USING LATENT ATTITUDINAL VARIABLES FOR MEASURING CARPOOLING PROPENSITY

Gonçalo Correia, Department of Civil Engineering, University of Coimbra.

João de Abreu e Silva and José Viegas, Department of Civil Engineering, Instituto Superior Técnico

ABSTRACT

The increase of urban traffic congestion has called for the study of alternative forms of supply for mobility of people. One is carpooling, a system in which a person shares his private vehicle with one or more persons in commuter trips. In theory, these systems could lead to great reductions in the use of private vehicles; however, in practice they have been obtaining limited success. One of main reasons for this is the psychological barrier associated with riding with strangers and loosing the flexibility associated with using one's private vehicle as a single occupant driver. However the effect of these issues is sometimes hard to determine as they reveal subjective attitudes which are not easy to determine.

In order to study the effect of these variables on carpooling propensity, a stated preference web survey was conducted in the Lisbon Metropolitan Area (Portugal), collecting the rating of several attitudinal questions in a likert scale and completing the information with socio-demographic data. A simultaneous estimation of the attitudinal factors and the probabilities of choice was conducted through a Structural Equations Model (SEM) allowing concluding that these attitudes have an important influence in the decision to carpool and that the positive aspects that it entails may overcome the negative ones if properly used to set up carpooling schemes.

Keywords: Carpooling, Discrete Choice Model, Exploratory Factor Analysis, Structural Equations Model, Latent Variables

INTRODUCTION

The rising of automobile usage deriving from urban sprawl and car ownership growth is making traffic congestion more frequent and intense in urban areas. Moreover the majority of the trips are single occupant vehicle trips (SOV). In 1990 approximately 90% of the work trips and 58% of the other trips in the United States were done in SOV (Shaheen et al., 1999).

Numbers of 1997 show that the occupancy rate of the automobiles in commuting trips for the 15 Countries of the European Union was, at that time, in the interval between 1.1 and 1.2 persons per vehicle (IEA, 1997).

This results in air pollution, energy waste and unproductive and unpleasant consumption of the time that persons have, and this does not show a tendency to slow down; in fact traffic congestion and the correspondent environmental damage present a tendency to be aggravated. This brings direct disadvantages for the users but also for the general economy and society at large. In 2001, the white book for transport policy in the European Union stated that "if nothing is done, the cost of congestion will, on its own, account for 1 % of the EU's gross domestic product in 2010" (European Commission, 2001), with a significant part of these costs respecting to urban transportation: traffic congestion associated to the automobile commuter trips. This is happening even in countries with high fuel prices, good Public Transport (PT) systems and dense land occupation (Shaheen et al., 1999).

The problem is not so much car ownership increase in the last decades but mainly the way the automobile is used. "A good deal of the demand for transport is concentrated on a few hours of the day, in particular in urban areas where most of the congestion takes place during specific peak periods" (Ortúzar and Willumsen, 2001), generally the morning and evening commuting periods.

The European Union Commission has published recently its Green Paper entitled "Towards a new culture for Urban Mobility", a document dedicated only to urban mobility and its specific issues. In this document the E.U. recovers its worries on the impact of congestion in the GDP; the emissions caused by private vehicles: "Urban traffic is responsible for 40% of CO_2 emissions and 70% of emissions of other pollutants arising from road transport" (European Comission, 2007); and traffic accidents as its main concerns.

Given the current state of urban mobility we may conclude that the majority of the big cities were not able to develop and implement effective mobility policies to control the modal share and traffic congestion thus needing now recovery measures to achieve sustainability in urban transportation.

The fact is that automobile utilization is very attractive and it is here to stay. Therefore the mobilization of private cars in more efficient commuter movements is necessary, aiming at moving the same number of persons in fewer cars. Carpooling systems aim at this higher occupancy, particularly in commuter trips, associating neighbors who travel to workplaces next to each other, using their vehicles one at a time on a day-to-day or week-to-week basis. The advantages for the user can be fuel cost reduction, automobile maintenance cost reduction and longer life (due to reduced usage per year), parking availability and increased trip comfort, along with improved accessibility to places for which PT provision is non-existent or of low quality. The advantages for society as a whole can be decreasing congestion and time spent in commuter trips, a decrease in vehicle emissions, and increased easiness in finding parking space.

Carpooling experiments have generally been obtaining a limited success, not being able to reach the scale where they would visibly reduce congestion. Despite this fact the concept is so attractively simple, promising a great potential impact on traffic reduction, that it stays a constant measure in all mobility plans and strategies for creating a more sustainable urban

mobility. The European Commission in the Green Paper states this as one of its objectives for improving urban mobility: "… optimizing the use of private cars. Less car-dependent life-styles can be promoted through new solutions like car-sharing. More sustainable use of the private car should be encouraged for example by carpooling, which will lead to roads with fewer cars each of them carrying more people" (European Comission, 2007).

Historically, the moments in which the automobiles registered a greater occupation correspond to times when fuel prices were higher. In fact carpooling appears for the first time during the Second World War when the import of petroleum was limited. In the mid seventies with the fuel crises lead by the OPEC there was the greatest increment in the concern with private vehicle occupation in the United States (Ferguson, 1997).

From that time to our days there has been significant research on carpooling systems acceptability and potential. Despite this fact, other than during the periods of fuel crises, automobile trips always increased in the main urban environments of the world. Research was not really able to find ways to manage and promote large-scale regional carpooling systems.

The question that arises is: If these systems are so good for the user and for society why are not persons joining carpooling schemes in a larger scale? In the end one major problem still remains for the realization of an effective large-scale carpool scheme, and this was identified early (Hansen et al., 1975):

- the sociological problem of changing cultural habits so that a large body of persons will participate in a carpool.

The sociological and psychological aspect of sharing the vehicle with persons that you might not know so well has proven to be a key aspect in determining carpooling attractiveness. This is aggravated by the possibility of having to share the vehicle with a stranger when one goes from a company based system, where demand is concentrated in one destination, to a regional ridesharing system, with multiple origins and destinations as it would be necessary in order to have a significant impact on traffic congestion.

In Portugal carpooling systems are incipient, and the concern with increased vehicle occupation has had scant reference, even in the media. The few experiments that are being taken to organize carpooling groups are mimicking some of the weakest past experiences of the United States and Europe and are thus reaching the same poor results. Only recently carpooling was mentioned in an official document as a measure for air quality improvement purposes for the Lisbon Metropolitan Area (LMA).

This paper addresses the relationship between socio-demographic profiles, attitudes towards carpooling and the propensity to use this mobility option using a Structural Equations Modeling (SEM) framework, which is the best tool for simultaneous equations of dependent and explanatory variables.

In order to pursue this objective, a web survey was conducted comprising a socio-demographic data gathering part, Likert scale indicators for measuring attitudes and also a

stated preference experiment comparing the Alone or with family commute with an external carpooling alternative. The data was collected in the scope of a PhD dissertation (Correia, 2009) where a binary logit discrete choice model was applied for the same purposes, however, attitudes were introduced in the model sequentially using factor analysis and not through joint estimation.

The next section makes an introduction on the importance of attitudes in affecting the choice to carpool reviewing previous research on the subject. Afterwards we explain in detail the construction process of the survey that gave origin to the data used for this research paper, and present the exploratory factor analysis run on the Likert scale questions in order to find a priori relationships between endogenous variables and indicators. It follows the structural equations model which was used to estimate the relation between socio-demographic variables, endogenous attitude variables, Likert scale indicators and the stated preference choice, modeled through a binary probit model. The paper ends with the main conclusions on the importance of the latent attitude variables and carpooling propensity.

CARPOOLING AND PERSONS' ATTITUDES

The early assessments of carpooling experiments were indicating that matching potential carpoolers on an urban area-wide basis was not as effective as employer-based programs not only because the distances between work destinations tended to be larger but also because there was no acquaintance between the participants. In respect to this last issue research showed that if most carpools created under commute trip reduction programs were household carpools, where pool members are only close acquaintances, then regional reductions in private vehicle trips may not result (Bard, 1997).

Using travel survey data to study the evolution of the ridesharing market, a study by Morency, based on data from four large-scale OD surveys conducted in the Greater Montreal Area (1987, 1993, 1998 and 2003) revealed that approximately 70% of all trips made by car passengers are the result of intra-household ridesharing (Morency, 2007). Moreover, around 15% of those trips are questionable, in that they were exclusively generated for the purposes of another individual, consequently generating an additional trip for the journey back home.

It is a reality that from the viability point of view the most difficult pools to form are those constituted by persons who are not part of the same household, “external” carpooling, and that is why they represent a smaller share of the total number of carpoolers in the U.S. where these programs started earlier. However, at the same time, these are the most interesting for their potential result in congestion reduction, because “the ‘external’ carpool feels the responsibility for vehicle provision and driving which is difficult to break when there is less intimacy between persons” (Teal, 1987).

Given the failure of the conventional approaches to broaden carpooling coverage it was clear that research had to move in order to better identify what drives or deters persons from participating in external carpool groups. This research was focused on individual attitudes and preferences rather than focusing only in time or cost factors (instrumental attributes of the alternatives).

Research by Margolin, et al. (1978) concentrated on the carpooling attitudes and perceptions of carpoolers versus solo drivers. The findings of this project included the limited appeal of external efficiency factors such as cost savings and pointed toward the power of social aspects of carpooling that can act as either barriers or incentives, and the need for personalized carpool programs that also reach out to actively involve the potential pooler.

Considering the low level of acceptance of public and even employer-based carpooling programs despite these being the most trustful schemes, Oppenheim (1979) conducted a number of surveys to uncover which factors influence the decision to join a carpool or not. These have tended to show that subjective perceptions of the situation of carpooling (e.g. relationship with car mates, constraints to independence, status as a passenger or driver) are more important than the instrumental attributes of carpooling. This suggested that carpooling programs place too much emphasis on compatibility of potential riders on the basis of geographic proximity, disregarding psychological factors.

This has been again confirmed by more recent studies. Johansson, et al. (2006), used a sample of Swedish commuters, and found that both attitudes towards flexibility and comfort, as well as being pro environmentally inclined, influence the choice of mode of the individuals. Although travel time and cost are still important, it follows that there are other ways, apart from economic incentives, to attract individuals to the desirable more sustainable modes of transport.

The results of these studies although not always agreeing on the power of attitudes in explaining mode choice, seem to point to their importance in determining how persons view transportation alternatives, even more so with the carpooling alternative that raises so many personal issues.

The study of attitudes belongs to the domains of social psychology. The Handbook of Social Psychology (Gilbert et al., 1998) defines that “Attitudes express passions and hates, attractions and repulsions, likes and dislikes. Persons have attitudes when they love or hate things or persons and when they approve or disprove of them. Because persons express their likes and dislikes in many ways, all aspects of responding, including emotions, cognitions, and overt behavior, are infused with the evaluative meaning that attitudes impart”.

These attitudes are important determinants for the level of trust between persons which is very important in organizational relationships. Carpooling can be considered as one of such organizations albeit of temporary nature. “Trust has had a broad discussion in the psychology field, however the understanding about how trust forms and on what trust is based still remains, and probably will remain since there is not even a common conceptual definition of trust” (Mcknight et al., 1998).

The success of these systems depends on the attraction of the system itself which is a function on its general attributes but also depends on the interaction between different persons (Figure 1).

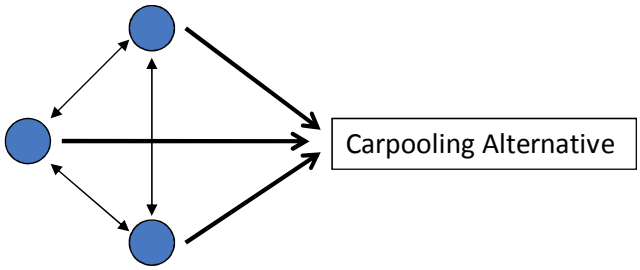

Figure 1 - Attitude functions relevant for carpooling

The more degrees of freedom the greater the possibilities of matching persons in carpooling groups. These interactions can be mathematically translated by using algebraic relations (Cargal, 1980). In Figure 2 we demonstrate that the number of interactions can be highly influenced by acquaintanceship. Using an example with 4 elements, the number of connections decreases from 6 to 2 if only interactions between elements who know each other are willing to carpool.

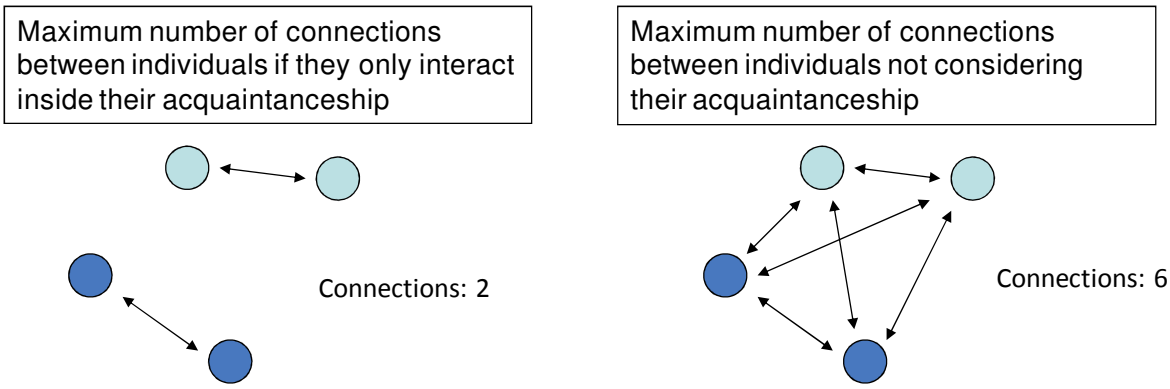

Figure 2 - Possible connections among carpooling participants as a function of the acquaintanceship

Focusing on these issues, previous research explored the more subjective factors of trust and relationships in carpool formation. Using the information from 26 carpool programs Kurth and Hood (1977) found that appeals to self-interest made through work organizations were more effective than other means of encouraging carpooling because employees of work organizations are from a known population with a common destination and, typically, a similar work schedule. They proposed that such appeals should focus on the benefits of carpooling for the individual rather than on general values. Interviews of selected long-term carpool participants (2 or more years) indicated that work organizations provide a safe setting in which personal information about potential participants can be obtained and that this information facilitates the formation of carpools. Later studies also pointed to the same conclusion, persons are likely to trust others who share their organizational affiliations and are more likely to engage in interactions, exploiting group identity to form personal bounds (Prentice et al., 1994; Mcknight et al., 1998).

This suggests the importance of a common base point for establishing a relationship of the kind needed to form carpooling groups. “Creating a group whose members have similar interests will tend to make the group more attractive, and emphasizing to group members their unique skills or knowledge will tend to make them believe their efforts matter”(Terveen

and McDonald, 2005). The amount of exposure persons have to each other strongly influences the likelihood of interpersonal interaction. Persons who are physically proximate are likely to frequent meet and interact allowing friendship development.

Several studies have been conducted in the past to evaluate the importance of preferences for carpooling that are influenced by the persons' attitudes toward the other occupants and the system itself. A seminal study conducted by Duecker at the University of Iowa included a survey focusing on gender, acquaintance of carpooling members and dimension of the groups (1977). Respondents were instructed to mark a line in a scale from very undesirable to very desirable for the several options of group configurations.

Results showed that the gender of the potential poolers was of little consequence when the other part was an acquaintance but became of great consequence when the other party was a stranger. Both females and males preferred to pool with females if the other parties were strangers. Moreover the desirability of ridesharing decreased as the number of strangers increased, especially for females (Duecker et al., 1977).

Owens in 1980, motivated by trying to explain why some ridesharing members remain in their ridesharing groups while others drop out interviewed 60 subjects, 30 ridesharing participants, and 30 dropouts. He concluded that group satisfaction, group agreements, group heterogeneity and equity norms had a strong discriminatory power over the distinction between these two groups.

A study using carpooling as a measure of social connection in U.S. urban areas found that the greater the number of neighbors who are of the same race the higher the carpooling propensity. The authors point that "if this tendency to connect socially along racial lines extends to other activities, such as political participation, or to community organization, there are likely to be important public policy implications of this fact, given the growing racial diversity of the U.S. and of many other countries" (Charles and Kline, 2006). Being true or not, it is very representative that carpooling should be used as a measure of social interaction between races. The assumption that a social interaction is an enabling factor for successful association of people in a carpooling scheme is relevant and follows previous findings.

METHODOLOGY

In order to study the influence of attitudes in affecting carpooling propensity we used the LMA as a case study. A web survey was designed comprising a social-demographic profile data gathering, indicator questions to measure the attitudes toward carpooling systems and the different types of groups and finally a stated preference experiment comparing the situation of driving Alone or with family with an external carpooling configuration.

This survey was planned and executed for supporting the research of a PhD dissertation where the main aim was to explore the effect of both instrumental and attitude aspects connected with carpooling and how this influences this alternative potential.

The Stated preference experiment produces a discrete choice variable namely driving alone or participating in a carpooling group. Previous work on the field of discrete choice modeling has emphasized the importance of psychological factors and attitudes in affecting decision-making (Koppelman and Hauser, 1979, McFadden, 1986, Ben-Akiva, 1992), thus improving the explanatory power of discrete choice models.

When Likert scale indicators are used to capture attitudes, there are different alternatives of integrating this information in a choice model:

- Include indicators directly in the utility function (Harris and Keane, 1979);
- Use factor analysis and then use the fitted latent variables in the utility (Madanat, 1995);
- Include latent attributes in the random utility model inferred from observed choices and not using indicators (Keane, 1997);
- Fit simultaneously a set of latent variables that provide the best fit to both the choice and the latent variable indicators (Ben-Akiva, et al., 1999).

Applying the first methodology leads to inconsistent estimates, therefore one should not use indicators obtained in survey experiments directly in the utility functions when applying choice models. The second alternative does not consider the indicators directly in the choice model, as it first uses factor analysis to reduce and translate the indicators latent information in order to extract a behavior scale that improves the explanation of the model.

The third option does not use indicators and deals with the attitudes of the respondents by using observed choices to calibrate latent attributes which are alternative specific not varying between individuals. Then the indicators of perception are used to aid in explaining in the interpretation of the latent variables.

The last method is undoubtedly the most complete one to integrate latent attitude variables in a choice model. It uses two sub-models, one which is a classical Choice model with explanatory variables linked by structural equations to an adimensional Utility and a Latent Variable model which uses measurement equations to connect the indicators with the Latent Variables, which in their turn depend on the explanatory variables. This creates interdependencies that are computationally difficult.

In previous work we have used the second approach. A factor analysis was conducted directly on the attitudes indicators and then the main factors were introduced in a discrete choice model, in that case a binary Logit, where they proved to have a very significant effect on carpooling utility. Nevertheless this sequential estimation is not advisable, as the error terms are not considered directly in the choice model estimation.

In the present work we have applied the fourth and most complete method, using a SEM modeling technique with latent (endogenous) variables that translate persons' attitudes. This is the most comprehensive method to find the relationships we are searching because the estimation is simultaneous and not compromised by a priori simplifications.

SURVEY

The survey was built from scratch using PHP as the main programming language. The initial page explained the carpooling transportation alternative, given that the Lisbon population is not familiar with the concept of organized ridesharing:

> What are carpooling systems?
>
> Carpooling is the English term that describes a mode of transportation which consists in grouping persons in order to share their private vehicles in commuter movements, with positive results in decreasing urban congestion and pollutant emissions. Alternately a person can drive or be driven by his partners, thus reducing his transport costs.

The objective of the following survey web page was to get useful information from the respondent in terms of its general socio-demographic characteristics. This information was gathered subject to the individual and also to his household.

The questions in this page as well as in the other pages were not asked in open answer text boxes. We used mostly the drop-box, which is a selection method that only allows choosing a predefined answer; this has the objective of decreasing the error associated with mistakes the respondent may do when filling the questionnaire. When the respondents entered each page, all drop-boxes were filled with the symbol "-", not allowing advancing to the next pages while this symbol was still present on any question.

This webpage started with a warning that translated to English reads as follows: "This survey is to be answered by persons who usually drive to their workplace in Lisbon Metropolitan Area, with or without passengers", remembering respondents of the target population we want to reach.

Table 1 - Questions in the General Information webpage

Question	Options
What is your gender	Male, Female
What is your year of birth	Years between 1990 and 1927
What is your marital status	Single, Divorced, Widow, Married, Union in fact
Number of persons of your household including yourself	1 to 7 or more
Professional activity	Craftsman or machinery operator, Clerk or salesman, Businessman, Student, Intermediate Professional, Administrative employee, Manager or liberal professional
Education	Elementary, High School, Graduation,

	Post-Graduation
Number of persons in your household with less than 16 years old	Nobody, 1 to 5
Number of persons with regular professional activity in the household	1 to 7
Number of persons with a valid driver's license in the household	1 to 7
Number of automobiles in the household	1 to 5
Type of vehicle that you usually drive	Commercial vehicle (2 seats), City vehicle, Family vehicle, Luxury, All-Terrain
Total monthly income of the household	0 to 1000, 1000 to 2000, 2000 to 3000, 3000 to 4000, 4000 to 5000, 5000 to 7500, 7500 to 10000, 10000 to 15000, 15000 to 20000, more than 20000 euros

The next pages of the survey asked other questions about the current mobility situation of the respondent, namely the total daily driving time and costs of using the vehicle for the daily commuter trip. These questions, however, are not going to be shown in this paper.

In order to measure the attitudes towards the carpooling alternative we asked persons to rate Positive and Negative aspects of carpooling. The first 5 questions were related to positive aspects which are usually associated with carpooling systems, while the remaining 7 are associated with the negative aspects (Table 2). Persons had to classify each aspect from 1 (Very Bad) to 7 (Very good).

Table 2 - Questions to extract attitude toward the main positive and negative aspects of carpooling

Survey Ref.	Question
1	Reduce the expenses with my vehicle (maintenance and fuel)
2	Reduce the pollutant emissions that my vehicle produces
3	In some days I do not need to worry about parking my vehicle
4	I have the possibility of relaxing and not drive in some days of the week
5	I have the possibility of socializing and meet new persons through this system
6	It constrains different activities which are outside the usual routine
7	It increases the travel time
8	I have personal driving preferences such as smoking or hearing loud

	radio that I have difficulty in abdicating
9	I do not want to depend on other persons
10	I lose my privacy
11	I have to socialize with persons who are culturally different from me
12	Being driven by another person

The following webpage of the survey was the "Group formation criteria" where we asked a series of questions that deal with group formation. The following ones are rating indicators for several group configuration alternatives depending on the number of passengers, gender, and level of acquaintance, classified from 1 (Very Bad) to 7 (Very good).

Survey Ref.	Question
One extra occupant	
1	You with a man that you know
2	You with a woman that you know
3	You with a man that you do not know
4	You with a woman that you do not know
Two extra occupants	
5	You with two persons that you know
6	You with one person that you do not know and another that you know
7	You with two persons that you do not know
Three extra occupants	
8	You with three persons that you know
9	You with one person that you know and other two that you do not know
10	You with three persons that you do not know

Table 3 - Questions to extract attitude toward different carpooling groups

The stated preference comparisons were built using the instrumental attributes of the current mobility situation of the respondent as reference (questions not shown in this paper) and changing them in order to reflect the expected attributes of a carpooling group situation. This includes:

- Walking time to meet a driver in the morning and afternoon when the person is a passenger
- Extra travelling time to pick-up carpooling partners when the person is a driver
- Expense savings from sharing the vehicle with external passengers

Another two attributes were included: the assurance of a guaranteed ride home and the alternative of searching other carpooling groups instantaneously for a near term trip with a different destination or a different schedule of the same usual destination.

Each responded had to answer 4 comparisons between driving alone or with family and an external carpooling situation thus only respondents that stated not currently carpooling with persons outside their household were allowed to fill out the web questionnaire.

SURVEY RESULTS AND DATA PRE-PROCESSING

The survey was conducted from February 6, 2008, until May 6, 2008, a four months period where the total number of respondents was 1,058 for the Socio-Demographic and Attitudes parts. While for the SP part, saved independently from the previous block, the number of respondents was 996, thus there were only 62 persons that filled all the initial pages and did not answer the SP part of the survey.

The following table presents simple indicators in order to pre-evaluate the direction of responses which were obtained (one should be reminded that each respondent had to make 4 choices without exception):

Table 4 - Aggregate Stated Preference Statistics

	Alone answers	Carpooling answers	Total
Number of answers per alternative	2120	1864	3984
	53.21%	46.79%	
Total number of answers given by a respondent that always chose the same alternative	1440	960	2400 out of 3984 choices (60%)
Number of respondents that always chose the same alternative	360	240	600 out of 1058 respondents (60%)

We observe in Table 4 that there is almost a balance between the “alone” answers and the “carpooling” answers with 53% and 47% of the choices respectively, this is very encouraging

for the carpooling alternative, however we should say that this result depends greatly on the sample that was obtained, as well as the effects of answering a stated preference survey, which is always influenced by sentiments of wanting to answer what is thought to be the most interesting or beneficial for the surveyor and most beneficial to society as a whole when this does not contradict a sufficiently strong personal opinion. We should also alert for the fact that as much as 60% of the answers were given by respondents who preferred either alone/with family or carpooling in all 4 stated choices, which is possibly an indicator of strong opinions on the subject.

Nonetheless one should not ignore the fact that by using a web survey one is introducing a process of sample self-selection, by which, only those who have a greater interest in the subject answer the questionnaire until its last page. This process may justify the revealed tendency for younger ages in the sample, and it is by itself an indicator that this should be a demographic group more inclined for choosing carpooling.

The analysis of the attitude indicators is very important as a framework to build the SEM, namely in helping determining which equations should be built in the model relating the endogenous attitude variables and these variables which are meant to measure the attitudes. The simplest approach to integrate the indicators in a choice model as it was described earlier is to conduct a factor analysis on the indicators and integrate them in the choice model directly. Even though this will not be our approach, factor analysis is a good reference for establishing an initial framework.

This analysis was conducted first to the positive and negative aspects of carpooling using the Varimax roatation technique (Kaiser, 1958), this is the most popular rotation method. It is an orthogonal method whose objective is to obtain for each factor only a few significant loads from the original variables with the others becoming very close to zero, so that the relationship of each factor with the original variables is easier to interpret.

The loadings can be seen in the following table, where we may observe better the relation between the original variables and the two factors. The loadings are now more clearly interpretable and identifiable with each of two main factors.

Table 5 - Attitude variables loadings on Factor 1 and 2 with Varimax rotation

Question	Factor 1 (*)	Factor 2 (**)
I1.1	0.124	0.609**
I1.2	0.047	0.604**
I1.3	-0.092	0.696**
I1.4	0.084	0.735**
I1.5	0.237	0.671**
I1.6	-0.426*	-0.048
I1.7	-0.610*	-0.033
I1.8	-0.625*	-0.012

I1.9	-0.719*	-0.200
I1.10	-0.805*	-0.126
I1.11	-0.663*	-0.088
I1.12	-0.690*	-0.035

We decide to retain both factors to introduce in the SEM. Factor 1 will be called NEGATIVE_ATTITUDE because it has its main loadings on the negative aspects of carpooling and Factor 2 will be called POSITIVE_ATTITUDE as it is, by its turn, mainly loaded on the positive aspects of carpooling participation.

We used again the Varimax technique to conduct an exploratory factor analysis on the questions related to group configuration and we reached the following factor loadings:

Table 6 - Group variables loadings on Factor 1 and 2 with Varimax rotation

Question	Factor1(*)	Factor2(**)
I2.1	0.101	-0.858**
I2.2	0.049	-0.833**
I2.3	0.862*	-0.071
I2.4	0.751*	-0.086
I2.5	0.115	-0.906**
I2.6	0.586*	-0.630
I2.7	0.922*	-0.076
I2.8	0.089	-0.861**
I2.9	0.644*	-0.530
I2.10	0.874*	-0.078

The importance of each factor in each original variable is now clearer. We may observe that the first factor is mainly connected with the questions where there is the presence of strangers in the group, whereas, the second factor is connected to groups where there is at least one acquaintance in the group. We will call the first factor GROUP_STRANGER and the second one GROUP_ACQUAINTANCE.

This pre-processing of the survey data has allowed establishing the number of endogenous attitude variables as well as their relationship with the indicators with which they are linked to by structural equations.

THE STRUCTURAL EQUATIONS MODEL

SEM (Structural equation modelling) represents an evolution and a combination of two types of statistical methods, factor analysis and simultaneous equations models (Kaplan, 2000). In SEM variables can be either exogenous or endogenous (Golob, 2003). These characteristics allow SEM to handle indirect and multiple relationships and also to study reverse relationships.

A structural equation model is described by the following equation (Karl Jöreskog and Dag Sörbom, 1993):

$$\eta = B\eta + \Gamma\xi + \zeta$$

where:

η is a $mx1$ random vector of latent endogenous variables;

B is a mxm matrix of coefficients of the η variables in the structural relationship . B has zeros in its diagonal and $I - B$ must be non-singular;

Γ is a mxn matrix of coefficients of the ξ variables in the structural relationship;

ξ is a $nx1$ vector latent exogenous random variables;

ζ is a $mx1$ vector of equation errors in the structural relationship;

The measurement model of the endogenous variables is described by the following equation (Karl Jöreskog and Dag Sörbom, 1993):

$$y = \Lambda_y \eta + \varepsilon$$

And the measurement model f the exogenous variables is described by the following equation (Karl Jöreskog and Dag Sörbom, 1993):

$$x = \Lambda_x \xi + \delta$$

Where:

y is a $px1$ vector of the endogenous observed variables;

x is a $qx1$ vector of the exogenous observed variables;

Λ_y is a pxm matrix of the regression coefficients of *y* in η;

Λ_x is a qxn matrix of the regression coefficients of x in ξ;

ε is a $px1$ vector of the measurement errors in y;

δ is a $qx1$ vector of the measurement errors in x.

The model replicated covariance matrix $\Sigma(\theta)$ is given by the following (Karl Jöreskog and Dag Sörbom, 1993):

$$\Sigma(\theta) = \begin{pmatrix} \Lambda_y A\left(\Gamma\Phi\Gamma' + \Psi\right)A'\Lambda_y' + \Theta_\varepsilon & \Lambda_y A\Gamma\Phi\Lambda_x' \\ \Lambda_x\Phi\Gamma' A'\Lambda_y' & \Lambda_x\Phi\Lambda_x' + \Theta_\delta \end{pmatrix}$$

Estimation of SEM models is performed by using the covariance analysis method – method of moments (Golob, 2003). 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 (Golob, 2003).

WLS, the method used to estimate the model presented in this paper was specifically developed to deal with discrete and censored variables. Its genesis occurred with a multivariate probit developed by Muthén (1979). Later this method was generalized by Muthén (1984) to accommodate structural equations with a mix of discrete, censored and continuous variables (Golob and Regan, 2002).

WLS minimizes the following fit function (Karl Jöreskog and Dag Sörbom, 1993):

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

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 $\Sigma(\theta)$, reproduced from the model parameters θ;
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 (Kaplan, 2000). For an identified SEM model the total effects of the exogenous variables on the endogenous variables (the coefficients of the so-called reduced-form equations) are given by (I - B)-1 Γ and the total effects of the endogenous variables on one another are given by (I - B)-1 – I (Golob, 2003), they are deducted from the general model expression solved in order to y (Kaplan, 2000). The indirect effects are given by the differences between the total and direct effects.

The process of building the SEM is not straightforward and many combinations can be tested in order to try capturing the seamless structure while having the best adjustment between data and model. In order to test the different model configurations and estimate its coefficients we used the software LISREL (SSI-Scientific Software International).

The proposed model is based on a sequential approach previously developed in which the attitudinal variables built using a principal components factor analysis were included in a discrete choice model (binary logit) for carpool choice (Correia, 2009). Thus the SEM model was used to test the same relationships in a simultaneous estimation framework and at the same time model the attitudinal variables as a function of socioeconomic attributes, thus treating them as endogenous.

The pre-processing of the indicators has allowed proposing strong relationships between the latent attitude variables and the indicators at the outset and these can be seen in Figure 3. Another endogenous variable is the continuous variable of the utility of carpooling, which has direct measurement relationship with the discrete choice variable (1 if carpooling was chosen

and 0 otherwise). Some intra-relations were also established between some attitude variables because this showed to improve the model. The instrumental attributes of the alternatives such as cost and travel time are directly linked to carpooling utility, while socio-demographic data is mainly linked to the other endogenous variables measuring the attitudes. Not all of the information gathered for the socio-demographic profile of the respondents showed to improve the model, and in fact only the following variables, were in the end included:

Table 7 - Variables included in the final model

Variable name	Construction
Socio-Demographic attributes	
GENDER	GENDER = 1 if sex="Male" GENDER = 0 if Sex="Women"
AGE	AGE = 2008 – Year of birth
WHITE_COLLAR	WHITE_COLAR=1 if Profession="Manager" or "Liberal professional" STUDENT=1 if Profession="Student"
COLLEGE_GRADUATION	GRADUATION=1 if Education = "Graduation" or "Post-Graduation" GRADUATION=0 otherwise
AVG_INCOME	AVG_INCOME is obtained by dividing the average point of the income interval by HOUSEHOLD_DIM
Instrumental attributes	
TRAVT	Travel time Carpooling - Travel time when driving alone or with family
TMPOINT	Time to reach a meeting point (Carpooling)
LN(CTOT)	LN(Total cost of the commute carpooling alternative) - LN(total cost of the alone/with family commute)
ASSURANCE	Guaranteed ride home
ALTERNATIVE	Alternative of riding in another group when having a near term trip

The final estimated model with the relation between its variables can be seen in the following figure where the estimated coefficients are represented on top of each arrow.

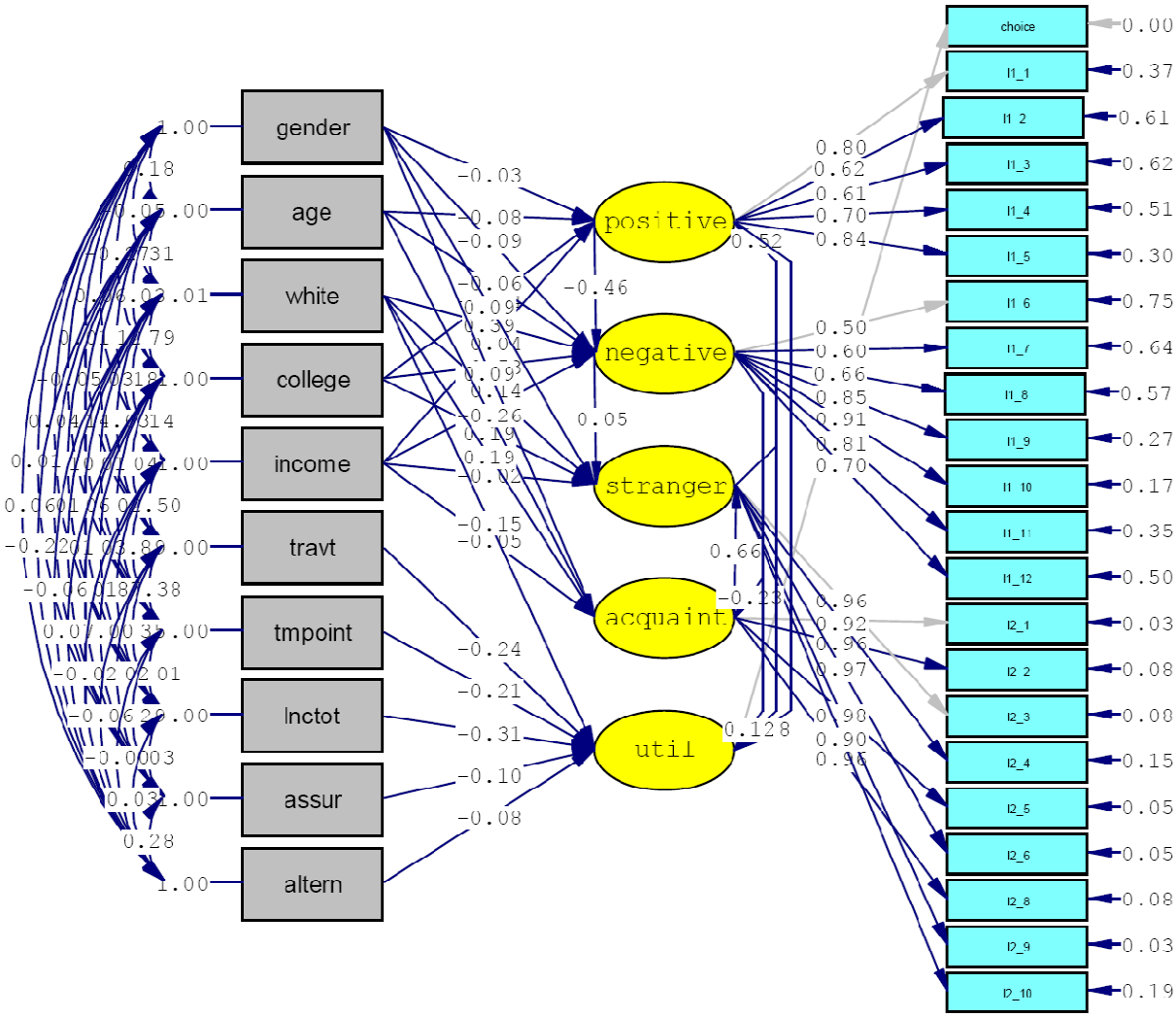

Figure 3 - Structural Equations Model with coefficients (LISREL output)

One should alert for the fact that the one Likert scale indicator (I2_7) was taken out as it was not allowing the model to correctly compute its polychoric correlation, due to the high correlation with other factors.

For better understanding of the model structure and its final results, the following table presents all estimated coefficients as well as the t-tests associated to their significance. Notice that the direction of the relations between the variables is given in Figure 3, the tabulation of the coefficients in the following table is only for facilitating the reading of the model results.

Table 8 - Final SEM results

	Endogenous variables				
Measured Variables	positive	negative	stranger	acquaintance	utility
choice	- -	- -	- -	- -	1.00 (*)
LAMBDA-Y					
I1_1	0.80(*)	- -	- -	- -	- -
I1_2	0.62 (54.07)	- -	- -	- -	- -
I1_3	0.61 (52.79)	- -	- -	- -	- -
I1_4	0.70 (60.51)	- -	- -	- -	- -
I1_5	0.84 (67.48)	- -	- -	- -	- -
I1_6	- -	0.50(*)	- -	- -	- -
I1_7	- -	0.60 (42.76)	- -	- -	- -
I1_8	- -	0.66 (39.77)	- -	- -	- -
I1_9	- -	0.85 (46.53)	- -	- -	- -
I1_10	- -	0.91 (45.55)	- -	- -	- -
I1_11	- -	0.81 (42.66)	- -	- -	- -
I1_12	- -	0.70 (41.00)	- -	- -	- -
I2_1	- -	- -	- -	0.99 (*)	- -
I2_2	- -	- -	- -	0.96 (208.86)	- -
I2_3	- -	- -	0.96 (*)	- -	- -
I2_4	- -	- -	0.92 (133.33)	- -	- -
I2_5	- -	- -	- -	0.98 (264.14)	- -
I2_6	- -	- -	0.97 (190.48)	- -	- -
I2_8	- -	- -	- -	0.96 (235.57)	- -
I2_9	- -	- -	0.98 (191.53)	- -	- -
I2_10	- -	- -	0.90 (161.70)	- -	- -
BETA					
positive	- -	- -	0.52 (32.75)	- -	- -
negative	-0.46 (-22.77)	- -	- -	- -	- -
stranger	- -	-0.05 (-3.09)	- -	0.66 (66.77)	- -
acquaint	- -	-0.23 (-14.34)	- -	- -	- -
util	0.37 (14.20)	-0.08 (-3.76)	0.12 (5.82)	- -	- -
GAMMA					
gender	-0.03 (-2.17)	-0.09 (-4.40)	0.09 (5.86)	0.09 (6.66)	- -
age	-0.08 (-6.92)	-0.06 (-2.90)	- -	-0.26 (-18.81)	- -
white	- -	0.39 (6.37)	-0.14 (-5.37)	0.19 (11.73)	-0.15 (-7.89)
college	-0.04 (-2.16)	-0.53 (-8.54)	0.19 (6.25)	- -	- -
income	-0.04 (-2.75)	0.01 (0.91)	-0.02 (-3.76)	-0.05 (-2.09)	- -
travt	- -	- -	- -	- -	-0.24 (-2.94)
tmpoint	- -	- -	- -	- -	-0.21 (-2.59)
ln(ctot)	- -	- -	- -	- -	-0.31 (-9.22)
assur	- -	- -	- -	- -	-0.10 (-2.64)
altern	- -	- -	- -	- -	-0.08 (-2.46)

* Fixed Parameter

The model converged in 59 iterations and the chi squared statistic is significantly different from zero implying that the sample covariance and model covariance matrices are different. Other goodness of fit indexes indicate an acceptable level of fit. The RMSEA is 0.067, NNFI is 0.95 and CFI is 0.96, all indicating an acceptable fit. The NFI is 0.96, GFI is 0.97 and AGFI is 0.97 all indicating a good fit. Finally the AIC and CAIC values show that the model is superior to the independent model but not to the saturated model. So it is possible to conclude that the model overall level of fit is not particularly good.

Nevertheless its results are similar in terms of significance and direction of direct effects when compared to the previous binary logit model (Correia, 2009). As we were expecting, the structural equations between the Likert scale indicators and the attitude endogenous variables are very strong and have all resulted with the expected signs. For each endogenous variable, one of the coefficients is set as reference, against which t-statistic tests can be run in order to find if each indicator increases the explanation of the correspondent endogenous variable. We see that all indicators are statistically significant, with t-statistics well above 1.96, meaning that we may reject the hypothesis that they do not improve model explanatory power.

Following the LAMBDA coefficients come the BETA coefficients which translate the relation amongst the endogenous variables. Several combinations were tested and this was the configuration that better improved the model. All coefficients have the expected signs, for instance, the positive attitude toward carpooling impacts negatively the negative attitude as it would be expected. Another example is the stranger variable that has a positive relation with the positive variable, meaning that a better rating of groups with strangers shows a better predisposition for carpooling, thus pointing by its turn to a higher rating of the positive aspects of carpooling.

A high rating of the negative aspects of carpooling has a negative impact on both the stranger and acquaintance types of groups. Only the acquaintance variable was not introduced directly in the endogenous utility variable, it is however linked to the stranger variable having a positive impact. All coefficients linked with the utility have the expected signs: a high rating of the positive aspects and the groups with a stranger element strengthens carpooling utility whereas a high rating of the negative aspects decreases carpooling utility.

In what concerns the socio-demographic variables we were able to establish significant relations between gender, age, white collar jobs, college degree and income of the respondents. Generally we see that variables denoting higher socio-economic status are associated with lower values of the positive aspects of participating in a carpool group, however having a college degree does not correspond necessarily to a negative perspective on carpooling nor feelings of repulsion against groups with strangers.

The basic demographic variables of gender and age improved the model and it was possible to find statistically significant relations with most of the endogenous attitude variables. In general older persons are associated with a lower preference for carpooling. The gender variable is associated with both a low positive and negative attitude toward carpooling perhaps denoting some general indifference and they should not make a distinction between groups with strangers and acquaintance at least when compared to women.

The white collar job variable was the only one to enter directly in the utility variable and this is a confirmation of the importance that socio-demographic variables have in shaping the decision to carpool. For jobs associated with higher status the carpooling alternative decreases its attractiveness.

Finally we analyze the instrumental attributes, which were introduced directly as explanatory variables for the utility of carpooling. The travel time, the time walking to meet a driver as well as the total cost of the transportation alternative are variables that vary across alternatives and thus only their difference may be introduced in the SEM. We opted to compute these differences subtracting the alone/with family variables to the carpooling situation variables. The total cost variable proved to be more significant when affected with the logarithm, denoting a second degree effect on carpooling utility. All instrumental variables have the expected signs: as the carpooling alternative travel time increases it decreases the carpooling utility.

The assurance of having a guaranteed ride home and the alternative of riding in another group when having a different schedule or destination did not improve the attractiveness of the carpooling alternative and in fact are not viewed as positive aspects, which particularly in the case of a guaranteed-ride home was not expected since this is usually one of the aspects which is valued by carpoolers in countries where the system has been running for a long time now.

CONCLUSIONS

The present paper used a SEM technique to analyze the impact that attitudes can have on the propensity to experiment the carpooling alternative. As it was possible to demonstrate in the literature review, attitudes have been pointed as one important factor behind poor performance of these systems in decreasing traffic congestion. Two main types of attitudes have been identified, one towards the system itself and the other towards having to share the same intimate space with other people, possibly strangers.

SEM allows considering these attitudes as endogenous variables avoiding the sequential estimation of factor analysis followed by their insertion in a choice model estimation. It also allows building relations between socio-demographic characteristics of travelers and their attitudes, rather than placing them directly in a utility function.

The use of SEM for the stated preference data obtained in a web survey for the Lisbon Metropolitan Area did not produce a very well fitted model, nevertheless it has proven to be better than an independent model, and in the end the coefficients proved to be statistically significant, which allows conducting an exploratory analysis of role of attitudes on carpooling choice.

Overall we conclude that the attitudes play an important role in the decision to participate in a carpooling group for our sample of commuter drivers in the LMA. The positive attitude measured by the positive aspects of carpooling had a very significant impact in increasing the number of travelers choosing the carpooling alternative in the experiment.

This positive attitude seems to be associated with younger persons with lower income and low academic background. A tendency for women to be more positive towards carpooling than men also resulted in the SEM. The gender variable is also significant in explaining the attitudes towards carpooling occupant types, men show a tendency for having more acceptance of different carpooling groups, they are more indifferent to size and acquaintanceship.

The variables linked to social status: type of job (white collar), academic background (College) and income also help determine the attitude towards these systems. In general higher social status is linked to a less positive attitude towards carpooling, although having a college degree has also pointed for a lower importance of the negative aspects of carpooling this is probably associated to a cohort of young persons that already have a college degree.

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