ANALYSIS OF THE SPATIAL AND PERSONAL CHARACTERISTICS THAT INFLUENCE COMMUTING TRAVEL BEHAVIOR

Eleni Zacharaki

PhD Candidate - Aristotle University of Thessaloniki,
Cooperator- Unit A- Intermediate Managing Authority of Transport- Ministry of Infrastructures, Transport and Networks

George Giannopoulos

Professor of Transport Engineering- Aristotle University of Thessaloniki,
Head- Hellenic Institute of Transport- National Centre for Research and Technology of Greece

ABSTRACT

Transportation systems in urban areas are increasingly pressed to serve the growing and dispersed travel patterns, due to the growth of suburban housing development, the emergence of suburban job centers and the segregation of residential and employment sites. This modification of activities' spatial allocation implies a modification to daily travel patterns of individuals and households and mainly, changes to daily commuting behavior in terms of mode choice, travel time, number of trips, trip chaining etc.

As this evolution of urban mobility is strongly supported by the massive use of private vehicles, inducing important negative environmental and socioeconomic impacts, a number of policies have been designed to tackle the reverse effects of mobility growth. The main policies in this direction are:

- Initiation, diffusion and use of new technologies in the transport sector
- Economic measures in order to change travel behavior (e.g. fuel taxation, congestion charging etc)
- Land use changes to influence travel behavior (e.g. neotraditional neighborhood design versus suburbanization)

The last policy is based on the concept of land use – transport interaction, which has been identified as a research subject in the literature for many decades. Theories on the relationship between the two systems recognize a feed back cycle between the two systems, based on the assumption that land use not only influences transportation outcomes, but that transportation investments also influence land use decisions. This approach led in a first generation of quantitative and aggregate integrated land use and transportation models, which tested the existence of these relations in order to guide the metropolitan planning

process. Despite the fact that some considerable progress has been made, no disaggregate behavioral framework has yet been developed.

Thus, investigating the "behavioral" side of the relationship between the built environment and travel behavior started to form the new research agenda. This paper comes to give some European evidence and to add a new perspective to the research debate. It aims to obtain some further insight concerning the influence of the built environment and personal characteristics on commuting travel behavior, by analyzing travel data from the greater Thessaloniki area in Greece, using a Structural Equation modeling framework. The analysis is delimitated to employed individuals and incorporates land use patterns and characteristics around the residence and employment sites, as their characteristics are influenced by the socioeconomic characteristics of the individuals and their households. Consequently, the paper will present:

1. A brief review of the factors that influence commuting travel behavior and the proposed modeling framework
2. The travel behavior variables selected for the current research work
3. The land use and transport supply variables for both the residence and the employment zones
4. The results and conclusions of the current research.

Keywords: structural equation modeling, travel behavior, density, diversity, travel patterns, mode choice, activity patterns

1. INTRODUCTION

Travel for work is a major element of the daily travel pattern of individuals. Usually it covers longer distance on average than most other trip purposes during a typical weekday, it follows a strict schedule, it goes through a specific route and involves almost every day the some mode. Commuters strive to optimize their time – cost function in order to make mode and route choices. Some seek for the most direct and efficient mode and route to shorten their travel time, while some others try to accomplish at the same time and other commitments (e.g. to drop or pick children from school, to make the daily shopping, or to conduct various errands). Thus commuting is central to structuring many people's lives in terms of where they choose to live and work and how they organize their days and weeks and shape travel behavior patterns for individuals and households.

These travel behavior patterns change over time, i.e. individuals periodically review their travel choices and outcomes. Changes depend on the viability of reliable travel alternatives and on the occurrence of special circumstances in individuals' lives. The first parameter is almost self – explanatory, while the second encompass a number of issues, called key events. Recent research suggests that key events may have important impact on travel behavior (Krizek, 2003; van der Waerden, Timmermans and Borgers, 2003; Kloekner, 2004; Stanbridge, Lyons and Farthing, 2004). Some examples are: the reallocation of residence or workplace, an advancement, the lifecycle stage of individuals, the structure of the household, the arrival or departure of a household member etc. In other words key events are substantial changes in an individual's circumstances that may have significant influence on travel behavior.

Consequently commuting travel behavior is a rather complex function, depending on parameters like personal and social characteristics of individuals and households, transport investments and supply, spatial allocation of activities and urban structures. According to previous research work, gender, household size and structure, age, income, education level and employment status is a set of crucial determinants of personal and social characteristics that influence travel behavior. The opportunities for work and live in specific areas and parameters like density, diversity and design of the sites shape urban structures, influence the decisions for spatial allocation of individuals' activities, and finally, give the travel alternatives. All three categories together influence the long term choice of residence and work location as well as the mid and short term choices for commuting and especially the travel length, the mode choice and the trip chaining. Any change in one parameter may influence or cause a change to all others.

More specifically, research up today has shown that women have different commuting patterns comparing with men. In general they tend to travel shorter distances for work, to make more trips (i.e. longer trip chains) and to use public transit more (Hjorthol, 2000; Polk, 2003). Another evident is that mothers' trip patterns are different from men and that in single working parents', travel patterns are different from their married counterparts. Talking into account the household structure[1] as well, studies found that women use more public transport to commute in one-car, two-worker households and married women make twice as many shopping and errand trips as men, while at the same time they are responsible in the majority of cases for chauffeuring dependents (Gordon et al, 1989; Hanson and Johnston, 1985; Hanson and Pratt, 1991; Wachs, 1992; Rosenbloom and Burns, 1993).

The presence of children and their ages influence the travel patterns of women more than men in all types of households: the more and the younger their children, the less likely working women are to use alternative modes of transport or to carpool. At the same time women with children tend to work closer to home than men with children, even in single parent households. As working women with children trip chain more, due to their increased household responsibilities, they are more captive to private car and in longer average travel time. In this case, the practicality of transit decreases as the need for trip chaining increases (Rosenbloom and Burns, 1993; Rosenbloom and Burns, 1994). Another important finding in the case of one adult household is that the average travel time for single mothers is longer than the average travel time for single fathers.

Land use factors like density, mix of land uses (diversity), centrality of the area, design (e.g. road type, path connectivity, existence and quality of sidewalks along streets, site/building orientation) etc can significantly affect travel and especially mode choice and average travel distance. Besides, different types of land uses have different accessibility features. In urbanized areas accessibility and transport diversity are increased and therefore automobile travel decreases and public transport usage increases. On the contrary, in suburban and rural areas in order to maintain an acceptable level of mobility and access to activities and services, residents are more auto dependent and their travel choices are straiten. These differences reflect the shorter commute and errand trips and better travel options in more central locations (Litman, 2009a).

In general land use factors effects on travel behavior are strongly associated with automobile ownership and average travel. Increased land use mix, employment and population density turn to lower levels of automobile ownership and per capita automobile travel. The same occurs for areas with attractive and safe streets that are able to accommodate safe pedestrian and cyclist traffic. In addition, high-density commercial centers have less automobile commuting as they support more and better travel choices (availability of transit alternatives, accessible and better quality of pedestrian facilities), chime in services (e.g. banks, offices etc) and amenities such as shops and cafes (Litman, 2009a).

[1] For reasons of simplicity and uniformity, in most cases households are categorized into the following four broad categories: a. Single adult households without children, b. Single adult households with children, c. Two-or-more adult households without children and d. Two-or-more adult households with children.

Transport infrastructure and the associated decisions for transport planning affect land uses directly and indirectly. The first category of effects refers to the space designated for the development of transport infrastructures. The second refers to the influence of transport system on areas' accessibility and thus to the available travel options and the spatial allocation of land uses and activities, i.e. location, type and cost of development. Consequently the impact of transport system on land uses influence travel behavior in terms of availability of travel options, location choices for workplace and residence and average travel distance for commuting. In general, automobile oriented transport planning (e.g. highway development, parking supply etc) supports urban sprawl, while walking and transit improvements encourage compact, mixed and multi-modal development (Moore and Throsnes, 1994; Kelly, 1994; Litman, 2009b).

2. SCOPE AND METHODOLOGY OF CURRENT RESEARCH

The overall purpose of the current research work is to contribute toward a better understanding concerning the interrelations between spatial structures on the residential locations and workplace, personal dynamics and travel behavior. In doing so, two steps are followed:

- Presentation of the general approach and the underlying relations between land uses and transport system that affect travel behavior in terms of basic assumptions and critical factors
- Application, validation and evaluation of the approach using structural equation modeling.

Spatial structures reflect the environment within which individuals live, move, work, socialize, and more generally participate in activities. The term "land use" is used to reflect the physical and functional characteristics of the space that hosts human activities, while the term "transport system" refers to both infrastructures and services that provide connection between the various spatially segregated activities.

Travel behavior results from land use, transport system and individual's characteristics. This is something generally recognized in theories and models regarding travel behavior, including activity based models as well as the conventional four - stage travel model. A simplified representation of this notion is presented in Figure 1.

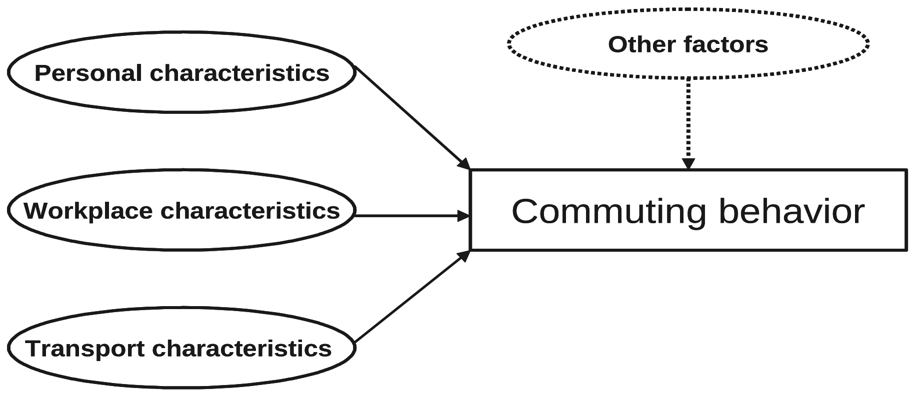

Figure 1- Simplified representation of commuting behavior

According to this Figure and the underlying assumptions used in the present research, we suppose that:

- individuals are the "actors"
- "activity participation" and specifically "work" is the key-concept
- travel is the by-product of activity participation, while travel choices (behavior) are the output of a complex process of comparing, evaluating and matching alternatives in order to reveal the one that fits better under the prevailing circumstances
- user characteristics, transport system and land uses influence travel behavior directly
- user characteristics influence directly the demand for space and changes in these characteristics and preferences affect land use through land use market
- the same occurs for the transport system (but with different rate and in a longer term, as transport get influenced mainly by policies about capital investments)

In addition, concerning the decision for residential location / relocation this paper acknowledges that the decision is influenced by the following factors:

- ownership of house in a specific location
- characteristics / quality of the area (e.g. type, street pattern, safety issues, environmental quality, distance from Central Business District – CBD, etc)
- accessibility by public transport
- structure of family (one-adult, two-adults household, etc)
- ability to make a different choice
- lifestyle options
- personal attitudes and perceptions
- distance from work (in the case of relocation)

Respectively, the decision for a specific workplace location is influenced by the following factors:

- labor market characteristics (e.g. job demand and supply, wage, prospects)
- existence of alternatives
- working hours
- distance from residential location and from CBD
- accessibility by various transport modes
- availability of car
- characteristics and quality of area
- personal qualifications and perspectives

It is profound that most points are common for the two decisions, like the issues of accessibility and quality of the area. These common points define the interfaces between the two decisions and finally between the location of the sites. The main question that exists and is under investigation from this research is: what influence commuting travel behavior the most: work location, residence location, transport system or socioeconomic factors and, is job location a reason for residence relocation?

The research methodology involved:

- Collection – preparation – checking the data from the General Travel Survey (GTS) conducted in Greater Thessaloniki Area in 1998 - 2000 by the Organization for Spatial Planning of Thessaloniki. Such surveys are conducted every 10 years in order to trace changes in mobility characteristics and to understand mobility patterns of inhabitants. Face-to face interviews were used to collect the (home interview) data and the respondents were randomly selected. The information gathered with this type of survey involved:

  - socioeconomic characteristics of the respondent's household, e.g. household size, gender and age of each member, income, employment status, car ownership, residence type, etc
  - travel characteristics of the previous day, i.e. number of trips, origin and destination of each one, start – end time, purpose, mode, number of mode changes in up to the final destination, travel time per mode.
- Preparing the methodological framework for the application of the SEM for the case of Thessaloniki.
- Application of the SEM and analysis of its results.
- Finally the drawing of the conclusions, and formulating the speculations and opportunities for further research.

3. CASE STUDY AND PRELIMINARY ANALYSIS

Based on data from the Thessaloniki Greater Area (maps of the area are given in Figures 2 and 3), a full scale analysis using factor analysis and SEM, has been performed. Factor analysis guided the variable selection process, in order to reduce the variables used in SEM and to guide the choice of latent variables. This part of the paper presents the preliminary results of the factor analysis, dealing with the relations among personal characteristics, land use characteristics, accessibility characteristics and travel behavior. Land use and accessibility provision variables for both the work and residence site have been used.

Figure 2 - Map of Thessaloniki Greater Area

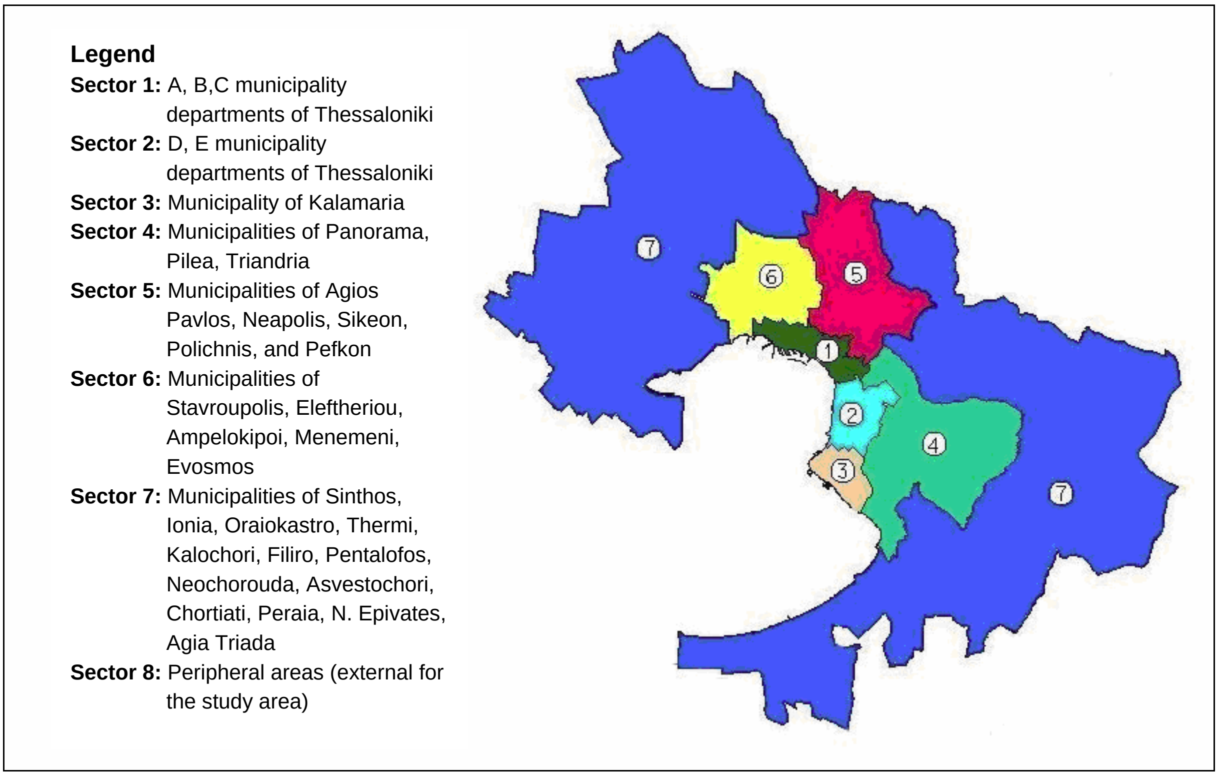

Figure 3 - Traffic sectors within the context of Thessaloniki's General Travel Survey

Concerning the data selection process, personal socioeconomic and travel data were obtained from the General Travel Survey (GTS) of the Thessaloniki Greater Area (1998 - 2000). In every such survey approximately 3.230 households or approximately 10.000 individuals participates. The survey questions consist of two parts: the first part refers to the general household characteristics (i.e. size, car ownership, income, type of residence, etc) and the second part is a personal questionnaire that aims to capture personal socioeconomic characteristics and daily mobility patterns for each member of the household. The second part of the questionnaire is completed only for members above six years.

The data sets of the Thessaloniki survey of 2000 were first examined as to their consistency and logical prowess, with those sets that did not satisfy a number of logical and "technical" tests being withdrawn from the data in order to avoid distortions and biases. The final analysis was based on data from 3835 respondents, which corresponds to the workers adults of the sample. Additional data for land use characteristics, like density and diversity, had to be recorded from the National Statistical Service Records (NSSR) at the level of municipality and interposed at the level of TAZ. The generally limited information available on such variables posed a serious constraint in the depth and diversity of the tests but at the end the whole set of data was deemed appropriate for the SEM analysis and the drawing of meaningful results.

Nevertheless it is useful to give a broad description of the spatial and sociodemographic characteristics of the study area using the information from Figures 2 and 3. The first one provides a map, mainly form the central area of the city of Thessaloniki and a few suburban areas with high population density, while the second gives the study area separated in sectors for the purposes of the GTS. The study area contains seven (7) sectors with similar characteristics or 293 traffic analysis zones (TAZ)[2]. The city, at least during the study time, had a monocentric character. That means that the central area (sectors 1 and 2 from figure

[2] The 8th sector refers to the peripheral – external for the study – areas.

3) hosted administrative, commercial and recreational activities, with limited residential use at the upper floors of the buildings. The street network is formed on four basic through road axis and follows a grid pattern. This picture changes for the rest sectors. More specifically, sectors 3, 4 and part of sector 7 (East Thessaloniki) host residential land uses for mid to high household incomes and punctual commercial and recreational development. At the other hand, sectors 5, 6 and part of sector 7 (West Thessaloniki) host residential land uses for low to mid household incomes and industrial development. In all cases the street network follows the grid pattern with fluctuating street coverage.

Initially theoretical consideration guided the variable selection process. In the stage of factor analysis the following variables has been examined:

- ✓ travel cost,
- ✓ travel time,
- ✓ number of trips (within the commuting trip chain) by public transport (PT trips),
- ✓ number of trips (within the commuting trip chain) with slow mode, i.e. walking and cycling (SM trips)
- ✓ number of trips (within the commuting trip chain) by private vehicle (PV trips),
- ✓ bus stops and bus lines per 1000 inhabitants and TAZ (BS/1000 inh., BL/1000inh.)
- ✓ network coverage per TAZ (as the ratio of the area for pedestrians divided by the area for automobiles)
- ✓ density (population per square kilometer and TAZ)
- ✓ diversity (floor space for mixed uses divided by floor space for all uses per TAZ) at the residential sites,
- ✓ average land value per square meter and TAZ
- ✓ average floor space per person and TAZ
- ✓ distance of the TAZ centroid from the Central Business District
- ✓ gender (ordinal),
- ✓ age
- ✓ income,
- ✓ household size
- ✓ percentage of household members under 18 years old and
- ✓ car ownership index (i.e. number of vehicles per household)

Table I that follows gives the basic descriptive statistics for the basic variables included in the analysis.

Table I - Descriptive statistics of variables included in the SEM analysis

	Minimum	**Maximum**	**Mean**	**Standard Deviation**
Car Ownership	0	8	1.17	0.8
Travel Cost	0	1667	475	640
Travel time (min)	0	2070	67	55
PT trips	0	12	0.9	1.3
SM trips	0	9	0.5	1.0
PV trips	0	8	1.4	1.9
BS/1000 inh.	0	6.8	0.7	0.9
BL/1000 inh.	0	8	0.6	1.0
Network Coverage	0	0.8	0.4	0.1
Density (inhabitants / km^2)	41.9	30393	16244	10003

Diversity (space for mixed use/ total available space)	0	0.5	0.3	0.2
Distance from CBD	0	27	6.2	6.6
Gender	57.4% male, 42.6% female			
Hhd size	1	8	3.5	1.2
Age	6	92	37.4	16.5
% of household members under 18	0	80	37	15
Income (monetary units)	0	879,465	277,811	155,483
Education level	8.7% none, 15.5% primary education, 38.2% secondary education, 23.1% higher education, 9.2 % students, 5.3% pupils			

The second step involved the implementation of factor analysis. For the purposes of this research work principal component analysis has been used, which is the most common form of factor analysis. This method seeks a linear combination of variables such that the maximum variance is extracted from the variables. It then removes this variance and seeks a second linear combination which explains the maximum proportion of the remaining variance, and so on. This is called the principal axis method and results in orthogonal - uncorrelated – factors. In order to make the output more understandable (and is usually necessary to facilitate the interpretation of factors) varimax rotation has been chosen. It is an orthogonal rotation of the factor axes to maximize the variance of the squared loadings of a factor (column) on all the variables (rows) in a factor matrix, which has the effect of differentiating the original variables by extracted factor. Each factor will tend to have either large or small loadings of any particular variable. A varimax solution yields results which make it as easy as possible to identify each variable with a single factor. It is of some important to mention that varimax rotation is the most common rotation option.

After implementing factor analysis as described above a number of variables has been excluded from the next step i.e. implementation of SEM, due to their limited contribution in explaining the total variance. The remaining variables were grouped in four factors characterizing the residence and employment locations, personal characteristics of travelers and their associated commuting travel behavior. Table II presents the factors and their defining variables, with the respective factor loads from the initial analysis of all parameters. These factors will be used in SEM.

Table II - Factors, variables and loads

Factor	Variable	Estimation Level	Source	Load
Quality of residential area	Density	TAZ	NSSR	0,924
	Bus stops per 1000 inh.	TAZ	GTS	0,916
	Diversity	TAZ	NSSR	0,906
	Distance from CBD	TAZ	GTS	0,739
Quality of employment site	Density	TAZ	NSSR	0,935
	Bus stops per 1000 inh.	TAZ	GTS	0,927
	Diversity	TAZ	NSSR	0,936
	Distance from CBD	TAZ	GTS	-0,544
Personal characteristics	Car ownership index	Household	GTS	0,718
	Gender	Individual	GTS	0,715
	Household size	Household	GTS	0,697
	Age	Individual	GTS	-0,587
	% of household members under 18 years	Household	GTS	0,536
	Income	Household	GTS	0,488

Travel behavior	Total trips for work	Individual	GTS	0,882
	Trips by private vehicle	Individual	GTS	0,771
	Trips by public transport	Individual	GTS	0,640

4. STRUCTURAL EQUATION MODELLING

Structural Equation Modeling (SEM) is a family of statistical techniques that incorporates and integrates simultaneous equations models and factor analysis. This modeling approach is able to handle a large number of endogenous - exogenous and latent (unobserved) variables specified as combinations of the observed variables. The researcher is required to develop a model in terms of a system of unidirectional effects of one variable on another. Direct effects correspond to arrows in a path diagram (Golob, T, 2003; Simon, W.P., Karlaftis, MG, and Mannering, FL, 2003).

It forms a confirmatory rather than exploratory procedure, which should be guided by prior theories about the structures to be modeled and is used to capture the causal influences of the exogenous on the endogenous variables and the causal influences of the endogenous variables upon another. It uses one of the following three approaches (Golob, T, 2003; Simon, W.P., Karlaftis, MG, and Mannering, FL, 2003):

- Strictly confirmatory, where a model is tested using SEM goodness of fit tests to identify if the pattern of variances and covariances in the set of data is consistent with a path model specified by the researcher
- Alternative models approach where one may test at least two causal models to determine which has the best fit, using the various goodness of fit measures
- Model development approach, where a model is tested using SEM procedures, found to be deficient, and then, an alternative model is tested based on the modification indices of the previous experiment.

SEM is a research technique dating from the early ’70s, with a number of applications in psychology, sociology, the biological sciences, educational research, political science and market research. Applications of SEM in travel demand modeling (models of vehicle ownership and usage, panel data modeling, activity participation and travel time, attitudes, perceptions and hypothetical choices) begin from 1980 and applications involving travel behavior and land use start after 1995.

The use of the SEM technique, as compared to traditional multiple regression has a number of advantages that can be summarized as follows (Van Acker, V., Witlox, F. and B. Van Wee, 2007):

- Possibility of making initial flexible assumptions;
- treatment of the “endogenous” and “exogenous” variables as random variables with errors of measurement;
- separation between measurement and specification errors;
- existence of latent variable with multiple indicators;
- overall test of model;
- modeling of mediating variables and error – term relationships;
- capability of handling of missing or non-normal data.

A SEM with latent variables is composed of up to three sets of simultaneous equations, i.e. a measurement submodel for the endogenous variables, a measurement submodel for the exogenous variables and a “structural” submodel. Estimation of a SEM model can be performed by use of various alternative techniques such as: “normal theory” (ML), generalized least squares (GLS), weighted least squares (WLS) with the alternatives of asymptotically distribution free weighted least squares (ADF) and elliptical reweighted least squares (ELS). Goodness of fit tests are used to determine if the model under consideration is consistent with the pattern of variance-covariances in the data (Golob, T, 2003).

5. RESULTS AND DISCUSSION

Table II presents the results of factor analysis that initially has been performed and the starting point for SEM: the model should contain four latent variables that will be associated with the indicators (variables) from the second column of table II (not the whole list of variables that has been used in factor analysis), in order to identify the measurement models. The analysis was performed using the software package AMOS and the maximum likelihood estimation approach. Modification indices have been calculated in order to improve the structure of the model. The final model – according to goodness of fit tests that are presented in table III – is acceptable, but not very satisfactory.

The final model and its standardized estimates are presented in figure 3. Arrows symbolize direct effects between two constructs or between a construct and its indicators. Due to interrelationships between model constructs, indirect effects occur also and they can be strong and able to change the total effect of each. The total effect of one variable on a second variable is the sum of the direct effect and all indirect effects from the first variable acting through intermediating variables on the second variable. The total effects are given in table IV.

Table III – Goodness of fit tests for the estimated model

Goodness of fit test	**Description**	**Value**
d.f.	degrees of freedom	150
χ^2	represents the discrepancy between the sample and the model – implied matrices	225.25
χ^2/d.f.	ratio that represents the “relative chi – square value” corrected for the degrees of freedom. If the ratio take values equal or less than 3 the model has a good fit, for values as high as 5 the model has adequate fit	1.502
Goodness of Fit Index (GFI)	measures the relative proportion of variance and covariance in the sample covariance matrix explained by the model – implied covariance matrix. Values closer to 1 indicates better fit	0.891
Normed Fit Index (NFI)	represents the proportion of independence model χ^2 explained by the model of interest. It takes values between 0 and 1, with values larger than 0.90 indicating a well – fitting model	0.814
Comparative Fit Index (CFI)	assumes a non-central χ^2 distribution for the independence model discrepancy. It takes values between 0 and 1, with values closer to 1.0 indicating good fit	0.853
Incremental Fit Index (IFI)	represents the incremental improvement of the model of interest over the independence model. It takes values between 0 and 1, with values closer to 1.0 indicating good fit	0.861
Root Mean Square of Approximation (RMSEA)	measures the estimated discrepancy between the model implied and the sample covariance matrix, corrected for degrees of freedom. Values less than 0.05 indicate a good fit and values as high as 0.10 represent a reasonable fit	0.111

Table IV - Standardized total effects

TRAVEL BEHAVIOR			
	Direct Effect	Indirect Effect	Total Effect
Quality of employment site	0.53	-0.93	- 0.40
Personal characteristics	-0.20	-0.77	-0.97
Quality of residential site	0.98	-	0.98

According to the path diagram in figure 2 a system of four equations has been deployed to describe travel behavior in the Thessaloniki greater urban area and more specifically:

1. *Travel behavior* = ƒ (quality of employment site, socioeconomics, quality of employment site total work trips, public transport trips, private vehicle trips)+ residual term
2. *Quality of employment site* = ƒ (bus stops per 1000 inhabitants, density, diversity, distance from CBD) + residual term
3. *Personal characteristics* = ƒ (vehicle ownership, income, age, household size, % of members under the age of 18, gender) + residual term
4. *Quality of residential site* = ƒ (bus stops per 1000 inhabitants, density, diversity, distance from CBD) + residual term

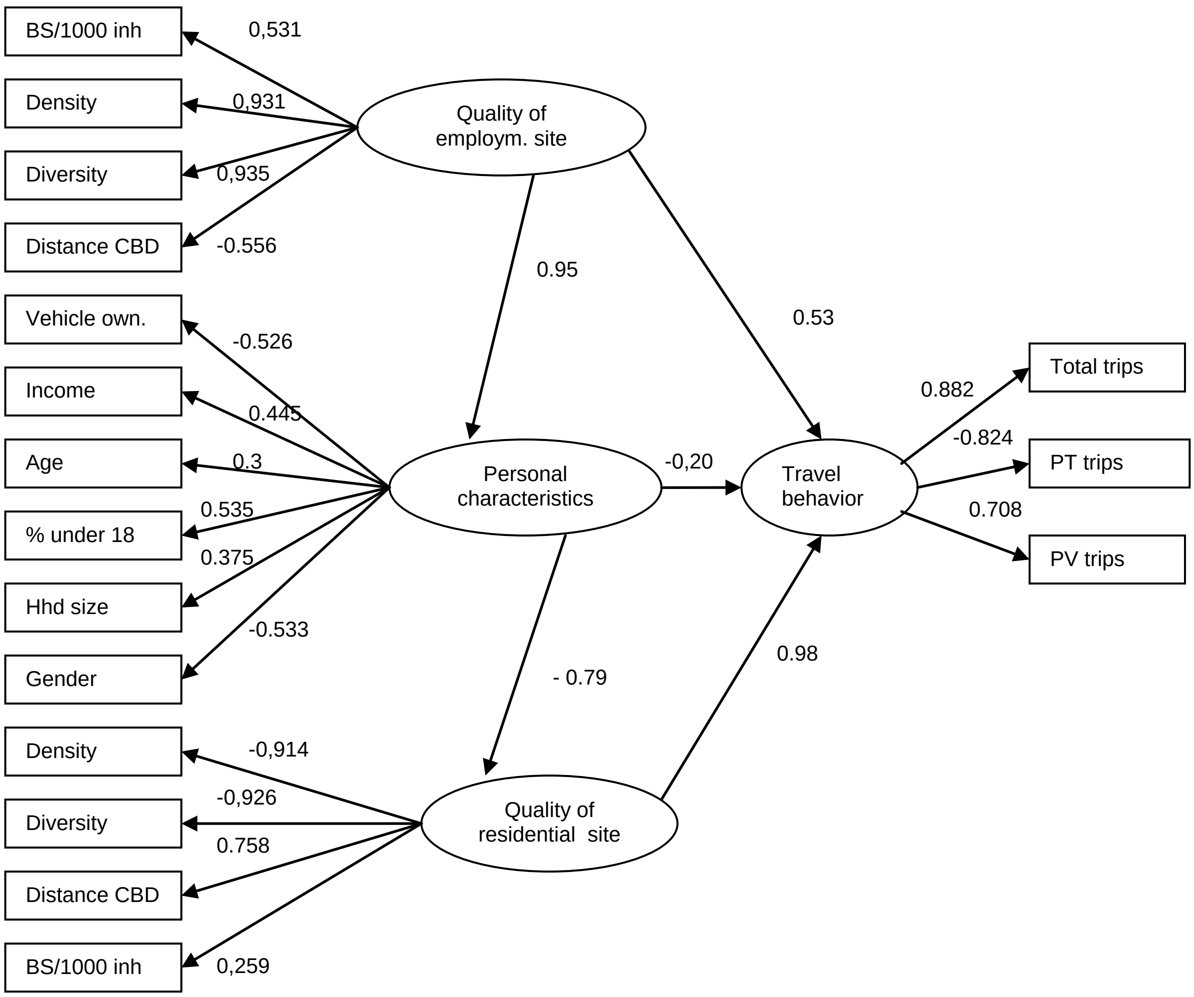

Figure 4 - Final model and standardized estimates

Comparing table IV and figure 4 it is obvious that due to indirect effects the total effects of the variables change. The quality of employment site has the weakest influence on travel behavior, while socioeconomic parameters and those that describe the quality of residential site hold the main roles. This is in accordance with what would be expected to happen.

Starting with the socioeconomic parameters, households with higher vehicle ownership tend to make more trips and especially by private vehicles and less by public transport. This trend is more increased when the traveler is female. According to the findings, women use more private vehicles for commuting, something that is possible to be imputed to their increased responsibility for errands in the way to/from work. Consequently they tend to trip chain more.

Being a member of a larger household with children, monthly income is shared in more persons, expenses grow up and probably, this is a reason for the increased share of public transport in such cases. It is expected this trend to be tenser in the case of one-worker households. With the adultness of children this may increase or decrease as a function of other socioeconomic parameters and especially income.

Older people, who still work, tend to trip chain less and to use more frequent public transport as a consequence of the decline in their daily errands, the adultness of children and the attenuation of driving ability. This is tenser in the case of low income workers and many-member households, where the access to private vehicle is limited or even trivial.

Quality of residential site is the other important determinant of travel behavior. Areas with high levels of density and land use mix, where various activities can be hosted, create an environment with less trips and especially private vehicle trips. These parameters oppose to automobile dependency, encourage public transport (and slow mode) use. Nevertheless, the overall mode split depends also from the distance of the Central Business District. Higher distances are accountable for increase to both total number of trips and private vehicle trips, as individuals have to visit public services often.

Better public transport service, in terms of bus stops' density seems to have an influence to total number of trips, which is not visualized –according to our data - to the number of public transport trips. First of all, this is a poor measure for the quality of public transport that it has been used due to lack of others. Another measure for this analysis would be bus line frequency, but it is a non-reliable measure, as it depends on the prevailing traffic conditions. However a possible explanation to this swing is that denser public transport services attract more passengers. As Thessaloniki has only bus based public transport system without the ability to expand or improve the service all day or during peak time, where commuting occurs, the level of service is rather low. Consequently travelers try to find alternative ways to reach their destinations.

The third influential parameter "quality of employment site" holds a moderate influence on travel behavior, but influences the choice of residential location. In order to be able to compare the results with those of the residential site and to answer to the dilemma "if individuals reallocate near their jobs" the same indices have been used, i.e. population density, distance from CBD, bus stops intensity and mix of land uses (diversity). The results support the previously identified trends: working sites with high population density and land use mix cause less trips and especially car trips, while public transport increase its share. They form an attractive alternative for both living and working there as a result of the increased opportunity for activity participation.

In the case of Thessaloniki this point explains the high rental cost for residential uses in the central areas, as well as the long travel times for commuting to work; individuals and households that can not afford the cost of living in the central areas, tend to live to the east or west side of the city. The final decision is determined from their socioeconomic (e.g. income) and household characteristics (e.g. existence of non adults in the household). Thus, in the majority of cases the one end of traveling to work is in the city center, while a significant portion of the population has to travel through the city center in order to get at work.

Denser public transport services, as described from the index "bus stops per 1000 inhabitants", increase public transport use for or during work (we are focused on the trips from the commuting trip chain), while long distance from administrative centers causes reduction to public transport use and increase to private vehicle trips. This means that people use public transport mainly for short trips, when the distance between the origin and destination increase, automobile dependency increase too.

Overall, the findings from this research work are in accordance with those drawn for Puget Sound Region and the Lisbon Metropolitan Area (de Abreau e Silva, J., Goulias, K, 2007). Despite the fact that different indices and a different approach have been used, the global conclusions are the same. Living and working in central areas with adequate public transport provision leads into a decrease in automobile trips and increase of public transport usage; metropolitan centres that offer more job opportunities attract people who live in suburban areas to work there, increasing thus commuting trips and travel distance.

5. CONCLUSIONS

Concluding, socioeconomic characteristics and the quality of residential areas, where commuting trips are generated, are the most influential parameters for travel behavior, while the quality of employment sites has a moderate role. Density and diversity are two parameters that encourage public transport and tackle automobile dependency. Distance from CBD is another important parameter and the findings of the current research drive to the conclusion that multi-center communities and polycentric development patterns are more favorable than mono-centric ones.

Describing and analyzing the same data indices for both the employment and residential areas it is possible to give some light in the query “if individuals relocate near their jobs”. The previously discussed analysis shows that people like to work near their homes, but it is not clear if they choose where to live according to where they work. The decision for relocation or not is a much more complex one and depends on a variety of parameters, dealing with socioeconomic aspects, environmental quality, perceived safety levels in the residential area, personal preferences, priorities, etc.

For the future and in order to obtain the more final results of this research, it is our intention to improve on the data used by going from the level of municipality (as it is the level of analysis shown here) to the more detailed level of “traffic analysis zone - TAZ” for better detail in both land use and accessibility provision data. As a concluding remark we would like to state that as this experiment shows so far, there is not an easily identifiable and definitive relation among the land uses, the transport system, and travel behavior. This lack of strong evidence can be attributed to the complex nature of the problem, the variety and type of explanatory variables and the methodology used, the available data and the degree of aggregation or disaggregation that is followed in the estimation of each variable.

The use of the SEM technique formed a useful methodological framework able to deal with the complex interdependencies among variables. This methodological framework proved that it can model the influences of independent variables upon dependent variables and influences in-between independent variables, giving the ability to isolate the direct and indirect effects of the independent variables on the dependent variables. The estimation of the indirect effect adds to the effort for better understanding of the relations between the variables and to the identification of casualties.

However and despite these difficulties this experiment and each experiment in the field by SEM can be treated in three ways:

a. As a research exercise that tries to investigate what influence travel behavior the most or to give evidence and confirm some relationships
b. As an input for the creation of a new generation of integrated land use transport interaction models, based on a behavioral framework, as it forms another step towards the understanding of behavioral aspects

c. As a practical tool - at a strategic level - able to guide policy making for the built environment and the capital investments according to the era's vision.

The third point is the most urgent. Towards the sustainability vision and the necessity for alternative development patterns and ways of travel, it is crucial to understand the behavioral characteristics of the travelers and how it is possible to affect them before drawing the plans for tomorrow. Is it better for our congested city to return to traditional neighborhood design or to suburbanization? Is it favorable to have one central administrative center or to promote decentralization or even to develop alternative structures? Questions like these can find answers through such approaches.

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