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Author(s):
Simma, A.; Axhausen, Kay W.

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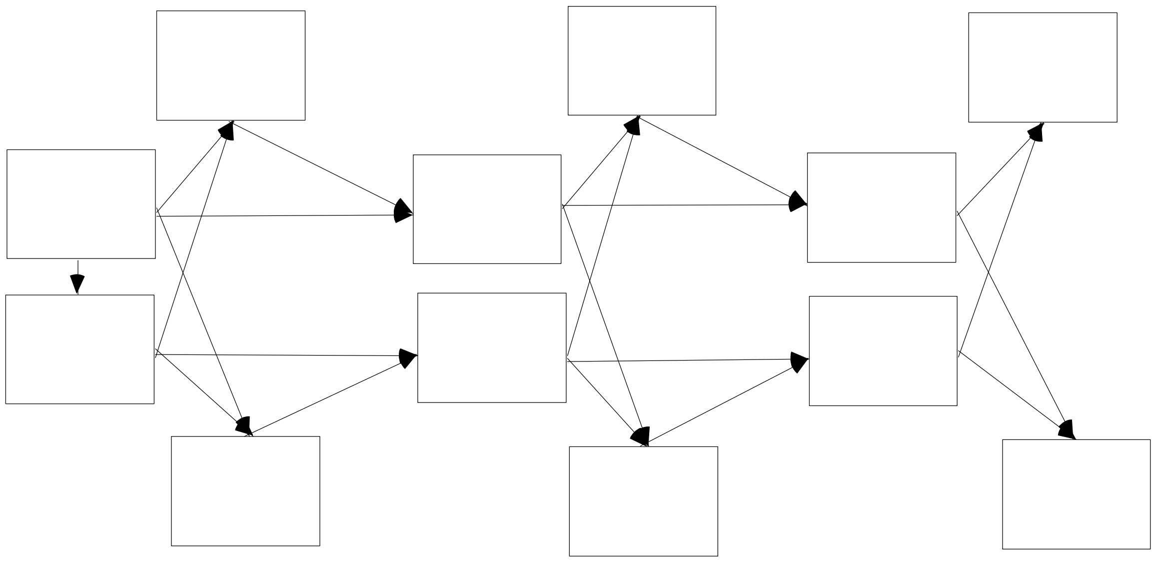

Commitments and modal usage: An analysis of German and Dutch panels

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A. Simma and K.W. Axhausen

A Simma
ARE
Kocherg. 10
CH-3003 Bern

KW Axhausen
IVT
ETH
CH-8093 Zürich

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A Simma		KW Axhausen
ARE		IVT
Kocherg. 10		ETH
CH-3003 Bern		CH-8093 Zürich
Telefon:	+41-31-322 5593	
Telefax:	+41-31-322 7869	
email:	anja.simma@are.admin.ch	

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Abstract

Travellers commit themselves to particular behaviours through the ownership of cars and season-tickets. They trade a large one-off payment for low or zero marginal cost at the point of use. It can be assumed that these commitments influence travel behaviour and future commitment situations. To the knowledge of the authors there is no literature which addresses the choice between the commitment to the one or the other mode and its impacts on travel behaviour as well as the temporal dimension.

The paper presents models using structural equation modelling to test a-priori hypotheses on the paths linking car-availability, season-ticket-ownership and modal usage at three different time periods. Modal usage is operationalised as the number of trips by car respectively public transport. The models are based on two different panel surveys (Germany and the Netherlands).

The results show that there is high stability in car-ownership and a relatively high stability in season-ticket-ownership (only for Germany). The commitments influence modal usage whereby the influence on the respective mode is higher than the influence on the other mode. The relationship between the two modes is a substitutive one.

Keywords

Car-ownership/availability; Season-ticket-ownership; Mode choice; Panel-analysis; Structural equation modelling

Content of tables and figures

1. Introduction

One key issue in transport planning is mode choice. Mode choice influences the environmental impacts of traffic, the utilisation of the roads, the safety on the roads, the structure of towns and settlements and consequently the liveability of our cities. Because the private car with its well known negative effects is the dominant means of transport in many areas, many studies have analysed the reasons for the imbalance between the car and other modes and discussed possibilities to promote the other modes (see for example Hensher, 1998). The commitment to a mode, especially the commitment to public transport, is a dimension which is seldom considered in these studies - mostly emphasising the supply of public transport.

With regards to the commitments of travellers and their impacts on modal usage not only the situation at one point of time is of interest, but also the temporal dimension. It is worthwhile to know how the situation within a time period influences the choices in the following periods. For example, it is probable that a person who has a car available and makes nearly all trips by car has a low readiness to change his or her behaviour as long as he or she is content with the current situation.

Previous literature covering the topic of commitments is very diverse, regardless of whether cross-sectional or panel data are used:

- Travel-behaviour-models concerning car-ownership/availability are abundant in the literature (Axhausen, 1991; De Jong, 1998; De Jong, 1996; Golob, Kim and Ren, 1996; Bradley, Golob and Polak, 1995; Hanly and Dargay, 2000; Hensher, 1992; Ramjerdi and Rand, 1996; Meurs, 1991; Hensher, 1987).

- Models of season-ticket-ownership are rarer (Axhausen, Bader and Köll, 1998; Monheim, 1987).

- Joint models are nearly – to the knowledge of the authors – non existent, but see two previous papers of the authors (Simma and Axhausen, 2001; Axhausen, Simma and Golob, 2001).

Mode choice models obviously calculate the variable costs of a trip considering these commitments (Nuzzolo, Crisalli and Gangemi, 2000; Bhat, 1998); Still, they rarely consider these a-priori choices, especially the public transport commitments.

For European and other countries with intensively used public transport systems this omission is hard to understand. It is idle to speculate about the reasons for this important omission, but the dominance of US modelling practice, where the issue is nearly non existent, and a habit of not asking about season-ticket-ownership of respondents, even in European travel surveys the topic is often avoided due to the complexity of season and discount ticket forms, are good first guesses.

This paper presents joint panel models of season-ticket-ownership and car-availability to analyse the effects of these commitments on travel behaviour and tries to fill the gap in the discussions about the imbalance between car and public transport. The results will provide insights into the trade-offs of travellers in two different study areas and will support the identification of new policy perspectives. Different study areas were chosen for two main reasons – first, to compare the stability of the results and second, to assess the influence of different traffic situations and cultural contexts.

The structure of the paper is as follows. The next section presents the surveys on which the analyses are based. The third section describes the basics of the modelling approach applied (SEM - *structural equation modelling*), whereas the fourth section - the core of this paper - covers the behavioural hypotheses, the modelling-procedure, the estimation results and their interpretation. The concluding section summarises the results and outlines both - possibilities for future work and some policy conclusions.

2. Description of the samples

The research questions posed in this paper, the relationships between commitments and modal usage and their temporal dimension can only be answered by travel diary panels. Two different panel surveys were considered here due to their availability, their quality and their inclusion of season-ticket information. Table 1 gives an overview of the basic features of these surveys.

- **Germany – "*Deutsches Mobilitätpanel*"** (see Chlond, Lipps and Zumkeller, 1996 and 1998): The German Panel is a representative household-survey. It has been conducted each year since 1994 during autumn. The surveys of 1994, 1995, 1996, 1997 and 1998 are already available. A household is interviewed at most three times to avoid panel fatigue and conditioning. The dataset comprises information about the socio-demographic composition of a household and the weekly travel behaviour of the household members older than 10 years. Those persons who participated three times were considered in the models.

- **Netherlands – "*Longitudinaal Verplaatsingsonderzoek 1984-1989*"** (see http://www.niwi.knaw.nl; Meurs 1991): The Dutch Panel is an - at least in the first year - representative household survey which was conducted ten times between 1984 - 1989. Each household was surveyed twice a year - in March and in September respectively October. The households were asked to fill out a household and a person questionnaire as well as a seven-day-travel diary, but wave 4 and wave 8 did not include a travel diary. About 600 households participated in all ten waves, about 1'500 households in all. Only those persons who participated ten times were considered in the models and their observations were weighted by the given weights (between 0.23 and 12.39 with a mean of one).

There are differences but also similarities between the two surveys. The surveys differ mainly in their design and survey protocol. The Dutch panel was designed for a limited time period, whereas the German panel has no time limit, but a limited number of waves per person. Because of the different number of waves per person the question arises how the two panels can be treated to make model comparisons possible.

Following the German example where three waves were allowed per person, it was decided to use also three different time periods for the Dutch case. The waves 1, 5 and 9 were selected, because they represent a wide time range, have constant time intervals between them and were conducted during the same month. Not much information is lost, because the figures in the other waves are similar to the selected waves. As a result of this adaptation the time span between two different periods is two years in the Dutch case and one year in the German case.

The similar contents of the two surveys were one reason for their selection. Each of the surveys contains information about the most important variables of the analysis (car-availability, season-ticket-ownership and modal usage), but the variable car-availability is defined differently. In the German case a person has a car available, if she or he has regular access to a car, whereas in the Dutch case it was necessary to calculate this variable (car-availability = number of cars per household / number of licence-holders). A person is owner of a season-ticket, if she or he has an annual or monthly ticket for a specific area or a specific route.

A set of socio-demographic variables, like age, gender, work-status and household-size, were asked in both surveys, but there are differences in the coding of those variables. The different variables were harmonised as far as possible for the general models to make comparisons possible. Because the Dutch panel also includes information about changes within a household and personal life, an additional model was developed to answer further questions.

Table 2 shows the descriptive statistics of the most important variables. On the one hand there are relatively big differences for the socio-demographic variables as well as for the commitment variables between the countries. This is an expression of the different cultures as well as of the different survey years (eighties compared to the nineties). On the other hand the average behaviour seems to be relatively constant over time in both countries. Often a change within a variable between two periods is compensated in the following period. Only in regard to season-ticket-ownership and public transport usage in the Netherlands a trend can be recognised.

In addition to the descriptive statistics it is interesting to look at the correlations between the commitment variables of the different time periods (see Table 3). There exist differences between the two countries as well as between the modes. The correlations between car-availability at the three periods are slightly higher in the Netherlands than in Germany, whereas the correlations between season-ticket-ownership at the three periods are clearly higher in Germany than in the Netherlands. They are generally higher for car-availability than for season-ticket-ownership. The correlations between the two commitment-types are clearly closer in the German case than in the Dutch case.

3. Modelling approach - structural equation modelling (SEM)

A precondition for the analysis of the complex questions posed in this paper is a method which can handle relationships between several dependent and independent variables at the same time. SEM meets these requirements (Maruyama, 1998; Mueller, 1996; Bollen, 1989). Moreover it is especially suited to analyse panel data, because models can be specified with variables and repeated variables joined by lagged causal effects and possibly autocorrelated error structures. SEM was applied for panel data analysis for example by Van Wissen and Golob (1992) or Golob and Meurs (1987). SEM is a confirmatory method which should be guided by prior theories about the structures to be modelled.

A SEM-model without latent variables has only one component – a structural submodel. The structural submodel captures the relationships between the exogenous and endogenous variables and between the endogenous variables themselves. It is defined by

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

in which the (m) endogenous variables denoted by η are a function of each other and of the (q) exogenous variables denoted by ξ. The unexplained portions of the endogenous variables (the errors in equations), have a variance-covariance matrix defined by $\Psi = E\,[\zeta\zeta']$.

The modeller specifies which elements of the B, Γ and Ψ matrices are free parameters, and these parameters are estimated simultaneously, together with their standard errors. Identification requires, among other conditions, that the matrix (I - B) must be non-singular. Model fit indices as well as direct and total effects are the result of a SEM-model. The direct effects correspond to the estimates of the parameters. The total effects of the exogenous and endogenous variables on the endogenous variables are given by the so-called reduced-form equations:

h®h: $(I - B)^{-1} - I$
x®h: $(I - B)^{-1}\Gamma$

The estimation of a SEM-model can be accomplished in several ways. The methods are based on matching model-replicated covariances with the observed covariances. Instead of covariances correlations can also be used. Here we use the Maximum Likelihood-method in conjunction with a correlation matrix. The advantages of the Maximum Likelihood-method are that it provides the most precise estimators, is relatively robust against violations of the normal distribution assumption and is less computational intensive than the ADF-WLS-method (arbitrary distribution function-weighted least squares). The parameter estimates can be interpreted as analogous to the standardised coefficients of a linear regression.

4. Models

4.1 Hypotheses

The base hypothesis of this paper is that there exist strong relationships between the ownership of season-tickets, car-availability and modal usage. It is postulated for these relationships that at a given point in time car-availability influences the ownership of season-tickets negatively and that both commitment variables influence the modal usage of their respective mode positively, the other mode negatively (Simma and Axhausen, 2001). If these relationships are regarded over time, the question arises how the situation at one time period is influenced by previous situations respectively how the situation at one time period influences the following periods. Different types of relationships are conceivable (see Figure 1 to 4).

- **Hypothesis 1 - Dominance of the respective commitment**: Car-availability respectively season-ticket-ownership influences the respective commitments in the following time period. Modal usage is only dependent on the respective commitments during the period.
- **Hypothesis 2 - Dominance of the respective modal usage**: The modal usage determines the commitment situation of the following period, but there are only impacts within a mode.
- **Hypothesis 3 - Dominance of both usage variables**: The commitment to a mode is not only influenced by the usage of the respective mode in the last period, but also by the usage of the other mode.
- **Hypothesis 4 - Mixed relationships**: The commitment situation as well as modal usage in one time period have impacts on the commitment situation of the following time period which again influences modal usage.

Additionally to those hypotheses it is assumed that there are relationships between the error terms of the variables. The idea behind this assumption is that variables could be constantly over- or underestimated. This is, for example, probable for the number of trips in different time periods.

It is not only necessary to define, if a relationship is present, but also the direction of the relationship – especially for testing the hypotheses. Generally it can be assumed that a decision for one mode is relatively constant over time. If one person has committed him- or herself to a mode, this person is not likely to change his or her behaviour as long as no other changes occur, whereby changes in the individual life and in the traffic situation are conceivable. The hypothesis of a constant behaviour is supported by the descriptive statistics of the respective variables. Additionally, it is postulated that the relationship between the modes is a substitutive one, because the commitment to a mode is connected with relatively high costs, especially the commitment to a private car.

The formulation of the Γ matrix was guided by earlier exploratory work using various SEMs (Simma, 2000a and 2000b). For those variables which are available in both surveys the following assumptions were made. The assumptions within the Γ-matrix were first best guesses and could be modified within the modification-process, whereby any modification had to be based on a-priori understanding, and should not be guided by the model results alone (SEM provides modifications-indices as well as t-values to give hints which variables should be freed or restricted).

- **Gender**: Women have a significantly higher dependence on public transport compared with men, as men have more often a car available.
- **Age**: The variable age is a numerical variable, but the relationship between age and travel behaviour respectively commitment situation is not a linear one. Therefore it was decided to use the variable age as well as the variable age square in the models, whereby the variable age covers a linear relationship, the variable age square a squared relationship. It is postulated that mobility is decreasing with increasing age.
- **Employment**: Employment is connected with an increase in car-availability and car-usage.
- **Licence-ownership**: People who possess a driving-licence tend to use it and consequently buy sooner or later a car.
- **Location of the household**: A binary variable indicating the centrality in the urban system is used to describe the location of the household. It is assumed that people living in rural areas are more car-dependent and have less access to public transport than people living in towns or cities.

4.2 Modelling-procedure

The base structure of the models is as follows - the socio-demographic variables are exogenous, the commitment and the travel behaviour variables are endogenous. The exogenous as well as the endogenous variables have already been mentioned (see section 2). In all models the situation in the first time period is the same (see Table 4). The effects of the first period on the following period and of the second period on the third are different following the four different hypotheses (see Figure1, Figure 2, Figure 3, Figure 4). Each of the four models has two variations with regard to the error terms. The paths between the number of trips by a specific mode at different time periods are always freed, the paths between the commitments are either freed or not.

After specifying which parameters were free, the models were estimated for the two different surveys. The estimated models were slightly modified within the Γ-matrix, because the fits of the first runs were less than satisfying. The results of the different models were interpreted and compared. Based on these interpretations one further model was developed, because the information about possible changes within the household, which had been surveyed in great detail in the Dutch case, deserved particular attention.

4.3 Estimation results of the common models

Models with slightly improved, bad rather bad fits (Bollen, 1989, 256-289; Mueller, 1996, 81-92) which are shown in Table 5 (the models with freed error terms between the commitment respectively the usage variables are shown) were the result of the modification-process. The Chi²-values are rather big, the descriptive fit indices are not perfect. The models would have had better fits, if the relationships between the first and the third period were freed in addition - these relationships did not seem important from a theoretical point of view. In the Dutch case the modification indices between the usage variables of the first and third period were high, in the German case the modification indices between the commitment variables of the first and third period.

For both surveys it can be stated that the first and fourth model type (see Table 5) perform best and that the second and third model type perform worst, whereby the fourth model type is slightly better than the first. The slight differences between the first and the fourth model type show that the inclusion of the usage variables as impact variables contribute a little to the improvement of the models. An interesting difference between the two surveys is, that, although more parameters are freed in the German case than in the Dutch case, the model fit indices are worse for the German case.

The values of the multiple-correlation-coefficients of the endogenous variable (comparable to the R^2s of a regression analysis) lie between 0.27 and 0.82 (German case) respectively between 0.03 and 0.58 (Dutch case) for the structural equations and between 0.06 and 0.37 (German case) respectively between 0.00 and 0.24 (Dutch case) for the reduced form (see bottom of Table 6). In the models the R^2s for the commitment variables were relatively high and the R^2s for the usage variables relatively low.

SEM results provide the fit of a specific model as well as the direct (comparable to standardised regression coefficients) and total effects between the variables, whereby the direct effects of the best fitting model - the fourth model type - are shown in Table 6. The total effects are not shown, because they do not provide further information - the signs of the parameter estimates do not change. Nearly all results are consistent with the assumptions. There are strong relationships between the endogenous variables, the relationship between the two modes is a substitutive one.

The similarities and differences between the models are noted. Generally it can be stated that the direction of the effects are mostly the same, but that the values of the parameter estimates varied considerably.

- **Effects of the commitment variables on modal usage**: In all three periods and in both cases the relationships are similar. Both commitment variables influence modal usage in a substitutive way, whereby the effects on the respective mode are greater than the effects on the other mode.
- **Effects of a situation on the following period**: The car-availability of the second and third period is mainly influenced by the last commitment situation. There exist differences between the countries with regard to public transport. In the German case the influence of season-ticket-ownership in one period on season-ticket-ownership in the following period is as great as the effect of car-availability, whereas in the Dutch case the season-ticket-ownership of the following period is influenced by the respective commitment situation and modal usage of the last period.
- **Gender**: The hypotheses that men have greater access to the car could be confirmed, but - at least in the German case - men also own more often a season-ticket.
- **Age**: The results suggest that it was useful to separate this variable. An increasing age is connected with an increase in car availability and a decrease in the usage of public transport (Dutch case). The signs are inverse for the variable age square.
- **Employment**: The effects from employment are similar to those from gender. People who are employed are more likely to have a car available and to use it. Additionally employment has a positive effect on season-ticket-ownership in the German case.
- **Licence-ownership**: To possess a driving licence has an positive effect on car-availability - as expected.

- **Location**: An urban living environment positively influences the ownership of season-tickets (German case) respectively the usage of public transport (Dutch case).

Besides the parameters within the Γ- and the B-matrix, parameters within the Ψ-matrix were estimated. In both cases the estimates between the usage variables are highly significant and positive, whereas the estimates between the commitment variables are neither significant nor positive. This means that the consideration of the relationships between the error terms of the commitment variables is not necessary.

4.4 Impacts of changes within a household

The hypothesis that persons are mostly not willing to change their behaviour unless changes occur within the household, in personal life or in the traffic situation, is tested by the following model. It is not only interesting to know if these changes affect the commitment and the usage variables, but also how. The Dutch panel is used for this analysis because it includes information about possible changes. In each of the nine following waves it was asked, if the income, the work- or living place had changed.

The variables indicating changes were combined accordingly the two selected periods. As a result, it is known if a specific change occurred between period one and two respectively between period two and three. Changes of the income, especially an income increase, are relatively frequent between two periods (about 45% of the surveyed households respectively about 35% of the surveyed persons could increase their income between two periods), whereas changes of the work or the living place are relatively rare (about 10% of the surveyed persons respectively of the surveyed households changed their working respectively their living place).

These change variables and the variable income (income in 5 classes) were added to the fourth model type whereby a change between two periods could only affect the following situations. The effect of a change of the living place between period one and two on period three was also freed, because this effect seemed theoretically sound. The adaptation on a new place needs some time.

This model was again estimated by the Maximum Likelihood-method and modified within the Γ-matrix. The inclusion of the change variables leads only to a small improvement of the model fit compared to the fourth model-type. For example the GFI increases from 0.90 to 0.92, the RMR decreases from 0.11 to 0.07. This small improvement can be explained by the fact that only few effects from the change variables are significant (see Table 7). The few significant effects from the change variables are mostly positive.

4.5 Interpretation of results

The most important result of all models is the fact that there are close relationships between the endogenous variables. As expected, the commitments influence modal usage at one point of time, whereby there exist great similarities between the countries. Car-availability increases the usage of car and decreases the usage of public transport, season-ticket-ownership increases the usage of public transport and decreases the usage of car, whereby the influence of a commitment on the corresponding mode is greater than the influence of this commitment on the opposite mode.

Not only the effects at one point of time are of interest, but also the temporal dimension. Car-availability at one point of time is mainly influenced by the last commitment situation. The estimates of the parameters nearly reach a value of 1, whereby a value of 1 would indicate that there exists no change at all. This means that persons who have a car available are not likely to give up this mobility chance. A very stable relationship can also be found for season-ticket-ownership in Germany. However, there exists more variation with regard to season-ticket-ownership in the Netherlands. The ownership of a season-ticket is dependent on the commitment situation in the last period as well as on modal usage.

Interesting are also the differences between the model types. Models freeing the relationships between the commitment variables perform better than models freeing the relationship between the usage variables and the commitment variables. This result shows that the commitment variables of the previous period are more important to explain a situation than the usage variables. Even far reaching changes within a household or in personal life cannot bring about substantial changes in the commitment situation and in modal usage - at least during the reporting period.

5. Conclusions and outlook

The models have shown that there are strong relationships between commitments and modal usage. The commitment to a specific mode promotes the usage of this mode and reduces the usage of the other mode and determines the situation in the following periods. The relationship between using the car and using public transport system is a substitutive one. These consistent findings stress the importance of including all commitments into any modelling structure used to describe travel behaviour. Modelling car-ownership is not enough.

The investigation of the temporal dimensions give hints at possible policy measures to combat the imbalance between the car and public transport. The high values of the parameter estimates for car-availability between two time periods indicate, that car-availability is very stable over time. This means that if a person has decided on a car, he or she is bound to this decision. Even great changes within personal life do not motivate persons to give up the car. Therefore, we have to look at the first commitment.

In contrast to car-availability the commitment to public transport is dependent on its usage - at least in the Dutch case. Public transport users are not as loyal to their mode as car users. This means that public transport operators should spend more energy on binding their customers. The investigation of the impacts of the socio-demographic variables have confirmed most of our posed hypotheses – e.g. that employment is connected with an increase of car-ownership and usage, that men have greater access to the car than women and that public transport is used especially in cities.

The aim to present comparable models restricted the set of variables included in the models. Obviously important variables, such as income, household division of labour, working hours, a detailed description of the home and work location, would improve the results. The exogenous variables could also be used to segment the models. It is hoped that future work will address these issues, but in particular it is hoped, that future studies will include, as a matter of course, both car-ownership/availability and season-ticket-ownership as endogenous elements in their model systems.

Additionally one should consider to study the history of commitments in more detail. The low variation which could be observed in the two panels is certainly a result of the short observation period. However, it would be interesting to answer the following questions:

- When was the first car bought? What were the circumstances?

- How often does it happen that a car-owner again gives up this mobility chance?
- Do different stages of ticket-ownership exist?
- When does a move start to affect travel behaviour respectively the commitments?
- When does a change in the personal situation start to affect travel behaviour respectively the commitments?

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7. Literature

Axhausen, K.W. Licence holding and car ownership: A review of available evidence, Working Paper, No. 623, Transport Studies Unit, University of Oxford, Oxford, 1991.

Axhausen, K.W., M. Bader and H. Köll. Public transport usage intensity of season tickets holders in the city of Innsbruck, Report to the Innsbrucker Verkehrsbetriebe GsmbH, Innsbruck, 1998.

Axhausen, K.W., A. Simma and T.F. Golob. Pre-commitment and usage: season-tickets, cars and travel, Working paper, No. 24, Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau, ETH Zürich, Zürich, 2000.

Ben-Akiva, M.E., J.L. Bowman and D. Gopinath. Travel demand model system for the information era, *Transportation*, Vol. 23, No. 3, 1996, pp. 241-266.

Bhat, C. Accommodating variations in responsiveness to level-of-service measures in travel mode choice modelling, *Transportation Research A*, Vol. 32, No. 7, 1998, pp. 495-507.

Bollen, K.A. Structural Equations with Latent Variables, Wiley, New York, 1989.

Bradley, M., T.F. Golob and J.W. Polak. Travel and activity participation as influenced by car availability and use, Working Paper, No. 286, Institute for Transport Studies, University of California, Berkeley, 1995.

Chlond, B., O. Lipps and D. Zumkeller. Haushaltspanel 1997/1998 – Auswertung, Schlussbericht, Institut für Verkehrswesen, Universität Karlsruhe, Karlsruhe, 1998.

Chlond, B., O. Lipps and D. Zumkeller. Auswertung der Paneluntersuchung zum Verkehrsverhalten, Schlussbericht, Institut für Verkehrswesen, Universität Karlsruhe, Karlsruhe, 1996.

De Jong, G. Forecasting car occupancy: Literature review and model development, in D. Hensher, S. Jara-Diaz, J. de Dios Ortuzar (eds.) Travel Behaviour Research: Updating the State of Play, Elsevier, Oxford, 1998, pp. 507-525.

De Jong, G. A disaggregate model system of vehicle holding duration, type choice and use, *Transportation Research B*, Vol. 30, No. 4, 1996, pp. 263-276.

Golob, T.F., S. Kim and W. Ren. How households use different types of vehicles: A structural driver allocation and usage model, *Transportation Research A*, Vol. 30, No. 2, 1996, pp. 103-118.

Golob, T.F. and H. Meurs. A structural model of temporal changes in multi-modal travel demand, *Transportation Research A*, Vol. 21, No. 4, 1987, pp. 391-400.

Hanly, M. and J.M. Dargay. Car ownership in Great Britain: Panel data analysis, *Transportation Research Record* 1718, TRB, National Research Council, Washington, D.C., 2000, pp. 83-89.

Hensher, D.A. The imbalance between car and public transport use in urban Australia: Why does it exist?, *Transport Policy*, Vol. 5, No. 3, 1998, pp. 193-204.

Hensher, D.A. Dimensions of Automobile Demand: A Longitudinal Study of Household Automobile Ownership and Use, Elsevier, New York, 1992.

Hensher, D.A. (1987) An empirical assessment of stability and change of household automobile use in a multiwave panel, in M.D. Uncles (ed.) Longitudinal Data Analysis: Methods and Application, London Papers in Regional science, London:

Maruyama, G.M. Basics of Structural Equation Modelling, Sage Publications, Thousand Oaks, 1998.

Meurs, H. A panel data analysis of travel demand, Dissertation at the Rijksuniversiteit Groningen, Groningen, 1991.

Monheim, R. Verkehrsmittelwahl und Zeitkartenbesitz im Ausbildungsverkehr: Eine Fallstudie bei Schülern und Studenten in Bayreuth, *Verkehr und Technik*, Vol. 40, No. 1, 1987, pp. 3-9.

Mueller, R.O. Basic Principles of Structural Equation Modeling - An Introduction to LISREL and EQS, Springer, Heidelberg, 1996.

Nuzzolo, A., U. Crisalli and F. Gangemi. A behavioural choice model for the evaluation of railway supply and pricing policies, *Transportation Research A*, Vol. 34, No. 5, 2000, pp. 395-404.

Ramjerdi, F. and L. Rand. Car ownership, car use and demand for alternative fuel vehicles, Norwegian Institute of Transport Economics, TOI-342-1996, Oslo, 1996.

Simma, A. Verkehrsverhalten als eine Funktion sozio-demografischer und räumlicher Faktoren, Dissertation, Universität Innsbruck, Innsbruck, 2000a.

Simma, A. Verkehrsverhalten als eine Funktion sozio-demografischer und räumlicher Faktoren, Working paper, 55, Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau, ETH Zürich, Zürich, 2000b.

Simma, A. and K.W. Axhausen. Structures of commitment in mode use: A comparison of Switzerland, Germany and Great Britain, *Transport Policy*, Vol. 8, No. 3, 2001, pp. 279-288.

Van Wissen, L.J. and T.F. Golob. A dynamic model of car fuel type choice and mobility, Transportation Research B, 26 (1) 77-96, 1992.

Table 1 Overview of the two surveys and the number of persons included

	Germany	Netherlands
Survey-years used	1994-1998	1984-1989
Waves per year	1 wave	2 waves
Number of waves in all	till 2000 7 waves	10 waves
Number of waves per person	max. 3 times	max. 10 times
Duration of reporting period	1 week	1 week
Time of reporting period	Autumn	Spring and autumn
Weighted	No	Yes
Number of persons[1] considered	1'056	1'057

[1] Persons were older than 17 years, at least mobile for one day and participating in all waves.

Table 2 Descriptive statistics for the most important variables (persons older than 17 years, participating in all waves) – Germany and the Netherlands

Mean/Frequency		Germany			Netherlands[1]		
Socio-demographic variables							
Age[2]	[years]			48			42
Employed[2]	[%]			60			41
Male[2]	[%]			49			43
Number of household-members[2]	[n]			2.74			2.84
Licence holders/household-members[2]	[%]			85			69
Urban[2]	[%]			43			45
		Period1	Period2	Period3	Period1	Period2	Period3
Commitment variables							
Car-available / cars per licence-holder	[%, n]	63.16	65.34	64.02	0.56	0.55	0.56
Season-ticket-owner	[%]	11.64	11.36	11.36	5.58[3]	3.78[3]	2.37[3]
Travel behaviour variables (per week)							
Number of car-trips	[n]	12.83	12.73	13.85	12.21	11.64	12.62
Number of public transport-trips	[n]	1.16	1.21	1.20	1.19	1.10	0.99

[1] Observation were weighted.
[2] First survey-year
[3] During this time the number of discount-ticket-owners increased.

Table 3 Correlations between the commitment variables of the three periods (above the diagonal and grew shaded the figures for the Netherlands)

	Car-availability			Season-ticket-ownership		
	Period1	Period2	Period3	Period1	Period 2	Period3
Car-availability						
Period 1		0.763	0.677	-0.122	-0.078	-0.117
Period 2	0.673		0.779	-0.053	-0.090	-0.130
Period 3	0.614	0.661		-0.065	-0.056	-0.117
Season-ticket-ownership						
Period 1	-0.200	-0.207	-0.226		0.367	0.160
Period 2	-0.178	-0.210	-0.223	0.623		0.402
Period 3	-0.172	-0.228	-0.229	0.577	0.670	

Table 4 Postulated direct exogenous and endogenous effects of the models for period 1

From	**To** Car-available	Season-ticket-owner	Car-trips	Public transport-trips
Car-available		-β	β	-β
Season-ticket-owner			-β	β
Usage of public transport				
Usage of car				
Male	γ			-γ
Age			-γ	-γ
Age square			γ	γ
Employed	γ		γ	
Licence-owner	γ		γ	
Urban	-γ	γ		

Table 5 Model fit of the modified models - separated after surveys and the selected travel behaviour variables

	Germany				the Netherlands			
	Type 1	Type 2	Type 3	Type 4	Type 1	Type 2	Type 3	Type 4
Sample size	1056	1056	1056	1056	1057	1057	1057	1057
Degrees of freedom	109	112	108	108	113	114	114	107
Chi²-value	1658	4412	4303	1613	1239	1957	2880	1172
Probability of χ^2-value	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Root Mean Square Residual	0.09	0.23	0.22	0.09	0.11	0.15	0.15	0.11
Goodness-of-Fit Index[1]	0.87	0.75	0.76	0.88	0.90	0.85	0.79	0.90
Normed Fit Index[2]	0.91	0.76	0.77	0.91	0.90	0.84	0.76	0.90
Critical N[3]	94	37	37	96	130	83	57	133

[1] The GFI measures how much better the model fits as compared to no model at all.
[2] The NFI measures how much better the model fits as compared to a baseline model.
[3] The CN gives the sample size at which the *F* value would lead to the rejection of H_o ($\Sigma = \Sigma(\theta)$).

Table 6 Direct effects and multiple-correlation-coefficients of the fourth model type for the two surveys (*Dutch case in italics*) - all effects significant at the 0.01 level

From **To**	Period 1				Period 2				Period 3			
	1[1]	2[2]	3[3]	4[4]	1[1]	2[2]	3[3]	4[4]	1[1]	2[2]	3[3]	4[4]
Male	0.21	0.20										
	*		*0.12*									
Age	0.59											
	0.96		*	*-0.31*								
Squared Age	-0.51											
	-0.90		*	*0.42*								
Employed	0.19	0.25	0.23	*								
			0.12									
Licence-owner	0.45											
	0.32		*0.20*									
Household-size	-0.13	-0.22										
	0.08		*									
Urban		0.29										
				0.16								
Period 1												
Car available		-0.51	0.37	*	0.89							
		-0.16	*0.28*	*-0.22*	*1.13*							
Season-ticket-owner			-0.28	0.55		0.88						
			-0.06	*0.31*		*0.24*						
Car-trips					0.04							
					*							
Public transport-trips						0.11						
						0.18						
Period 2												
Car available							0.43	-0.09	0.90			
							0.34	*-0.21*	*0.88*			
Season-ticket-owner							-0.21	0.54		0.96		
							*	*0.39*		*0.34*		
Car-trips									0.07			
									0.06			
Public transport-trips										*		
										0.17		
Period 3												
Car available											0.38	*
											0.37	*-0.16*
Season-ticket-owner											-0.22	0.60
											-0.04	*0.33*
R^2 for structural equations	0.37	0.37	0.43	0.32	0.77	0.77	0.31	0.40	0.75	0.83	0.27	0.37
	0.12	*0.03*	*0.32*	*0.23*	*0.44*	*0.12*	*0.13*	*0.27*	*0.58*	*0.12*	*0.16*	*0.19*
R^2 for reduced form[5]	0.37	0.20	0.21	0.06	0.31	0.17	0.08	0.06	0.27	0.16	0.06	0.06
	0.12	*0.01*	*0.24*	*0.06*	*0.15*	*0.00*	*0.02*	*0.01*	*0.12*	*0.00*	*0.02*	*0.00*

* Estimated, but not significantly different from zero
[1] Car available
[2] Season-ticket-owner
[3] Car-trips
[4] Public transport-trips
[5] R^2s for reduced form are only related to the exogenous variables.

Table 7 Direct effects of the exogenous variables and multiple-correlation-coefficients in the model concerning within-household-changes - all effects significant at the 0.001 level (β-parameters similar to the last model)

From **To**	Period 1				Period 2				Period 3			
	1[1]	2[2]	3[3]	4[4]	1[1]	2[2]	3[3]	4[4]	1[1]	2[2]	3[3]	4[4]
Male			0.07									
Employed			0.18									
Licence-owner	0.28		0.24	-0.11								
Household-size			0.06									
Urban				0.15								
Income	0.15											
Period 1 to period 2												
Increase in hh-income												
Increase in p-income							0.05*					
Change of workplace						0.10	0.07	0.04				
Change of living place					0.04							0.07
Change of hh-size												
Period 2 to period3												
Increase in hh-income									0.05			
Increase in p-income											0.09	
Change of workplace												
Change of living place												0.09
Change of hh-size									-0.09			
R^2 for struct. equations	0.15	0.02	0.25	0.29	0.56	0.26	0.15	0.35	0.46	0.23	0.16	0.40
R^2 for reduced form[5]	0.15	0.01	0.11	0.02	0.10	0.01	0.03	0.02	0.07	0.00	0.04	0.01

* only significant at the 0.05 level
[1] Car available
[2] Season-ticket-owner
[3] Car-trips
[4] Public transport-trips
[5] R^2s for reduced form are only related to the exogenous variables.

Figure 1 Path-diagram for hypothesis 1

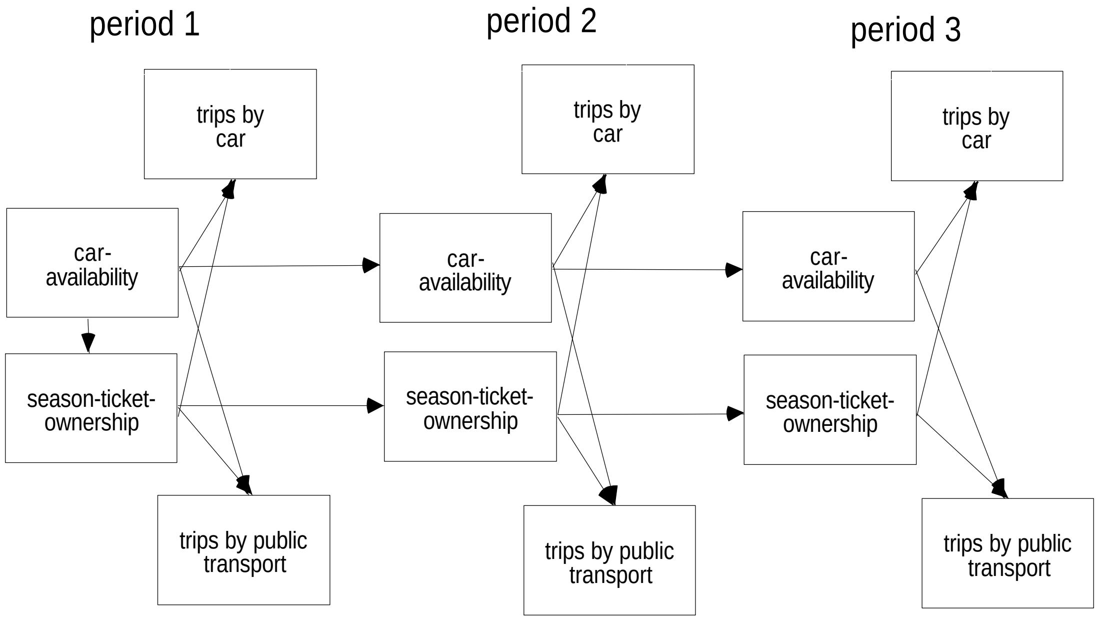

Figure 2 Path-diagram for hypothesis 2

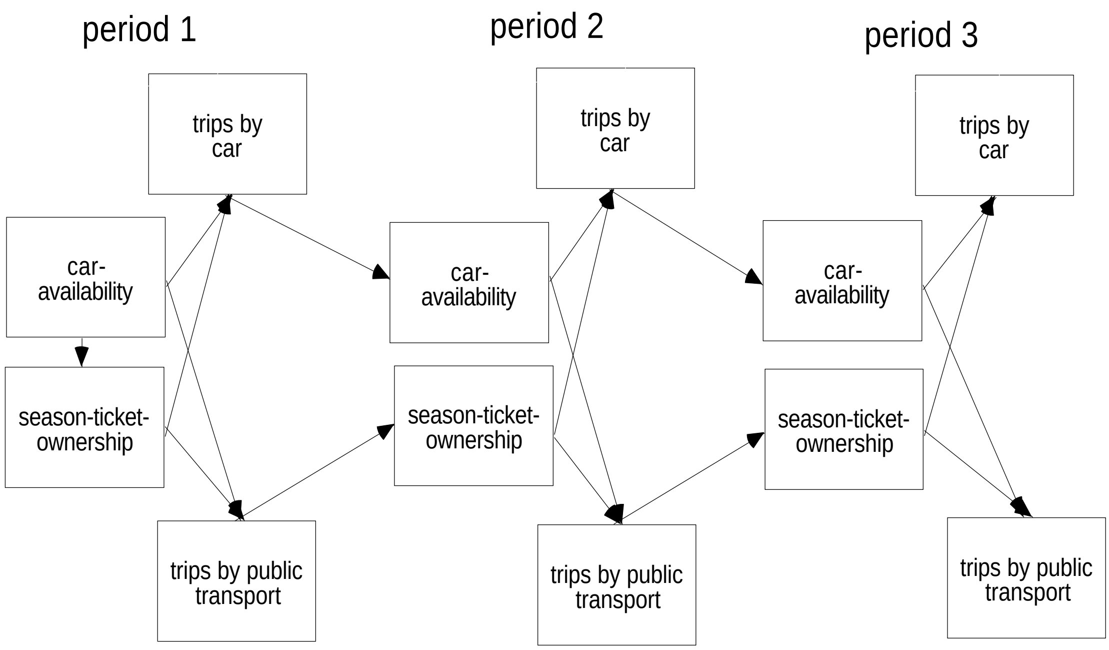

Figure 3 Path-diagram for hypothesis 3

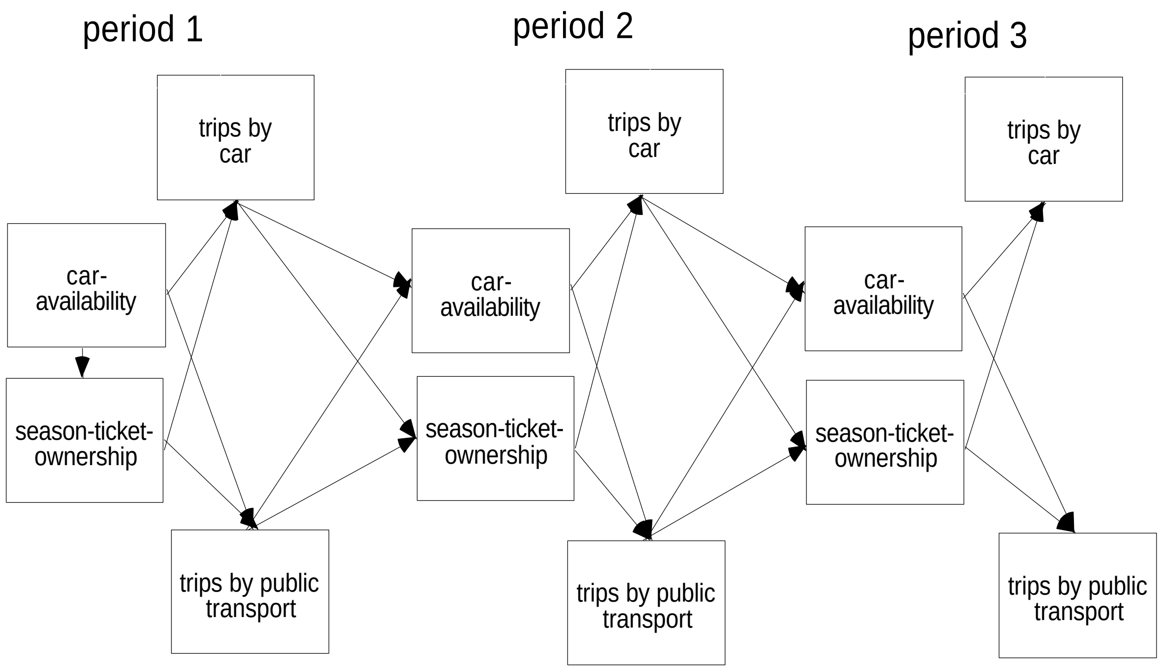

Figure 4 Path-diagram for hypothesis 4