A STRUCTURAL EQUATIONS MODEL OF LAND USE PATTERNS, LOCATION CHOICE, AND TRAVEL BEHAVIOR IN SEATTLE AND COMPARISON WITH LISBON

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ABSTRACT

This paper addresses the relationship between travel behavior and land use patterns using a Structural Equations Modeling framework and a more comprehensive modeling than in the past. The proposed model structure in this paper is by design heavily influenced by a model developed for Lisbon (1) to allow comparisons. In that paper the existence of significant effects of land use patterns in travel behavior was found. The travel behavior variables included in the model are multidimensional and comprehend both short term, number of trips by mode and trip scheduling, and long term, home location, car and pass ownership, mobility decisions. The modeled land use variables measure the levels of urban intensity and density, diversity, both in terms of types of uses and the mix between jobs and inhabitants and the public transport supply levels. The land use patterns are described both at the residence and employment zones. In order to explicitly account for self selection bias the land use variables are explicitly modeled as functions of socioeconomic attributes of individuals and their households. The Seattle findings are presented and then compared to the Lisbon findings. Many commonalities between the two environments were found but also many important differences pointing to the need for policy initiatives that are local and tailored to the specific context.

1. INTRODUCTION

Nowadays urban mobility is strongly supported by the massive use of automobiles, inducing important environmental, socioeconomic and territorial impacts, many of them perceived as strongly negative. This originated several proposals of policies designed to tackle these negative impacts. The three most important are: a) Policies advocating the diffusion and use of new technologies, b) policies advocating economic measures in order to change travel behavior, and c) policies advocating the use of land use changes to influence travel behavior. During the past 20 years the debate between advocates of the two latter policies has been rather intense (for examples see 1, 2, 3, 4, 5, 6, 7and 8). Consequently, the study of the relations between land use patterns and travel behavior was the object of important attention from researchers. Due to this continuous attention important theoretical and methodological innovations were made. The first generation of quantitative models tested the existence of these relations using aggregate (zonal based) models with important shortcomings. The first generation of studies was subjected to several criticisms (9, 10, 11) with most important their lack of behavioral basis. These criticisms, paved the way for the appearance of disaggregate (individual based) approaches and the application of models based on the utility theory (12, 11).

Within the framework of utility theory travel demand is treated as a derived demand (13). By this reasoning the land use patterns influence travel behavior by changing generalized costs. This type of influence occurs either in long term decisions (e.g., car ownership) or short(er) term decisions (e.g., mode or destination choice). Long term decisions influence short term decisions by restricting the alternatives available (14). Other recent methodological advances expanded the framework of utility maximization in the activity based approach. In this case the land use patterns are determinants of opportunities and restrictions posed in the pursuit of activities (15). However, the use of models based on the utility theory is plagued with difficulties. Using Logit or Probit models does not necessarily imply a utility theory based model since the model should reflect a theory based specification (11). Cervero (16) also points out that most of these models have been badly specified. These innovations also highlighted other shortcomings of the empirical models developed in this area. One of them is the endogenous relations that occur among behavioral variables such as self-selection (17) due to endogenous effects between land use variables and individual or family characteristics. A more radical hypothesis asserts that the differences in travel behavior found for residents in different urban environments is due to the fundamentally different characteristics of people living in different environments and not on the policy of changing these environments. One solution to unravel all these relationships is to formulate many equations representing these behavioral facets and allow them to be correlated in their observed and unobserved components. In this way causal inferences of mutual influence can be measured by estimated correlation among the variables in a system of equations.

Another important issue is the measurement of variables describing land use characteristics. One of the most widely used is urban density, although it could not be the most adequate variable, since it encompasses many diverse characteristics that cannot be easily replicated by simply changing density (9).Other land use variables more generally used include mix of employees and residents, mix and diversity of land use categories, urban design measures, housing characteristics, and accessibility variables. Related important issues are the multidimensionality of urban space, and the interconnections that exist between land use variables (18, 19). The former of these issues is due to the necessity of having at the same time an important number of land use variables that could encompass the multidimensionality of urban space, and to the need for a reduction in the number of variables employed to capture the multidimensionality of urban space. The interconnections and amplification effects that could exist between land use variables means that they could present negligible effects when analyzed one by one and significant effects when included in more comprehensive indexes (19). These problems prompted the use of data reduction techniques (e.g. factor or cluster analysis), which allow the maintenance of the levels of richness in the characterization of land use patterns (18).

One relatively recent analytical innovation key to this paper is Structural Equations Modeling (SEM) (20, 21). SEM allows the parameterization of endogenous relations between variables accounting for self-selection effects (17, 21). It also allows the modeling of a comprehensive framework of hierarchical relationships among long term decisions to medium or short term decisions. Relatively new estimation algorithms of SEM allow the estimation of discrete and censored variables, thus allowing them to be used within the framework of utility theory (20).

All of these methodological innovations were incorporated in the model presented in this paper with a structure that replicates a previously developed model for the Lisbon Metropolitan Area (1) to compare the results obtained.

2. CASE STUDY AND MODEL DESCRIPTION

The present model used data from the Puget Sound Transportation Panel (PSTP). Puget Sound is the region surrounding Seattle. PSTP contains a large number of waves, repeated observation of the same persons over time, between 1989 and 2003 (22). The data used correspond to a sample taken from the ninth wave of this panel survey, which was in 2000. The choice of this wave was due to the availability of land use data of the same vintage (see also 23 and 24). This sample with 1025 observations was made by selecting one adult worker in each of the households interviewed in this wave. Table 1 contains the individual and household variables and the travel behavior variables used in this sample.

The model structure for both Seattle and Lisbon (1) examines the relations among socioeconomic characteristics, land use patterns, relative residential and employment locations, car ownership, public transportation pass ownership, and travel behavior.

The point of departure for model specification is as follows. Land use patterns both around the residence and employment locations are influenced by the socioeconomic characteristics of the individuals and their households. Both land use patterns and socioeconomic variables influence travel behavior of employed individuals. This influence is assumed to be at least partly mediated by variables describing several travel behavior related decisions, going from long term decisions to shorter term decisions. These variables include, the distance between employment and residence locations (commuting distance), car ownership and transit pass ownership that are considered as being longer term decisions. These, in turn, influence shorter term decisions such as the number of trips made daily by different modes and the time spent between the first and last trips, corresponding to the height of Hägestrand prism in time geography. Land use variables are also influenced by travel behavior variables. In this way, we can test for possible effects due to the fact that travel behavior is one of the observed outcomes of individual preferences and also the feedbacks due to the information that individuals have about optimal shorter term decisions (25).

TABLE 1 Here

The Seattle and Lisbon models' general structure is presented in Figure 1. The arrows entering each box in the flowchart indicate variables used as explanatory variables for the variables in the box that are the dependent variables. These relationships are tested statistically for their influence. In a model of this type we can also differentiate between direct and indirect influences. In this way, we can identify the influence land use variables have on trip making directly by examining their magnitude and significance in the trip making equations. We can also track the influence of land use variables on trip making through other variables such as car ownership. The total influence of land use on trip making is the sum of direct and indirect influences. The socioeconomic variables used in the model include gender, age, household total income (in three binary variables – low, medium and high income), household size, average age of the household, an indicator for households with only two individuals and another for households with teenagers.

In this model the created land use variables considered both the traffic analysis zone (TAZ) surrounding residence and work locations and a grid cell system of 750x750 m around the place of residence and employment of each individual, respectively labeled home and work. The land use variables included a global population density (considering both inhabitants and employees), a built floor space density, and the density of arterial intersections in each grid cell. The distance of each TAZ to Seattle Regional Centre was also included, and an entropy indicator was built using the built floor space of each type of land use including residential, commercial and services, industry and government/public services. This indicator measures the diversity balance between several categories of land uses, and it was first used by Cervero, Frank, and Pivo as cited in Kockelman (26). Transit supply variables were also created, including the number of bus services during the morning peak and midday in each grid cell.

FIGURE 1 Here

In a similar way as in the Lisbon model all of these land use variables were reduced to 5 factors characterizing both the residence and employment locations (capturing 77% of variation). With the exception of one factor there was a clear distinction between factors describing land uses in the residence and employment area. The factors and their defining variables and their scores are presented in the Table 2.

The first two factors present high scores in variables describing the intensity and centrality of land uses. They are named employment and residence in central and denser areas respectively. The third and fourth factors are clearly connected with transit supply both at the residence and employment areas. They are named, bus supply in the employment and residence areas. The fifth factor measures the balance of land uses both at the residence and employment areas. It is named Mix of Land Uses. These five factors capture the most important dimensions of the home and work location and are used as five dependent variables in the model. In this way we avoid the need to model spatial locations one by one and we convert them into the five major latent characteristics.

TABLE 2 Here

3. STRUCTURAL EQUATION MODELLING

SEM represents an evolution and a combination of two types of statistical methods, factor analysis and simultaneous equations models (27). In SEM, variables could be either exogenous or endogenous (20, 21). These characteristics allow SEM to handle indirect and multiple relationships. Due to these characteristics SEM is particularly adequate as a tool to model the complex relationships between travel behavior and land use patterns.

A structural equation system with observed variables only, as the one presented in this paper (no measurement sub models) can be expressed as:

$$y = \mathrm{B}y + \Gamma x + \zeta$$

Where

y is the vector of *p* endogenous variables;

x is a vector of *q* exogenous variables;

ζ is a vector of *p* disturbances with variance-covariance matrix Ψ;

B is (*p*x*p*) matrix containing the coefficients for the equations relating the endogenous variables;

Γ is a (*p*x*q*) matrix containing the regression coefficients for the equations relating endogenous and exogenous variables.

The model-replicated combined variance-covariance matrix of the observed (*p*) endogenous and (*q*) exogenous variables, arranged so that the endogenous variables are first, is given by the partitioned (*p*+*q* by *p*+*q*) matrix (27, 20).

$$\sum(\theta) = \left[\begin{array}{c:c} (\mathrm{I}-\mathrm{B})^{-1}(\Gamma\Phi\Gamma' + \Psi)\left[(\mathrm{I}-\mathrm{B})^{-1}\right]' & (\mathrm{I}-\mathrm{B})^{-1}\Gamma\Phi \\ \hdashline \Phi\Gamma'\left[(\mathrm{I}-\mathrm{B})^{-1}\right] & \Phi \end{array}\right]$$

. Φ is the covariance matrix among exogenous variables. Estimation of SEM models is performed by using the covariance analysis method – method of moments (20).The objective function is to minimize the differences between the sample variance-covariance matrix, S, and the model-replicated matrix $\Sigma(\theta)$. The methods used for model estimation are normal theory maximum likelihood – ML, generalized least squares – GLS and weighted least squares – WLS (20) (21). WLS, used in this paper, was specifically developed to deal with discrete and censored variables. Its genesis occurred with a multivariate Probit developed by Muthen (28). The latter was generalized (29) to accommodate structural equations with a mix of discrete, censored and continuous variables (30).

WLS minimizes the following fit function (31)

$$F(\theta) = (s - \sigma)' W^{-1} (s - \sigma)$$

Where

s' is the vector of the elements in the lower half, including the diagonal of the covariance matrix **S.** **σ'** is the vector of corresponding elements of **Σ(θ)**, reproduced from the model parameters θ; $\mathbf{W^{-1}}$ is the positive definite weight matrix of order u by u, where ***u=(P+q)(P+q+1)/2***. These weights are estimates of the fourth-order moments (the variances of the covariances).

The direct effects in the SEM model are given by the parameters of the **B** and Γ matrices and can be interpreted in the same way as regression coefficients (27) and they are the direct influence that one variable has on another. For an identified SEM model the total effects of the exogenous variables on the endogenous variables are given by $(\mathbf{I} - \mathbf{B})^{-1}\Gamma$ and the total effects of the endogenous variables on one another are given by $(\mathbf{I} - \mathbf{B})^{-1} - \mathbf{I}$ (20), they are deducted from the general model expression solved in order to ***y*** (27). Total effects are the sum of both direct and indirect effects (27). The indirect effects are given by the differences between the total and direct effects. They capture the influence of a variable on another variable through a third mediating variable, thus helping to identify self defeating policies due to contrary direct and indirect effects.

4. ESTIMATION RESULTS DISCUSSION

The model estimation results are presented in the following way. First the direct effects between exogenous and endogenous variables (matrix gamma) are presented in Table 3. Then, the direct effects between endogenous variables (matrix beta) are reported in Table 4. The total effects between land use variables and the other endogenous variables are presented last in Table 5.

The estimated model shows a good fit. The value of its chi-squared statistic is 100.15, with 104 degrees of freedom. The ratio between these two values means that the differences between the population covariance matrix and the model implied covariance matrix are small. An acceptable goodness of fit is obtained when this ratio is smaller than 2 and very good fit when it is close to 1 (32, 33). Also the standard Bayesian criteria (AIC and CAIC) indicate that this model is superior either to the independence or the saturated models.

TABLE 3 Here

The direct effects as presented in the gamma matrix are in general in accordance with what would be expected. Men and people with higher levels of income tend to spend more time outside home. People belonging to older and larger households tend to spend more time at home. Younger people tend to make more trips by non motorized modes and older people tend to make more transit trips, also being a man reduces the probability of making transit trips. A higher income reduces the probability of making trips by transit and non motorized modes. Being a member of an older household reduces the number of trips by transit. Moreover, people belonging to larger households tend to make fewer non motorized trips. The contrary happens for households with only two members. There are no significant direct effects between socioeconomic variables and the number of trips made by car, meaning that all the effects from the socioeconomic variables on car trips are mediated through other endogenous variables.

People in households with two members have a lower probability of having a transit pass presumably due to the ability to share tasks and drive. As expected bigger households and with higher levels of income have a higher probability of owning more cars. Gender also affects the number of cars in the household, since the presence of women in labor market is not as high as men, although this difference could be considered small. Being an older man increases the commuting distance. In American cities the suburbanization and sprawling phenomena are more intense and have occurred for a longer time than in Europe in general and Lisbon in particular. The effects of income show that neither higher or lower levels of income influence directly the commuting distance.

The results show that land use variables are influenced by the socioeconomic variables, thus revealing the existence of self-selection effects. Younger women tend to work in denser and central areas, also people with medium and higher levels of income and belonging to smaller and younger households tend to work in this type of areas. Men belonging to smaller households and with medium income levels tend to reside in more dense and central areas. Women with lower income levels and belonging to smaller households tend to work more frequently in areas better served by bus. The direct effects of socioeconomic variables on the levels of transit supply in the residence area are mainly those of income. Higher levels of income have a negative impact and medium levels of income have a positive one. In mix of land uses, only age and the household size have a significant impact, both positive. These results show that generally younger, richer people and belonging to smaller households tend to work in more central areas. In addition, people living in more central areas tend to belong to smaller households. This is what one would expect as a description of *urbanites*. These results show that people with generally lower levels of car availability tend to locate their residence and employment sites in areas better served by public transport.

TABLE 4 Here

The time spent between the first and last trips is positively influenced by the commuting distance and by the possession of a transit pass. Having a transit pass also influences negatively the number of trips by car and positively all the others, meaning the existence of some levels of mutual reinforcement between transit and non motorized modes. The number of trips using transit is also positively influenced by the land use factor employment in a denser and central area and negatively by the factor residence in a central and denser area, probably meaning that people residing in a place with a high score in this factor might use non motorized modes more than transit, presumably due to the distances involved between activity opportunities.

The number of trips by car is negatively influenced by the transit supply levels in the area of employment and positively by the factor employment in a denser and central area. Although this direct effect might appear as contrary to what might be expected this could be at least partly a compensation effect due to the fact that this factor influences positively the probability of having a transit pass. Nevertheless the number of cars in the household is influenced by the income levels as is also the land use factor employment in a central and denser area. This could mean that although density and centrality could act as a deterrent to car ownership levels, the levels of income combined with the fact that public transport in Seattle is mainly built around a bus network could act as an impediment to a more widespread use of public transport by people working in central locations.

The pass ownership is negatively influenced by the number of cars in the household and the levels of bus supply in the employment area. This variable is positively influenced by the commuting distance and by the residence and employment in central and denser areas. Both indications may lead to different markets transit agencies could tap. The number of cars in the household is negatively influenced by the land use factors employment in a denser and central area, bus supply in the employment area and mix of land uses. The commuting distance is positively influenced by the number of cars in the household, by the employment in a denser and central area and by the bus supply in the employment area. These effects are consistent with the hypothesis of a more intense suburbanization of the population being the employment more centralized. Two land use factors are directly affected by travel behavior variables. One is the residence in a denser and central area, which is negatively influenced by the commuting distance, and the other is the bus supply in the residence area which is negatively influenced by the number of cars in the household. People who prefer to live closer to their workplace tend to choose more central and denser locations and people who prefer to own fewer cars tend to locate their residence in a place better supplied with public transport.

The direct effects between pairs of endogenous variables show in general the confirmation of the following hypotheses:

- Land use variables affect directly travel behavior;
- The relations between travel behavior variables are consistent with the hypothesis that long term decisions condition shorter term ones. With three exceptions the direct effects are all above the diagonal of the Beta matrix;
- Land use variables are also directly influenced by travel behavior variables.

Table 5 shows the total effects between endogenous variables. It should be noted that interpreting a model with the direct effects provides misleading conclusions when the direct and the total effects are very different. It is the total effects that should be used in identifying the impact land use variables have on travel behavior.

TABLE 5 Here

The overall finding is that total effects from the land use factors to the travel behavior variables show the existence of significant influences. In fact, people working in more central, denser and mixed areas and with higher levels of transit availability tend to own fewer cars. In contrast, car ownership is not influenced by the residential area land use characteristics. People living and working in more central, denser and mixed areas tend to have a higher probability of owning a transit pass. On the contrary the levels of bus supply have negative total effects, although with a much lower level of magnitude.

The total effects of land use factors on the number of trips show that density and centrality both at residence and employment areas increases the number of trips in transit and in slow modes. The effects on the number of trips by car are negative in the case of land factor residence in a denser and central area and not significantly different from zero in the case of the land use factor employment in a denser and central area. The variable mix of land uses influences negatively the number of trips by car and positively the number of trips by other modes. The levels of bus supply both at residence and employment locations tend to influence negatively the number of trips by every mode, with the exception of bus supply in the residence area which has a positive effect on the number of trips by car. This is an indication that simply increasing bus services will not be sufficient to attract ridership and it may also have negative impacts (e.g., residents of an area giving rides to bus riders for their long haul trip). The effects of land use patterns on the time spent between the first and last trip go also in two directions, the residence and employment in denser and central areas influences positively this trip scheduling variable and the levels of bus supply in the residence areas influence it negatively.

5. COMPARISON WITH THE LISBON MODEL AND CONCLUSIONS

One of the main objectives for building this model was to compare its results with a similar model built for the Lisbon Metropolitan Area (1). This comparison is presented mainly in terms of model structure and estimation results since the variables used in both models are not the same due to different data availability in the two areas studied. Also, the travel behavior variables used in both models are almost the same with the exception of the number of kilometers travelled by mode, only available for Lisbon . Variables describing individuals and household characteristics were also similar. The most important differences are in the number and breadth of land use variables that in the Lisbon model are vaster but measured at the zonal level. In spite of these differences the estimation results obtained in both models point to similar global conclusions. People with different socioeconomic characteristics and income levels tend to work and live in places of different urban environments. Also, land use patterns in the areas of employment and/or residence are influenced by travel behavior variables presumably capturing the impact of desired mobility and lifestyles on the choice of places to live and/or work. Both models lead to the conclusion that land use variables affect travel behavior in a significant way. Moreover, both models show that the effects of land use are in great part "passed through" variables influencing long(er) term decisions like commuting distance, car ownership, and transit pass ownership. Equally important is also that both models account for self selection effects due to socioeconomic characteristics. The results show that land use affects travel behavior even when we account for self selection.

There are, however, some important differences between the Lisbon and Seattle models. In the Lisbon model car ownership is a function of pass ownership, but in Seattle it is the other way around. This could be explained by the fact that Lisbon has a much more developed public transport network and less generous parking supply, thus offering more transit options and imposing heavier restrictions on car ownership levels. In Seattle it is exactly the opposite. When a commuter cannot purchase a car she/he relies on transit. In the Lisbon Model the number of trips by mode is a function of car ownership and transit pass ownership and also they are a function of one another, an evidence of competition between modes. In the Seattle model the number of trips by mode has only direct effects from transit pass ownership. There is no evidence of direct competition between modes. In terms of the total effect from transit pass and car ownership they tend to have the same signal.

The direction of total effects from commuting distance on the number of trips by mode is different in both models. In Lisbon the commuting distance affects positively the number of trips by car and transit and negatively the number of trips by non-motorized modes. In Seattle commuting distance affects positively the number of trips by transit and non-motorized modes, and negatively the number of trips by car. This points out to the possibility of a strong market for Seattle transit such as the long distance commuters, which is a neglected market segment in the US.

Although a direct comparison between Lisbon and Seattle cannot be made in terms of the size of the land use effects on travel behavior, the results tend to generally point to similar conclusions that are: a) Living and working in central, denser and mixed areas tends to have a positive effect on the number of trips by non-motorized modes, and increasing the chances of owning a transit pass; b) living in denser, central and mixed areas tends to reduce the number of car trips and the car ownership levels in the household; and c) working in central and denser areas tends to increase the commuting distance, which is a sign of the polarizing power that the center of both metropolitan regions have, attracting people living in suburban and exurban areas. Regarding this last effect it can also be seen that in the Seattle Model the total effects of car ownership on commuting distance are positive, contrary to what was found in Lisbon. This can be again explained by the fact the public transport network and particularly the regional rail network in Lisbon is much more developed than the one in Seattle which relies mainly on a bus network with ferries that serve just a few specific locations. Thus for people living in the suburbs and working in the center of Lisbon public transportation is a more convenient option when compared to Seattle. This fact points to the importance of public transport supply levels together with land use patterns. In addition, socioeconomic variables in both models stress the impact that income has on travel behavior. Both models show that higher levels of income tend to have a positive effect on the commuting distance and on the car ownership levels. The total effects of income on transit pass ownership are different. In Lisbon there is a negative relationship with income and in Seattle that relationship is positive but not significant.

The results presented in this model are strong evidence in favor of using land use regulation and land use change as a tool to change travel behavior. Public transportation supply increases are not supported by our model results except if tailoring to markets is applied (e.g., the long distance commuters in Seattle). It should also be added that the impact of these policies will be different depending on local circumstances. It is still not known, however, if the commonalities and differences between the two metropolitan areas here are due to local peculiarities of generally valid relationships. This motivates the expansion of this study to other urban environments and the repetition of the analysis using variables measured at the same scale and with the same content.

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TABLE 11 Sample travel behavior and socioeconomic characteristics

Variables		Average	Standard Deviation
Endogenous travel behavior variables	Time spent between first last trips	10.55	3.04
	Nº trips - non motorized	0.31	0.91
	Nº trips - transit	0.31	0.82
	Nº trips - car	3.76	2.52
	Transit pass	0.18	0.39
	Number of cars	2.11	0.79
	Log commuting distance	3.51	1.05
Socioeconomic exogenous variables	Age	46.76	10.84
	Gender – male (%)	0.51	
	Low income (%)	0.09	
	Medium income (%)	0.46	
	High income (%)	0.33	
	Household size	1.55	0.64
	Average age	46.11	10.46
	Household with 2 members (%)	0.41	
	Household with teenagers (%)	0.03	

TABLE 12 Land Use factors and their defining factor loadings

Land use factors	Most Important Variables	Loadings
Employment in a central and denser area	Population density work	0.947
	Building density work	0.966
	Intersections density work	0.915
	Distance form CBD work	-0.586
Residence in a central and denser area	Population density home	0.933
	Building density home	0.917
	Intersections density home	0.706
	Distance form CBD home	-0.561
Bus supply in the employment area	Bus availability AM work	0.997
	Bus availability midday work	0.997
Bus supply in the residence area	Bus availability AM home	0.898
	Bus availability midday home	0.904
Mix of Land Uses	Entropy home	0.830
	Entropy work	0.490

TABLE 13 Gamma matrix - direct effects between endogenous and exogenous variables

	Age	Gender (1if man)	Low income	Medium income	High income	Household size	Average age	Household with 2	Nº teens
Time spent between first and last trips		0.107	-0.040	0.076	0.106	-0.087	-0.182		
		4.115	*-3.926*	*5.043*	*5.695*	*-2.404*	*-3.674*		
Nº trips non motorized	-0.162			-0.039	-0.037	-0.207		0.167	0.176
	-2.685			*-5.373*	*-3.992*	*-6.307*		*5.819*	*6.532*
Nº trips transit	0.218	-0.044	0.013		-0.077		-0.199		
	3.854	*-2.878*	*2.276*		*-8.669*		*-9.036*		
Transit pass								-0.066	
								-2.675	
Nº cars		0.113	-0.036		0.180	0.370			
		3.221	*-2.345*		*7.372*	*14.607*			
Log commuting distance	0.758	0.260		-0.037					-0.067
	6.924	*10.683*		*-2.561*					*-3.085*
Employment in a central and denser area	-0.188	-0.133	-0.067	0.093	0.144	-0.225	-0.197	0.053	
	-2.566	*-6.044*	*-7.387*	*8.239*	*11.593*	*-6.481*	*-3.328*	*2.132*	
Residence in a central and denser area		0.041		0.082		-0.459		0.260	0.257
		2.110		*7.152*		*-14.788*		*8.870*	*9.080*
Bus supply in the employment area		-0.038	0.033			-0.023		-0.018	
		-23.759	*46.627*			*-31.363*		*-13.287*	
Bus supply in the residence area				0.020	-0.052				
				2.443	*-5.726*				
Mix of Land Uses	0.085					0.087			
	2.627					*8.079*			

Note: t-statistics are presented in italic

TABLE 14 Beta matrix - direct effects among endogenous variables

	Transit pass	Nº cars	Log commuting distance	Employment in a central and denser area	Residence in a central and denser area	Bus supply in the employment area	Bus supply in the residence area	Mix of Land Uses
Time spent between first and last trips	0.093 *4.310*		0.224 *2.451*					
Nº trips non motorized	0.293 *8.055*							
Nº trips transit	0.519 *10.049*			0.172 *3.938*	-0.082 *-3.532*			
Nº trips car	-0.385 *-14.377*			0.175 *3.788*		-0.019 *-4.579*		
Transit pass		-0.295 *-9.481*	0.129 *7.154*	0.382 *10.051*	0.248 *10.705*	-0.034 *-14.465*		
Nº cars				-0.095 *-3.995*		-0.017 *-6.109*		-0.073 *-3.345*
Log commuting distance		0.116 *3.861*		0.510 *8.833*		0.013 *4.928*	-0.070 *-4.234*	
Residence in a central and denser area			-0.254 *-9.823*					
Bus supply in the residence area		-0.044 *-3.971*						

Note: t-statistics are presented in italic

TABLE 15 Total effects among endogenous variables

	Transit Pass	Nº cars	Log commuting distance	Employment in a central and denser area	Residence in a central and denser area	Bus supply in the employment area	Bus supply in the residence area	Mix of Land Uses
Time spent between first and last trips	0.093	0.000	0.230	0.153	0.023	0.000	-0.016	0.000
	4.310	*0.002*	*2.545*	*3.413*	*4.011*	*-0.141*	*-2.218*	*-0.002*
Nº trips non motorized	0.293	-0.084	0.019	0.130	0.073	-0.008	-0.001	0.006
	8.055	*-6.214*	*3.720*	*6.177*	*6.435*	*-7.081*	*-2.839*	*2.980*
Nº trips transit	0.519	-0.146	0.055	0.412	0.046	-0.014	-0.004	0.011
	10.049	*-7.166*	*4.917*	*11.075*	*1.917*	*-8.420*	*-3.216*	*3.052*
Nº trips car	-0.385	0.111	-0.026	0.005	-0.096	-0.008	0.002	-0.008
	-14.377	*8.667*	*-3.974*	*0.117*	*-9.005*	*-2.057*	*2.893*	*-3.167*
Transit pass		-0.287	0.066	0.443	0.248	-0.028	-0.005	0.021
		-9.325	*3.996*	*13.143*	*10.705*	*-14.093*	*-2.905*	*3.181*
Nº cars				-0.095		-0.017		-0.073
				-3.995		*-6.109*		*-3.345*
Log commuting distance		0.120		0.498		0.011	-0.070	-0.009
		3.968		*8.627*		*4.407*	*-4.234*	*-2.540*
Residence in a central and denser area		-0.030	-0.254	-0.127		-0.003	0.018	0.002
		-3.498	*-9.823*	*-6.641*		*-3.992*	*3.830*	*2.402*
Bus supply in the residence area		-0.044		0.004		0.001		0.003
		-3.971		*2.941*		*3.455*		*2.553*

Note: t-statistics are presented in italic

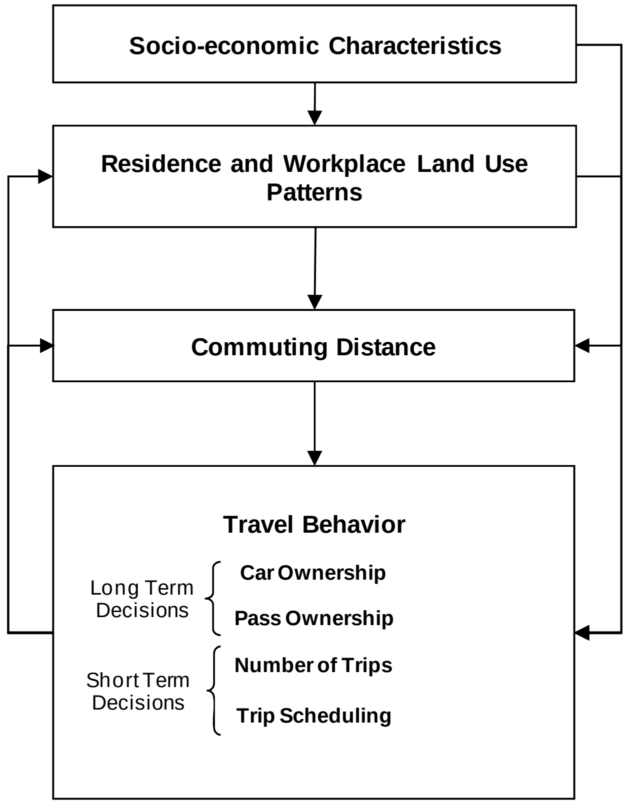

FIGURE 3 Model general structure