Cervero, 1989, and Frank & Pivo, 1994):

$$\text{Land use Mix} = -\sum_{j} \frac{(P_j \cdot \ln(P_j))}{\ln(J)}$$

Where *P* is the ratio of the tract area of the j_{th} land use type, and J is the number of land uses included in the calculation. Four land use types were considered for building this index: Residential use, commercial use, public facilities and parks.

As figure 3 illustrates, higher land use mix areas are also concentrated in within the 23 special wards area; however, the spatial distribution is more spread out than the distribution of the population density which is more closely related to the transit network. The main reason for this is that while the entropy index does measures the evenness of distribution of land uses within a given tract, it does not account for intensity of land use (Krizek, 2003), hence, the correlation between density and land use mix is not necessarily as straightforward.

Several limitations have been identified in the literature regarding the use of the entropy index as a measure of land use mix, particularly the equal weighting of all land uses, and the lack of power to differentiate between different land use combinations which might have different or no effects towards accessibility (Hess et al.,2001, and Brown et al.,2009). Nevertheless, given the non-stringent nature of land use controls in Japanese cities, and the resulting highly mixed urban areas, the probability that the measured effects are spurious as a result of very particular combination of land uses that do not contribute to accessibility is assumed to be lower. Average index values stand at 0.56 with a standard deviation of 0.10.

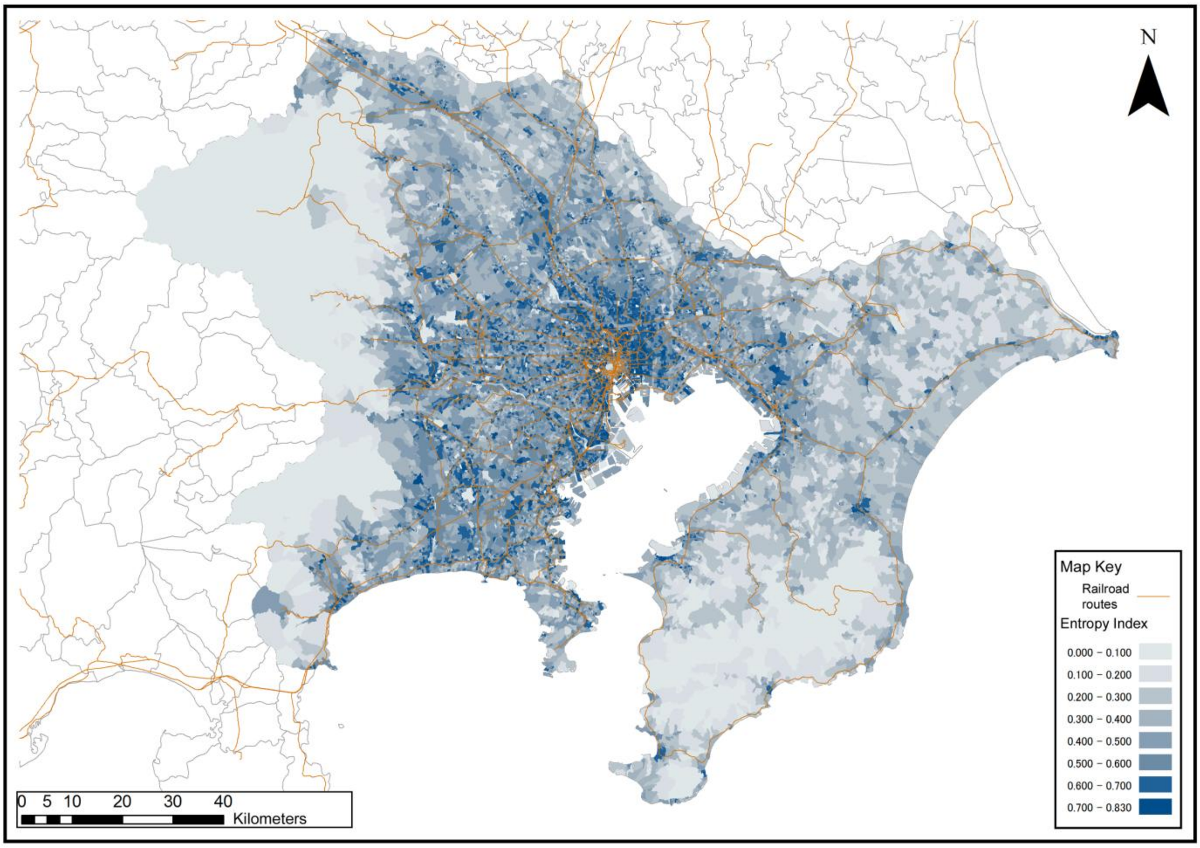

Figure 3. Entropy index map of the study area

Distance to closest station was estimated as the average distance to the closest station within each tract measured from its centroid. Measured average distance was 0.55 kilometers, with a standard deviation of 0.52 kilometers and a maximum value of 3.19 kilometers.

Finally, three dummy variables were created as indicators of city size; the first one includes the Tokyo 23 special wards, the “Large City” variable includes the cities of Chiba, Saitama, Yohokama and Kawasaki, while the “Small City” variable includes the cities of Tokorozawa, Matsudo, Ome and Inagi (see table 1).

Regarding preference variables, data from the aforementioned attitude survey was used. Respondents were asked to rate on a five point likert scale the level of consideration given to several aspects when decided to move to their current residential location. Three items that indicated prioritized modal access when moving to their current residence were selected for this analysis:

1. Ease of travel by car.
2. Ease of use of Public Transport use.
3. Ease to meet daily need by walking or biking to destinations around home.

Binary coded variables were generated as non-mutually exclusive preference indicators, where respondents on the fourth and fifth levels of the likert scale for each item were coded "1" and all others were coded "0". 45% of the sample had high preference for car use, compared to 81% who exhibited public transport access preference and 75% non-motorized access preference (see table 2). Given that categories are non-mutually exclusive, joint preferences are also presented; individuals who exhibited car and public transport preference accounted for 41% of the sample, while car and non-motorized means added up to 39%. Joint preference for transit and non-motorized means accounted for 70% of the sample, while individuals who exhibited all preferences accounted for 37%.

Table 2. Modal access preference frequencies

Access Preference	**Frequency**	**N**	**Relative Frequency**
Car	482	1076	0.45
Public Transport	872	1076	0.81
Non-Motorized	810	1076	0.75
Joint Preferences			
Car + PT	436	1076	0.41
Car + NMT	417	1076	0.39
PT + NMT	749	1076	0.70
All Preferences	393	1076	0.37

Socio-demographics accounted for include gender, worker status, age, and household size, ownership of exclusive car use, access to a car for shared use inside the household, and number of bicycles per person in house. Table 3 summarizes the descriptive statistics of the variables used in this study.

Table 3. Descriptive Statistics

Variable Name	**Mean**	**Std.Dev.**	**Minimum**	**Maximum**
Dependent Variables				
Number of non-work trips	2.127	1.247	0	8
Number of car non-work trips	0.936	1.142	0	6
Number of transit non-work trips	0.336	0.687	0	5
Number of non-motorized non-work trips	0.856	1.049	0	5
Total non-work traveled distances (Km)	17.489	48.068	0	1200
Total non-work car trip distances (Km)	7.324	14.053	0	135
Total non-work transit trip distances (Km)	9.114	47.127	0	1200
Total non-work non-motorized trip distances (Km)	1.031	1.837	0	16
Socio-demographic variables				
Male	0.427	0.495	0	1
Age	47.948	14.347	18.00	96.00
Worker	0.574	0.495	0	1
Household size	3.174	1.136	1	8
Transport mean ownership				
Exclusive use car	0.227	0.419	0	1
Shared use car	0.418	0.493	0	1
Bicycles per person in HH	0.550	0.409	0	2

Table 3. Descriptive Statistics (Continued)

Variable Name	Mean	Std.Dev.	Minimum	Maximum
Built environment characteristics				
Log of gross density	8.530	1.405	0.00	11.74
Entropy index	0.560	0.102	0.19	0.83
Distance to closest train station	0.546	0.516	1.00	3.19
Tokyo 23 Special Wards (Dummy)	0.094	0.292	0	1
Large City (Dummy)	0.451	0.498	0	1
Small City (Reference)	0.300	0.459	0	1
Residential location preference				
Car access residential preference	0.448	0.498	0	1
PT and NM residential preference	0.696	0.460	0	1

MODEL STRUCTURE AND RESULTS

Model specifications

Two aspects of travel behavior are analyzed in this study, number of trips by mode and travelled distance by mode, this section will first describe the basic model characteristics and then proceed to discuss the estimation results.

In order to analyze the effect of the built environment and individual preferences on number of trips conducted by mode, a negative binomial regression was chosen in order to account for the nature of the distribution of the data (see figure 4).

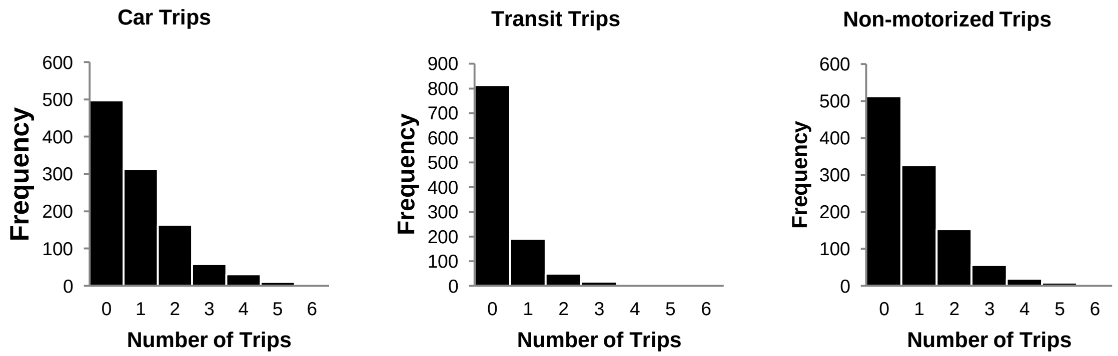

Figure 4. Frequency of number of non-work trips by mode

Following Cameron & Trivedi (1986), for this analysis the Negbin 2 form was used, where the probability density function is:

$$Prob(Y = y_i|\boldsymbol{x}_i) = \frac{\Gamma(\theta + y_i)}{\Gamma(y_i + 1)\Gamma(\theta)} r_i^{y_i}(1 - r_i)^{\theta}$$

Where $\lambda_i = exp(\boldsymbol{x}_i'\boldsymbol{\beta})$

And $r_i = \lambda_i/(\theta + \lambda_i)$

Where λ is the conditional expectation of y_i. An important feature of the negative binomial model is that it relaxes the equidispersion assumption in the Poisson case that $Var(y|\boldsymbol{x}) = \lambda$, by introducing an unobserved heterogeneity parameter α and parameterizing variance as: $Var(y|x) = \lambda_1(1 + \alpha\lambda_i)$, where $\alpha = 1/\theta$, and θ is an index of precision parameter (Greene, 2009).

To evaluate the goodness of fit of the models, an R-squared statistic based on the deviance residuals for NB2 models was used as suggested by Cameron & Windmeijer (1996), where deviance for the maximum likelihood is defined as:

$$DEV_{NB2} = \sum_{i=1}^{N} 2\left\{y_i\, log\left(\frac{y_i}{\hat{\lambda}_i}\right) - (y_i + \hat{\alpha}^{-1})log\,(\frac{y_i + \hat{\alpha}^{-1}}{\hat{\lambda}_i + \hat{\alpha}^{-1}})\right\}$$

Thus

$$R^2_{DEV\ NB2} = 1 - \frac{\sum_{i=1}^{N}\left\{y_i\, log\left(\frac{y_i}{\hat{\lambda}_i}\right) - (y_i + \hat{\alpha}^{-1})log\,(\frac{y_i + \hat{\alpha}^{-1}}{\hat{\lambda}_i + \hat{\alpha}^{-1}})\right\}}{\sum_{i=1}^{N}\left\{y_i\, log\left(\frac{y_i}{\bar{y}}\right) - (y_i + \hat{\alpha}^{-1})log\,(\frac{y_i + \hat{\alpha}^{-1}}{\bar{y} + \hat{\alpha}^{-1}})\right\}}$$

Where the numerator of the second equation corresponds to the deviance of the fitted model and the denominator corresponds to the deviance of the intercept only model, given estimated values of α.

For analyzing travelled distances, a Tobit regression model was selected given that, as illustrated in figure 4, for each mode a considerable fraction of the sample did not conduct any trips during the survey period, hence the respective distributions for distances travelled by each mode are truncated at zero. Following the Tobit model assumptions (Tobin, 1958) we define the conditional mean function of y_i in terms of a latent variable y_i^* :

$$y_i^* = \boldsymbol{x_i'\beta} + \boldsymbol{\varepsilon_i},$$

$$y_i = \begin{cases} 0 & if \quad y_i^* \leq 0 \\ y_i^* & if \quad y_i^* > 0 \end{cases}$$

Then
$$E(y_i|\boldsymbol{x_i}) = \Phi\left(\frac{\boldsymbol{x_i'\beta}}{\sigma}\right)(\boldsymbol{x_i'\beta} + \sigma\lambda_i)$$

Where
$$\lambda_i = \phi\left(\frac{\boldsymbol{x_i'\beta}}{\sigma}\right)/\Phi\left(\frac{\boldsymbol{x_i'\beta}}{\sigma}\right)$$

Where λ_i is the inverse Mills ratio; that is, the ratio between the standard normal probability density function and the standard normal cumulative density function evaluated at $\frac{\boldsymbol{x_i'\beta}}{\sigma}$**.**

Regarding goodness of fit measures for the Tobit models, Pseudo R-squared measures are usually reported; nevertheless, to our best knowledge there is no clear agreement in the literature regarding which Pseudo R-squared statistic to use. In this analysis, following Veall & Zimmerman (1994) we report a modification of the McKelvey & Zavoina R-squared:

$$R^2 = \frac{\sum_{i=1}^{N}\left(\hat{y}^*_i - \bar{y}^*\right)^2}{\sum_{i=1}^{N}\left(\hat{y}^*_i - \bar{y}^*\right)^2 + N\hat{\sigma}^2}$$

Where $\hat{y}^*_i = \boldsymbol{x_i}'\boldsymbol{\beta}$ and $\bar{y}^*$ is the mean of $\hat{y}^*_i$. Nonetheless, Veall & Zimmerman (1994) point out that no Pseudo R-squared will share the nice properties of the OLS R-squared, and notes the usefulness of a Pseudo R-squared statistic that might serve as a good predictor of what an OLS R-squared would be on uncensored data. In that sense, although we do report the statistic, its meaning should be considered carefully.

For both the trip frequency and distance models, three nested models were estimated for each mode: The base model including only individual and household characteristics, the built environment model (hereinafter BE model) which adds built environment variables to the base model, and the full model (BE+AT) which includes also the preference variables.

Trip frequency model estimation results

Concerning the overall estimation of the models, the dispersion parameter α is statistically larger than zero in all models, providing evidence on the overdispersion of the data, and validating the use of the negative binomial regression over the Poisson regression. Table 4 and 5 present estimated results.

When comparing the nested models for each mode in terms of its Likelihood ratio all models are significantly different from the base model, implying that accounting for built environment features and preferences provides a superior fit than the base model. Nevertheless, for the transit models, the full model (BE+AT) is not any different from the built environment model (BE) suggesting no effect from individual preferences on transit trip frequency, evident on the large standard error of its coefficients. In that sense, discussion hereinafter will be made based on the car trip and non-motorized trip full models and on the transit trip BE model.

All else equal, men carry out on average 18.7% less non motorized trips than women. Age was negatively associated with car trip frequency and positively associated with non motorized trip frequency, suggesting that as people age and become unable to drive, they tend to rely more on walking and biking for transport. On average, workers exhibit 14.8% less car trips and 22.6 less Non motorized trips than non-workers, an intuitive result given the high rate of transit commuting in the region; the coefficient on public transport trips was however, not statistically different from zero. As expected, car ownership is positively associated with non-work car trip frequency and negatively associated with other modes. Ceteris paribus, individuals with vehicles for their exclusive use exhibit car trip frequencies

72% higher than those with access to a common car inside the household; conversely, exclusive car ownership translates into 67% and 32% less transit and non-motorized trips than their common car access counterparts respectively. Number of bicycles per person was also associated with 56.8% higher frequency of non-motorized trips.

Regarding the effect of the built environment, population density around home location is negatively associated with car trip frequency, with an estimated elasticity of -0.066. On transit and non motorized trips, the effect of density is not statistically different from zero.

Land use mix, as measured by the entropy index, although not significant in the car trip model, exhibits a positive association with both transit and non motorized trips, yet at the 0.10 level. The semi-elasticities of land use mix on transit and non motorized trips are estimated at 1.76 and 0.96 respectively; that is, for every one point increase in the land use mix index, on average, public transport trip frequency increases by 1.76% and walk and bike trip frequency increases by almost 1%. The effects of the land use coefficient must however be interpreted carefully given the nature of the entropy index and its lack of power to detect the independent effect of each particular land use type.

Regarding average distance to closest station, results show a significant negative association between distance to train stations with transit and non motorized trip frequencies, with estimated semi-elasticies of -0.29 and -0.15 respectively, suggesting a 29% reduction in transit trip frequency and a 15% reduction in non motorized trip frequency for every extra kilometer away from a station. The effect of distance to station on walking and biking trips might however, not only be related to transit accessibility, but also be a result of the fact that services and activity opportunities usually agglomerate around train stations; in that sense, the variable also serves as an indicator of land use mix and intensity of land use.

Concerning the effect of preferred modal access when deciding last residential location, three non exclusive modal access preferences were considered in the analysis; nevertheless, after testing for statistical difference between each other, transit and non-motorized variables were merged together.

Car access preference was consistently insignificant in all the models, suggesting no significant association between preference for car access and travel behavior. On the other hand, transit and non motorized access preference was negatively associated with car trip frequency and positively associated with walk and bike trips. Ceteris paribus, individuals with transit and non motorized preferences exhibit on average 15.8% less car trips and 42.5% more non motorized trips.

In terms of possible bias in the built environment coefficients as a result of omitting preference variables, although estimated models suggest a significant association between individual preferences and travel behavior, the introduction of preference variables only changes slightly the coefficients of the built environment variables, suggesting that omission bias in the built environment coefficient, if any, might be rather small.

Table 4. Negative binomial regression estimation results

	Car Trip Models				Transit Trip Models				NM Trip Models			
	BE		BE+AT		BE		BE+AT		BE		BE+AT	
N	1076		1076		1076		1076		1076		1076	
Log likelihood	-1352.06		-1349.45		-763.41		-762.578		-1283.81		-1275.07	
Restricted log likelihood (Const.)	-1457.47		-1457.40		-837.18		-837.182		-1374.12		-1374.12	
Deviance R^2	0.123		0.127		0.114		0.116		0.120		0.134	
Deviance R^2 (Base model)	0.113		0.113		0.098		0.098		0.110		0.110	
LR Test X^2 (null: Base model)	12.08 (df=3)	***	17.31 (df=5)	***	41.34 (df=3)	***	43.00 (df=5)	***	12.49 (df=3)	***	29.97 (df=5)	***
LR Test X^2 (null: BE Model):	-		5.22 (df=2)	**	-		1.66 (df=2)		-		17.48 (df=2)	***
Constant	0.372	*	0.516		-1.030		-1.102		**-0.717**	*	**-1.048**	***
	(0.381)		(0.389)		(0.668)		(0.672)		**(0.400)**		**(0.403)**	
Male	-0.114		-0.119		-0.180		-0.178		**-0.234**	***	**-0.207**	**
	(0.091)		(0.092)		(0.137)		(0.138)		**(0.084)**		**(0.083)**	
Age	**-0.005**	*	**-0.005**	*	0.001		0.002		**0.007**	***	**0.007**	***
	(0.003)		**(0.003)**		(0.004)		(0.004)		**(0.003)**		**(0.003)**	
Worker	**-0.148**	*	**-0.160**	**	0.069		0.079		**-0.266**	***	**-0.256**	***
	(0.077)		**(0.079)**		(0.129)		(0.130)		**(0.079)**		**(0.079)**	
Household size	0.033		0.029		**-0.230**	***	**-0.229**	***	-0.022		-0.015	
	(0.032)		(0.032)		**(0.060)**		**(0.061)**		(0.034)		(0.034)	
Exclusive use car	**1.130**	***	**1.093**	***	**-1.090**	***	**-1.041**	***	**-0.594**	***	**-0.548**	***
	(0.114)		**(0.116)**		**(0.208)**		**(0.211)**		**(0.112)**		**(0.113)**	
Shared use car	**0.784**	***	**0.767**	***	**-0.508**	***	**-0.463**	***	**-0.411**	***	**-0.384**	***
	(0.089)		**(0.091)**		**(0.138)**		**(0.143)**		**(0.083)**		**(0.083)**	
Bicycles per person in HH	-		-		-		-		**0.455**	***	**0.456**	***
	-		-		-		-		**(0.088)**		**(0.087)**	
Log of gross density	**-0.067**	***	**-0.069**	***	0.065		0.067		0.027		0.031	
	(0.026)		**(0.026)**		(0.047)		(0.047)		(0.028)		(0.028)	
Entropy index	-0.549		-0.552		**1.015**	*	**1.053**	*	**0.680**	*	**0.670**	*
	(0.348)		(0.350)		**(0.594)**		**(0.600)**		**(0.372)**		**(0.374)**	
Distance to closest train station	0.030		0.013		**-0.341**	**	**-0.322**	**	**-0.171**	**	**-0.159**	**
	(0.070)		(0.071)		**(0.146)**		**(0.147)**		**(0.077)**		**(0.077)**	
Car access residential pref.	-		0.085		-		-0.172		-		-0.106	
	-		(0.079)		-		(0.133)		-		(0.078)	
PT and NM residential pref.	-		**-0.173**	**	-		0.051		-		**0.353**	***
	-		**(0.079)**		-		(0.143)		-		**(0.086)**	
Dispersion Parameter												
α	**0.226**	***	**0.220**	***	**0.667**	***	**0.651**	***	**0.140**	***	**0.114**	*
	(0.061)		**(0.060)**		**(0.195)**		**(0.193)**		**(0.063)**		**(0.060)**	

Base Model(omitted): Individual and Household Attributes only; BE: Built environment; BE+AT: Built environment and attitudes
Value in parenthesis is standard error; Significance level:*10% **5% ***1%

Table 5. Negative binomial regression marginal effects

	Car Trip Models				Transit Trip Models				NM Trip Models			
	BE		BE+AT		BE		BE+AT		BE		BE+AT	
Male	-0.108		-0.112		-0.165		-0.163		**-0.209**	***	**-0.187**	**
Age	**-0.005**	*	**-0.005**	*	0.001		0.002		**0.007**	***	**0.007**	***
Worker	**-0.138**	*	**-0.148**	**	0.072		0.082		**-0.233**	***	**-0.226**	***
Household size	0.033		0.029		**-0.205**	***	**-0.204**	***	-0.022		-0.015	
Exclusive use car	**2.095**	***	**1.984**	***	**-0.664**	***	**-0.647**	***	**-0.448**	***	**-0.422**	***
Shared use car	**1.191**	***	**1.153**	***	**-0.399**	***	**-0.371**	***	**-0.337**	***	**-0.319**	***
Bicycles per person in HH	-		-		-		-		**0.577**	***	**0.578**	***
Log of gross density	**-0.065**	***	**-0.066**	***	0.067		0.069		0.027		0.031	
Entropy index	-0.422		-0.424		**1.759**	*	**1.866**	*	**0.975**	*	**0.954**	*
Distance to closest train station	0.031		0.013		**-0.289**	**	**-0.276**	**	**-0.157**	**	**-0.147**	**
Car access residential preference	-		0.089		-		-0.158		-		-0.100	
PT and NM residential preference	-		**-0.158**		-		0.052		-		**0.424**	***

Travelled distance models

Regarding Travelled distance models, estimation results and marginal effects are summarized in table 6 and 7 respectively. Regarding the difference among the nested models, for all modes, the BE models were significantly different from the base models; however, the car trip full model was significantly different from the BE model only at the 0.10 level, while the transit full model was not significant at all. The non motorized model on the other hand, was statistically different from the BE model at the 0.1 level.

All else equal, individuals with access to an exclusive car, travel on average 8.6 kilometers in a two day period than other groups, and approximately 3 kilometers more than those individuals with access to a shared car within the household. Conversely, exclusive car drivers ride on average 47 kilometers less on public transport and walk and bike 1.2 less kilometers, than other groups. When compared to shared car users, exclusive car users ride 18 kilometers less on transit and approximately 240 meters less in non motorized means.

Concerning built environment variables, density and land use mix around home locations were not statistically different from zero in any of the models. This might be attributed to the scale of measurement of these variables. More specifically, car and transit trips are expected to go beyond the local neighborhood; in that sense, while built environment characteristics at home location might influence trip frequency by mode, these variables might have little effect if any on traveled distances once the decision to travel by a given mode is taken. Thus, to account for built environment characteristics in larger scale, city size dummy variables were used as proxies for land use and density at the city level.

Individuals living within the Tokyo 23 special wards drive on average 2.7 kilometers less by car than residents of small cities and 1.5 less than residents in large cities such as Yokohama, Chiba, and Saitama. Conversely, Tokyo Ward residents exhibit 50.6 more transit kilometers in a two day period than their small city counterpart and approximately 39 kilometers more than large city residents. Surprisingly, there effect of city size on non motorized trip distances was not statistically different from zero.

Regarding the effect of preferred modal access when deciding last residential location, as with the trip frequency case, individual preferences were not significant in the transit trip model. Furthermore, car access residential preference was positively associated with car trip distances, yet only at the 0.1 level. The strongest effect of individual preference on trip distances was observed on non motorized trips. All else equal, those individual with access preference for transit and non motorized modes exhibit on average almost one kilometer more in a two day period than other groups.

Table 6. Tobit regression estimation results

	Car Trip Models		Transit Trip Models		NM Trip Models	
	BE	BE+AT	BE	BE+AT	BE	BE+AT
N	1076	1076	1076	1076	1076	1076
Log likelihood	-2875.53	-2873.05	-1888.34	-1888.05	-1711.12	-1702.11
Restricted log likelihood (Const.)	-2944.38	-2944.38	-1917.24	-1917.24	-1755.42	-1755.42
McKelvey and Zavoina Ps.R^2	0.036	0.038	0.005	0.005	0.027	0.031
Base Model Ps.R^2	0.034	0.034	0.005	0.005	0.024	0.024
LR Test X^2 (null: Base model)	8.15 (df=2)**	13.11 (df=4)**	14.7 (df=2)***	15.26 (df=4)***	8.64 (df=2)**	26.66 (df=4)***
LR Test X^2 (null: BE Model):	-	4.96 (df=2)*	-	0.56 (df=2)	-	18.02 (df=2)***
Constant	**-11.229** ***	**-9.454** **	-22.355	-24.074	**0.897** *	0.140
	(4.075)	**(4.280)**	(24.872)	(26.270)	**(0.535)**	(0.565)
Age	-0.046	-0.057	-2.230	-1.781	**0.012** *	**0.013** *
	(0.053)	(0.053)	(9.710)	(9.729)	**(0.007)**	**(0.007)**
Worker	1.439	1.177	0.001	0.028	**-0.881** ***	**-0.845** ***
	(1.504)	(1.509)	(0.323)	(0.325)	**(0.201)**	**(0.201)**
Household size	0.565	0.536	**-16.652** ***	**-16.586** ***	-0.001	0.012
	(0.643)	(0.644)	**(4.303)**	**(4.304)**	(0.087)	(0.086)
Exclusive use car	**19.384** ***	**18.448** ***	**-47.105** ***	**-44.910** ***	**-1.375** ***	**-1.207** ***
	(2.040)	**(2.078)**	**(13.851)**	**(14.146)**	**(0.274)**	**(0.277)**
Shared use car	**13.021** ***	**12.378** ***	**-25.242** **	**-23.413** **	**-1.065** ***	**-0.968** ***
	(1.798)	**(1.824)**	**(10.877)**	**(11.139)**	**(0.225)**	**(0.229)**
Distance to closest train station	2.188	1.890	-16.162	-15.599	**-0.547** ***	**-0.482** **
	(1.386)	(1.395)	(10.197)	(10.219)	**(0.205)**	**(0.205)**
Tokyo 23 Special Wards (Dummy)	**-5.723** **	**-5.901** **	**50.644** ***	**50.421** ***	0.044	0.150
	(2.837)	**(2.843)**	**(15.471)**	**(15.523)**	(0.342)	(0.341)
Large City (Dummy)	**-2.629** *	**-2.557** *	12.117	11.952	-0.074	-0.100
	(1.507)	**(1.507)**	(10.165)	(10.167)	(0.207)	(0.206)
Small City (Reference)	-	-	-	-	-	-
	-	-	-	-	-	-
Car access residential pref.	-	**2.925** *	-	-7.554	-	-0.318
	-	**(1.517)**	-	(10.121)	-	(0.207)
PT and NM residential pref.	-	-2.516	-	2.701	-	**0.941** ***
	-	(1.606)	-	(10.615)	-	**(0.224)**
Disturbance Standard Deviation						
σ	**20.854** ***	**20.837** ***	**111.966** ***	**111.947** ***	**2.829** ***	**2.809** ***
	(0.654)	**(0.653)**	**(5.320)**	**(5.320)**	**(0.091)**	**(0.090)**

Base Model(omitted): Individual and Household Attributes only; BE: Built environment; BE+AT: Built environment and attitudes
Value in parenthesis is standard error; Significance level:*10% **5% ***1%

Table 7. Tobit regression estimated marginal effects

	Car Trip Models		Transit Trip Models		NM Trip Models	
	BE	BE+AT	BE	BE+AT	BE	BE+AT
Age	-0.022	-0.027	-2.230	-1.781	**0.012** *	**0.013** *
Worker	0.678	0.553	0.001	0.028	**-0.881** ***	**-0.845** ***
Household size	0.266	0.252	**-16.652** ***	**-16.586** ***	-0.001	0.012
Exclusive use car	**9.127** ***	**8.672** ***	**-47.105** ***	**-44.910** ***	**-1.375** ***	**-1.207** ***
Shared use car	**6.131** ***	**5.818** ***	**-25.242** **	**-23.413** **	**-1.065** ***	**-0.968** ***
Distance to closest train station	1.030	0.888	-16.162	-15.599	**-0.547** ***	**-0.482** **
Tokyo 23 Special Wards (Dummy)	**-2.695** **	**-2.774** **	**50.644** ***	**50.421** ***	0.044	0.150
Large City (Dummy)	**-1.238** *	**-1.202** *	12.117	11.952	-0.074	-0.100
Car access residential preference	-	**1.375** *	-	-7.554	-	-0.318
PT and NM residential preference	-	-1.183	-	2.701	-	**0.941** ***

Significance level:*10% **5% ***1%

DISCUSSION OF FINDINGS

Estimated results suggest significant statistical associations between the built environment and non work travel behavior in line with findings from the literature even after accounting for individual preferences. Higher densities were negatively associated with car trip frequency and higher land use mix was positively associated with transit and non motorized trip frequency. Nevertheless, it is important to highlight that although built environment characteristics such as population density and land use mix around home location were significantly associated with trip frequency, no significant relation was found between such local level features with trip distance, even for non motorized trips. In that sense, built environment features at the regional level might explain better travel distances.

Significant associations were also found between car preference with car travel distances, as well as between transit and non motorized preferences with fewer car trips and more –and longer– non motorized trips. This suggests that residential self-selection partly explains differences in car and non motorized travel behavior. However, no significant relation was found between individual attitudes and transit trip frequency or distance.

Regarding policy implications, although a causal effect is yet to be established, results from the estimated models suggest that even after controlling for individual preferences and self selection, the built environment exerts some influence on travel behavior, both in terms of trip frequency as well as travelled distances, providing some empirical support to compact city policy advocates.

Concerning the present study, several limitations have also been identified. First of all, given the aggregated nature of the built environment variables, results might be sensitive to way analysis units are defined and segmented, this is known as the modifiable areal unit problem (MAUP). In that sense, two important issues merit further analysis, i) how does the effect of the built environment varies as scales of analysis change, and ii) depending on the travel behavior aspect of interest, which is the most adequate scale of analysis. Certainly, considering simultaneously different analysis scales might shed some light on these questions, and help understand better the dynamics of the built environment and travel behavior.

Regarding attitudinal variables, although individual preferences have been controlled for, it was done in a rather rough way due to data limitations. A more complex analysis on attitudes and preferences is desirable to account in a more comprehensive manner for individual taste variations. Finally, the present analysis was based on individual trip frequency and did not account for characteristics of tours. A tour based analysis that takes into account different types of trip chains might prove a useful strategy to improve the behavioral content of the analysis.

CONCLUSION

This study analyzed the relation between the built environment, individual modal access preferences –as measurements of residential self selection– and travel behavior in the case of the Kanto Region in Japan. Two models were estimated, a negative binomial model to analyzed trip frequency by mode and a Tobit regression model to analyze traveled distances by mode. Findings suggest that even after controlling for individual preferences, the built environment still exerts some effect on travel behavior, both in terms of trip frequency and travel distances.

Although several limitations have been identified the current study, results reported here might help create ground for international comparison on the effects of the built environments and attitudes on travel behavior.

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