Working Paper

Mobility as a function of social and spatial factors
The case of the Upper Austria Region

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

Publication Date:
1999-06

Permanent Link:
https://doi.org/10.3929/ethz-a-004234420

Rights / License:
In Copyright - Non-Commercial Use Permitted

This page was generated automatically upon download from the ETH Zurich Research Collection. For more information please consult the Terms of use.
MOBILITY AS A FUNCTION OF
SOCIAL AND SPATIAL FACTORS:
THE CASE OF THE UPPER AUSTRIA REGION

Paper submitted for presentation at the 79th Annual Meeting of the Transportation Research Board,

A SIMMA
Institut für Geographie
Leopold-Franzens-Universität
Innsbruck
Tel 0043-512-507 5428
Fax 0043-512-507 2895
anja.simma@uibk.ac.at

TF GOLOB
Institute for Transportation Studies
University of California
Irvine
Tel 001-949-824 6287
Fax 001-949-824 8385
tgolob@uci.edu

KW AXHAUSEN
IVT
ETH
Zürich
Tel 0041-1-633 3943
Fax 0041-1-633 1057
axhausen@ivt.baum.ethz.ch

JUNE 1999
MOBILITY AS A FUNCTION OF SOCIAL AND SPATIAL FACTORS:
THE CASE OF THE UPPER AUSTRIA REGION

A Simma
Institut für Geographie
Leopold-Franzens-Universität
Innsbruck

T Golob
Institute for Transportation Studies
University of California
Irvine

KW Axhausen
IVT
ETH
Zürich

ABSTRACT

The research presented here explores the interactions between land use, household structure and travel patterns. The data are from an extensive travel diary of over 100,000 households in the Land of Upper Austria, combined with extensive data on land uses and local economic activities. Structural equation models are developed at both the person and household levels to explain mobility simultaneously in terms of socio-economic and spatial variables. The observed endogenous variables in these models include car ownership, rates of trip and journey (trip chain) generation, distance travelled, mean speed, and the interaction between distance and speed. Latent factors associated with mobility level and mobility intensity are formulated from these observed variables. It was found that socio-demographic factors affect mobility mostly through car availability, while spatial factors tend to affect mobility independent of car availability.

KEYWORDS

Mobility intensity, mobility level, travel volume, interaction, space, socio-demographics, Upper Austria, structural equation model, factor analysis
INTRODUCTION

Discussion about the interaction between the amount and structure of personal travel and the structure of the environment has been very active in recent years on both sides of the Atlantic (Downs, 1994; Calthorpe, 1993; Garreau, 1991 or Hoffmann-Axthelm, 1996). The American side has contributed more in terms of empirical analysis (e.g. Cervero and Gorham, 1995; Gordon and Richardson, 1997a). The American debate also focuses more on the issue of sprawl and includes a strong political and aesthetic element (e.g. Duany and Plater-Zyberk, 1991, Gordon and Richardson, 1997b; Crane, 1997; Ewing, 1997; Levine, 1997), as well as alternative suburban development patterns (i.e. neo-traditional neighbourhoods etc.). In contrast, European discussion is framed more by the issue of sustainability and how it can be achieved (e.g. Banister, 1994). The focus on sustainability naturally leads to the inclusion of the social dimensions of economic and societal development, which preoccupy European policy makers against the background of sustained high unemployment in most European countries.

Most prominent among the social variables of interest is the change in household and family structure, as the prototypical two-married parent family looses its numerical dominance due to increasing numbers of single, unmarried couple, one-parent and other household forms (e.g. Beck and Ziegler, 1997, Peuckert, 1996). These changes are associated both with changes in modal split and as a result the spatial distribution of homes work places and activities (e.g. Fagnani, 1993, Hanson and Pratt, 1988), as well as the development of different lifestyles. Most important among the spatial changes is the general coarsening of the grain of opportunities, as retailers and service providers consolidate their locations into bigger units forcing their customers to trade off longer access against cheaper goods/services and/or greater selection. The loss of the village store is in the Austrian example the typical indicator of this process.

It is against this background that this paper explores the interactions between land use developments, household structures and travel patterns using a data set of particular richness and suitability: the 1992 travel diary survey conducted in the Austrian Land Upper Austria (Oberösterreich). This province of about 1.3 million people includes urban centres, suburban sprawl (of European density), and rural villages, as well as tourism-dominated regions. This comprehensive coverage of spatial types is represented in the data collected, as all municipalities of the province were included in the survey. This spatial range also ensures the coverage of all household types given the range of social environments inherent in the different types of municipalities and villages.

The modelling of the interactions between these three dimensions (land use, household structure as an indicator of social change and travel behaviour) requires a tool, which can extract both the underlying structures within the dimensions, as well as relate them to each other. Structural equation models (SEM) have shown themselves to be suitable for this task (e.g. Bollen, 1989). This paper will report
results from explorations of the data using this tool extending earlier results, which had concentrated on the household structure and travel interaction (Golob and van Wissen, 1989, Golob and McNally, 1995).

The paper has the following structure. The next section reviews briefly the methodological approach to the study. This is followed by a description of the method and of the available data. The core of the paper is formed by the discussion of three models addressing the issues of interest – on the one hand the creation of mobility-factors and on the other hand two models of the interactions one at the person level and one at the household level. The paper concludes with an outlook for further research.

2 REVIEW

The unit of analysis in this paper is the individual within the household, interacting with the social and spatial environment, as well as the household as a whole. Understandings developed through activity-based travel demand models forms the basis of the analysis.

The activity-based approach to the analysis of travel behaviour and travel demand originated in the UK, the US and Germany in the 1970’s to overcome the limitations of the standard four-stage approaches. The starting point of the approach was the switch of focus from aggregate trip making to individual activity participation and the identification of travel as a derived demand. The work was stimulated by developments in geography (Hägerstrand) and urban planning (Chapin). Both had analysed the activity patterns of individuals and groups of individuals. While the unit of analysis was the same, the two approaches had different basic assumptions. Chapin (1974) saw travel primarily as a result of individual preferences and unconstrained choices, whereas Hägerstrand (1970) saw it as the outcome of fulfilling a complex set of constraints. The activity approach recognises both and analyses travel and activity behaviour as “choice in the context of constraints” (Jones, Dix, Clarke and Heggie, 1983, p. 266). It is this fuller understanding which allows the activity-based approach to offer more comprehensive and insightful analyses of travel behaviour.

The aim of the initial work was the definition of behaviourally homogenous groups of travellers for transport planning. Kutter (1972) studied the travel behaviour of a-priori defined groups. He assumed that the socio-demographic characteristics of the individuals translate into social roles, which in turn imply common activity and travel patterns. Using factor analysis he identified groups by their socio-demographics, in particular age, gender, car-ownership and labour force participation. Later work confirmed Kutter’s results. Schmiedel (1984), for example, used cluster-analysis to aggregate a-priori-defined groups based on their time-budgets for different types of activity. The seven behaviourally defined groups he identified are very similar to Kutter’s and are based on essentially the same socio-
demographic characteristics. Schmiedel concluded that the social roles are dominant in comparison with the time-space regime.

The finding that travel behaviour is strongly influenced by socio-demographic characteristics was developed further in two directions. First, this finding was integrated in complex, computer-aided models, e.g., AMOS (Kitamura, Pendyala and Pas, 1995) and VISEM (Fellendorf, Haupt, Heidl and Scherr, 1997) Second, the finding was also investigated in greater detail, e.g., the life-cycle, person-characteristics, the impacts of income and available time, gender differences and household-structure (Kitamura, 1988). Models were developed for some of these aspects.

- **Lifecycle-model** (e.g., Hanson and Hanson, 1981, Kostyniuk and Kitamura, 1982, Jones, Dix, Clarke and Heggie, 1983, Pas, 1984 or La Morsanglière and Raux, 1983): The different lifecycle-models are an attempt to distinguish different groups – relevant with regard to travel behaviour. The division of groups is orientated towards the stages in family-lifecycle. Despite the encouraging results the lifecycle-model was criticised, especially the concentration on the family and the arbitrary division of groups.

- **Expanded Lifecycle-model** (e.g., Zimmermann, 1982, Stapelton, 1980): This kind of model extended the lifecycle-model and attempted to overcome the problem of the concentration on the family. Different lifestyles, e.g. one-parent-families or living arrangements, were incorporated. But a systematic application of these models is still missing.

- **Lifestyle-model** (e.g., Salomon and Ben-Akiva, 1982, Salomon, 1983, Pas 1984): Decisive for the development of these models was the wish to capture the wholeness of the individual and his or her behaviour. In nearly every study lifestyle is defined in different ways. E.g. for Salomon lifestyle is the behavioural pattern that results from three major life decisions: the decision to form a household, the decision to participate in the labour force and the orientation toward leisure.

- **Role-model** (e.g., Damm, 1983, Townsend, 1987): The role-model is an alternative approach for grouping socio-demographic variables. The most important variables in these models are gender and employment status.

- **Interactions** (e.g., Golob and McNally, 1995): The focus of this kind of model is the interactions between household-members and the resulting activity patterns. The idea behind this model is that great dependencies exist between household-members and that they can be seen in the behaviour.

- **Household-model** (e.g., Golob, Kitamura and Lula, 1994, Golob, 1999): In the last kind of models the focus is on the household-heads and their interactions. Household-models look at the household as a whole and take household aggregations of mobility factors as endogenous variables.

These different models show that the variables used as proxies for the style and manner in which individuals and households live have been found to be significantly related to their travel behaviour. What is unclear is the relative importance of each variable and the way differences in each variable may determine differences in the overall travel patterns of households and individuals.
The analysis of the impacts of spatial structures has flourished recently, especially in the US, where requirements of the clean-air legislation and the interest in “neo-traditional neighbourhood design” have highlighted the need for better understanding of these impacts (e.g. Kitamura, Mokhtarian and Laidet, 1997; McNally and Ryan, 1992). These studies suffer from their neglect of the family structures involved and from the narrow range of spatial structures available in the US, in general, and in their Californian study areas, in particular. Nevertheless, the results confirm that spatial structures have an impact on travel behaviour.

While each of the themes of this project has been analysed in depth over the last twenty years, the review has shown that the interactions between them have not, mostly because the suitable analysis tools were missing in the past (for an early attempt see Neuwerth, 1987). Current social, spatial and economic trends require a much better understanding of these interactions to support appropriate policy formulation. This paper hopes therefore to contribute to the filling of these gaps.

3 APPROACH AND DATA SOURCES

3.1 Structural equation models

A structural equation model (SEM) is simply a set of simultaneous equations specified by direct links between variables. An SEM with latent variables has at most three components: a measurement submodel for the endogenous variables, a similar measurement submodel for the exogenous variables, and a structural submodel. Here we develop two types of SEMs, those that consist only of a measurement model for endogenous variables, and those that consist of a measurement submodel for the endogenous variables together with a structural model. The measurement submodel is used to define unobserved endogenous variables (called latent variables, or factors) in terms of observed endogenous variables (or indicators):

\[ y = \Lambda \eta + \varepsilon \]  

(1)

where \( y \) is a (p by 1) column vector of indicator variables, \( \eta \) is a (m by 1) column vector of factors, and \( \Lambda \) is a (p by m) matrix of factor loadings. Usually, the submodel represents a reduction in dimensionality, where there are more observed variables than factors (m < p). The unexplained portions of the observed endogenous variables (measurement errors) are defined by the (p by 1) vector \( \varepsilon \), which has a variance-covariance matrix defined by \( \Theta_\varepsilon = \mathbb{E}[\varepsilon \varepsilon'] \). An SEM consisting of this measurement submodel alone is generally known as confirmatory factor analysis, and the parameters to be estimated are the free elements of the \( \Lambda \) and \( \Theta_\varepsilon \) matrices that are postulated to be different from zero.
The optional structural submodel captures the relationships between the factors and observed exogenous variables, and between the endogenous variables themselves. It is defined by

$$\eta = B\eta + \Gamma x + \xi$$  \hspace{1cm} (2)

in which the (m) latent endogenous variables are a function of each other and of the (q) exogenous variables (denoted by the q-dimensional column vector x). The unexplained portions of the latent endogenous variables (the errors in equations), have a variance-covariance matrix defined by

$$\Psi = E[\xi\xi']$$. A structural SEM with latent endogenous variables is defined by equations (1) and (2).

The modeller specifies which elements of the $\Lambda$, $B$, $\Gamma$, $\Theta$, and $\Psi$ 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. By solving (1) in terms of the exogenous variables, the total effects of these variables on the endogenous latent variables are given by the so-called reduced-form equations:

$$\eta = (I - B)^{-1} \Gamma x$$  \hspace{1cm} (3)

Estimation of an SEM with latent variables can be accomplished in several ways. Here we use normal-theory maximum likelihood, the most commonly used method. The method (described in detail in Bollen, 1989) is based on matching model-replicated variance-covariances to observed variance-covariances. This method has been used in travel demand modeling by Golob and McNally (1995), Lu and Pas (1999) and Golob (1999).

### 3.2 General Description of Upper Austria

Upper Austria has a size of 12,000 km² (slightly smaller than Connecticut) and about 1.3 million inhabitants. At a very general level Upper Austria can be divided into three parts.

- **Mühlviertel** in the north of Upper Austria
- **Zentralraum**
- **Salzkammergut** in the south of Upper Austria

The northern part of Upper Austria is disadvantaged in several ways. This area is neither well suited for agriculture nor for tourism. Additionally the border to Czech Republic was closed for five decades. As a result the possibilities for industrial developments after World War II were limited. Widely spread settlements and large, isolated farm houses are the dominant settlement structure in the Mühlviertel.
The situation is different in the other parts of Upper Austria. The Zentralraum is the centre of agriculture and industry. Very important enterprises can be found in the main cities, for example VOEST in Linz (steel works) or the Steyr mechanical engineering group in Steyr. Especially the western parts of the Zentralraum are important for agriculture. Half of the population lives in this area and 13 of the 15 largest towns are situated here.

The Salzkammergut is characterised by tourism with its lakes (e.g. location of “Sounds of Music”) and skiing areas.

Upper Austria consists of 15 districts, three cities with district status (Linz, Steyr and Wels) and 445 incorporated communities. The respective district capitals are both centres of local administrations, as well as the main shopping and industrial locations for their area. Linz is the centre of the region. The situation of the communities, especially the distance to the district capital and to Linz, is important for the travel behaviour of its inhabitants.

Figure 1: Upper Austria: administrative structure

The communities are very different in their structure. The numbers of inhabitants, of commuters, of hotel-beds, of workplaces and of infrastructure facilities as well as the local purchasing power vary considerably (see Table 1):
• **Inhabitants**: 26% of the communities have less than 1,000 inhabitants, 40% of the communities have between 1,000 and 2,000 inhabitants and further 18% of the communities have between 2,000 and 3,000 inhabitants. That is to say the large part of the communities are rather small. Only one community has more than 100,000 inhabitants – Linz.

• **Workplaces**: Linz not only has the most inhabitants, it also has the most workplaces. Other important work locations are the district-capitals.

• **Hotel-beds**: In some communities – especially in communities on the lakes - there are nearly twice as many hotel-beds as inhabitants.

• **Commuters**: Because workplaces are concentrated in Linz and the district capitals, people in the small villages have to commute. In some communities the commuter share amounts to more than 80%.

• **Purchasing power**: The purchasing power-index varies between 49 (Kaltenberg – a small village in the northern part of Upper Austria) and 136 (Mondsee - a tourism village in the Salzkammergut).

• **Industrial sectors**: In some communities the agriculture is still dominant. In other communities – especially in the tourism-communities - many people work in the service-sector. As a result of large industrial enterprises the share of blue-collar worker amounts to nearly 50% in some communities.

• **Number of infrastructure-facilities**: The number of infrastructure-facilities is a measure for the supply-level of a community. It is high, if many households can reach a shop, a supermarket, a bank, a post-office, a kindergarten, school, a pharmacy and a doctor in walking-distance, and it equals zero, if no household can reach any infrastructure-facility. Only three communities are without all of these infrastructure facilities, but in every community there are at least some households which cannot reach an infrastructure-facility within a reasonable time.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Descriptive statistics for Upper Austrian communities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic</strong></td>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>Number of inhabitants</td>
<td>3081</td>
</tr>
<tr>
<td>Number of households</td>
<td>1146</td>
</tr>
<tr>
<td>Number of hotel-beds</td>
<td>192</td>
</tr>
<tr>
<td>Beds per inhabitant</td>
<td>0.09</td>
</tr>
<tr>
<td>Number of commuters</td>
<td>682</td>
</tr>
<tr>
<td>Share of commuters</td>
<td>69</td>
</tr>
<tr>
<td>Purchasing power index</td>
<td>85</td>
</tr>
<tr>
<td>Share of agricultural-employment</td>
<td>14</td>
</tr>
<tr>
<td>Share of industrial employment</td>
<td>33</td>
</tr>
<tr>
<td>Share of service-sector employment</td>
<td>54</td>
</tr>
<tr>
<td>Number of infrastructure-facilities</td>
<td>2.6</td>
</tr>
<tr>
<td>Distance to the district capital (km)</td>
<td>17</td>
</tr>
<tr>
<td>Distance to Linz (km)</td>
<td>56</td>
</tr>
</tbody>
</table>
3.3 The 1992 Upper Austrian Travel Survey
The government of Upper Austria conducted a travel survey in Upper Austria in autumn 1992 renewing its data base for the first time since early 1980’s. It mostly followed in design and protocol the well known example of the German KONTIV survey (Axhausen, 1995). A postal questionnaire was used to collect the information. Every third household was selected from the official and mandatory local registers of residents and households.

Each of the selected households was contacted up to four times. The survey pack included one questionnaire for the household as a whole and six individual trip diaries for the different household member. Responses were expected from persons aged older than five years (Amt der Oberösterreichischen Landesregierung, 1995).

The return rate was high. On average 70% of the households sent the questionnaires back. The response rate was relatively low in Linz (55%) – the capital of Upper Austria - and high in the northern parts of Upper Austria (80%).

The result of the 1992 Survey was a database with up to 900,000 observations. Each observation had 100 variables. The database was divided into three different files:

- Household-file (123,628 observations, 25 variables)
- Person-file (328,242 observations, 44 variables)
- Trip-file (898,552 observations, 31 variables)

3.3.1 Datasets used
Two different datasets were created for the modelling process.

- **Person dataset**: Those respondents who lived in Upper Austria, who were mobile and reported their behaviour fully, were included (205,613 persons).
- **Household-dataset**: Those households which lived in Upper Austria, which had reported their travel behaviour fully and had at least one mobile person, were included (99,462 households).

Additionally further variables were created, mostly aggregates, such as e.g. the distances travelled on a given day or the number of elderly people living in a household.

The reason for the exclusion of the non-mobiles was that the focus of this study were the outdoor-activities. Nonetheless it is interesting to take a closer look at the question who is mobile and who not (20% of the respondents were not mobile). To answer this question a probit-model of the likelihood to be mobile was estimated.
The probability depends in the main on the socio-demographic variables: age, household size, licence-holding and gender. Especially older women without a driving licence living alone tended to stay at home. Additionally some spatial variables are significant, e.g. the number of infrastructure-facilities increasing and the share of female commuters decreasing the likelihood of leaving the house.

4  ANALYSIS

4.1  Description of the respondents

Average household size was 2.9 persons. The most common household size was the two-person-household with 27%. Approximately 20% of the households include one, three or four persons. Two thirds of the households did not have children. One child lived in 16% of the households, two children in 13% of the households and three children in 4% of the households.

Twenty-six percent of the households did not own a car, 47% of the households owned one car, 21% of the households two cars. On average there were 1.1 cars per household. The average car-ownership per household increased with increasing household-size. One-person-households owned 0.4 cars on average, three-person-households 1.3 cars and six-person-households 1.9 cars.

In addition to these household-characteristics, the accessibility of certain services was established by the survey. Sixty-seven percent of the households could reach a shop within a ten-minute walk, 56% a school, 50% a post-office, 77% a bus-station and 35% a railway-station.

The average age of the respondents was 39 years. The age-structure of the population showed that the middle-aged were the largest age group. More women than men, especially elderly women lived in Upper Austria.

The age-structure influenced the distribution of the professional activities. More than 40% of the inhabitants were employed, mostly full-time. The portion of retired people and pupils was nearly the same and had a share of 20% each. There were great differences in the professional activities according to gender. Men usually worked or had worked, women either worked or/and were responsible for the household.

Mobility potential differed by gender and age. Women and elderly had less opportunities to choose between different modes than men and young people. Only 63% of the women, but 88% of the men had a driving licence, only 29% of the women, but 75% of the men owned a car. Only 35% of people aged older than 64, but 90% of people in the age group 25 to 44 years had a driving licence, only 25%
of people aged older than 64, but 61% of people in the age group 25 to 44 years owned a car. Especially older women were not able to use a car.

Age influenced number of trips as well (see Table 2). Persons of the age group from 25 to 34 years had 3.5 trips per day and were the most mobile group. With increasing age the number of trips decreased. At the same time the number of immobile persons increased from 11% to 44% in the age group older than 64.

Besides the number of trips the number of car-trips, the number of journeys, the travelled distances, the time spent travelling and the average speed or travel are important with regard to travel behaviour. Except for time spent travelling all these variables showed the same trend as the number of trips. They increased up to the age-group 25 to 44 years and then decreased again. Time spent travelling reached its peak in the age-group 18 to 24 years.

Table 2  Upper Austria 1992: Travel characteristics by age for mobile respondents

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>&lt;18 years</th>
<th>18-24 years</th>
<th>25-44 years</th>
<th>45-64 years</th>
<th>&gt;65 years</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of trips</td>
<td>2.71</td>
<td>3.24</td>
<td>3.56</td>
<td>3.32</td>
<td>2.92</td>
<td>3.22</td>
</tr>
<tr>
<td>Average number of car trips</td>
<td>0.47</td>
<td>2.08</td>
<td>2.37</td>
<td>1.92</td>
<td>0.96</td>
<td>1.68</td>
</tr>
<tr>
<td>Average number of journeys</td>
<td>1.31</td>
<td>1.49</td>
<td>1.55</td>
<td>1.47</td>
<td>1.37</td>
<td>1.45</td>
</tr>
<tr>
<td>Average distance travelled</td>
<td>13.76</td>
<td>26.67</td>
<td>22.80</td>
<td>18.23</td>
<td>9.85</td>
<td>18.87</td>
</tr>
<tr>
<td>Average duration of travel</td>
<td>53.22</td>
<td>60.98</td>
<td>54.58</td>
<td>53.49</td>
<td>50.05</td>
<td>54.24</td>
</tr>
<tr>
<td>Average speed</td>
<td>13.64</td>
<td>24.65</td>
<td>22.75</td>
<td>18.36</td>
<td>10.77</td>
<td>18.74</td>
</tr>
</tbody>
</table>

The mobility characteristics also varied by gender. The differences were big with regard to speed and distance travelled and small with regard to the number of journeys (Table 3).

Table 3  Upper Austria 1992: Travel characteristics by gender for mobile respondents

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Female</th>
<th>Male</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of trips</td>
<td>3.20</td>
<td>3.25</td>
<td>3.22</td>
</tr>
<tr>
<td>Average number of car trips</td>
<td>1.45</td>
<td>1.93</td>
<td>1.68</td>
</tr>
<tr>
<td>Average number of journeys</td>
<td>1.45</td>
<td>1.46</td>
<td>1.45</td>
</tr>
<tr>
<td>Average distance travelled</td>
<td>15.52</td>
<td>22.47</td>
<td>18.87</td>
</tr>
<tr>
<td>Average duration of travel</td>
<td>52.01</td>
<td>56.63</td>
<td>54.24</td>
</tr>
<tr>
<td>Average speed</td>
<td>16.31</td>
<td>21.36</td>
<td>18.74</td>
</tr>
</tbody>
</table>
4.2 Analysis of the latent mobility variables/factor analysis

The first stage in modelling the interactions between household structure, land use and travel behaviour is the identification of the factor structure underlying the different variables used to describe the travel of the respondents. If it is possible to reduce the dimensionality of the process analysed, the further analysis can then be directed at a smaller and behaviourally more significant number of variables.

Using a substantial set of variables (number of trips, number of car-trips, number of journeys, distances travelled, time spent travelling, average speed and day-area (distance travelled*average speed – an interaction term of the two well-known measures of mobility speed and distance), initial explanatory factor analyses were performed to explore the structures. They were used to reduce the number of variables employed. The best fitting structure was based on a two-factor-model retaining as variables: the number of trips, number of journeys, travelled distances, average speed and day-area.

Confirmatory factor analysis within a SEM-framework was then used to refine the structure. It allows to constrain some of the factor loadings to zero while testing the number of factors as well as modelling the correlations between measurement errors. The initial two-factor-model was confirmed for the person dataset (see Table 4).

Table 4  Person dataset: Results of the confirmatory factor analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Factor 1 Estimates</th>
<th>t-statistics</th>
<th>Factor 2 Estimates</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trips</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of journeys</td>
<td>0.80 30.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance travelled</td>
<td>0.22 7.43 0.93 67.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average speed</td>
<td>0.78 26.98</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day-area</td>
<td>0.13 4.50 1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results were highly significant. On the one hand, the overall measures of fit were good.

- Chi-square: $\chi^2 = 8.54$ with 5 degrees of freedom, $p = 0.13$
- Root mean square residual: $\text{RMR} = 0.036$
- Goodness-of-fit index: $\text{GFI} = 0.99$
- Adjusted goodness-of-fit index: $\text{AGFI} = 0.98$

\[1\] RMR is a measure of the average of the fitted residuals. If RMR is near to zero, a lot of the variance can be explained by the model.
On the other hand, the explanatory power of the variables was high with t-statistics ranging from 4.5 to 67.6. It was very high for the relationship between distances travelled and factor two and relatively low for the relationship between day-area and factor one.

The factor pattern is clear. The first factor measures activity-level in the sense that is high when a person undertakes many trips and journeys, but does not correlate with the intensity of that travel. The second factor is a measure for distances travelled and the chosen mode through average speed and day-area. A person can travel very long distances, but at same time need not make many trips and vice versa. The two factors could be named: mobility level and mobility intensity.

4.3 Person-model of life-style, location type and mobility

4.3.1 Model Specification

Structural Equation Modelling (SEM) is used to create a person-model of household-structure, land use and mobility. The first step in the modelling process to specify the endogenous and exogenous variables, the latent variables and the relationships between the variables.

The exogenous side of the model consists of two different variable-blocks: spatial variables and socio-demographic variables. These variables are incorporated in the model as observed variables. Therefore no exogenous measurement model is required. The exogenous variables are either continuous or dummies. The dummies are coded in the following way.

- **Gender:** 0 = female, 1 = male
- **Work-status:** 0 = at home (household, retired or unemployed), 1 = not at home (working or education)
- **Car-ownership:** 0 = no car, 1 = at least one car

The endogenous variables are meant to capture individual travel behaviour. As travel behaviour is viewed as a complex hypothetical construct, latent variables are used in the modelling process. Here two factors are specified: mobility level and mobility intensity. All observed endogenous variables that are indicators of the latent factors are continuous. In addition to these variables, the dummy-variable “car ownership” is also defined as an endogenous variable which is identical to its latent variable. The idea behind making car-ownership endogenous is that we do not have to assume a one-way causality between car ownership and travel-behaviour.

The assumed relationships between the exogenous and the endogenous variables should reflect the situation in Upper Austria - in particular the spatial structure and the different community types - as well as the different household structures which occur in the Western part of the world. The typical
socio-demographic variables which would in general be available from exogenous sources are used as an approach to household structure in this model.

It is postulated that the socio-demographic variables have mainly an effect on car-ownership and through car-ownership on the other mobility-variables and that the spatial variables directly influence the mobility-factors. The effects of the variables age, gender, work-status and the spatial variables on the mobility-variables should be positive, the effects of age-square and number of persons on the mobility-variables negative.

Additionally the relationships between the endogenous variables are specified. Car-ownership is assumed to have an effect on both mobility variables, and the mobility level is assumed to have an effect on the mobility intensity. Because of these relationships this model is a recursive model and therefore has convergent effects. Nonetheless it would be possible to add feedback effects.

4.3.2 Results

The initial run of the model showed that most of the postulated effects had the right signs, but that many exogenous variables had very little explanatory power. Therefore variables without significant effects were excluded. Eight exogenous variables remained in the model, four socio-demographic and four spatial variables. The estimated direct effects are shown in the path diagram of Figure 2. There are seven factor loadings (elements of the \( \Lambda \) matrix of equation (1)), three of which are fixed at unity to provide scales for the latent variables. In addition, the model has three causal links between the latent endogenous variables (elements of the \( \mathbf{B} \) matrix of equation (2)) and nine regression effects from the exogenous variables (elements of the \( \mathbf{\Gamma} \) matrix of equation (2)). The total effects of the exogenous variables on the mobility factors (the coefficients of equation (3)) are listed in Table 5.

These results suggest the following interpretation. The socio-demographic variables mainly have an effect on car-ownership and through car-ownership on the mobility variables. The signs correspond to the hypothesis. The influence of age is linear and therefore positive and the influence of age-square is quadratic and therefore negative. The spatial variables have no effect on car-ownership, but influence both mobility-factors, especially the mobility-intensity. In other words, car-ownership is relatively independent of the residential area, but highly dependent to the individual characteristics. The mobility factors depend on both exogenous variable-blocks.

The assumed structure of the endogenous was verified by the modelling process. Car ownership had an effect on both mobility variables and the mobility level had an effect on the mobility intensity. It was not necessary to add non-recursive effects.
The model-fit-indices showed that the data-set fitted the model-structure well.

- Chi-square: $\chi^2=104.08$ with 61 degrees of freedom, $p=0.000046$
- Root mean square residual: $\text{RMR}=0.039$
- Goodness-of-fit index: $\text{GFI}=0.97$
- Adjusted goodness-of-fit-index: $\text{AGFI}=0.95$

### Table 5 Person dataset: Estimated total effects between exogenous and endogenous variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Car-ownership</th>
<th>Mobility level</th>
<th>Mobility intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.68 ***</td>
<td>0.28 ***</td>
<td>0.42 ***</td>
</tr>
<tr>
<td>Age²</td>
<td>-1.41 ***</td>
<td>-0.23 ***</td>
<td>-0.35 ***</td>
</tr>
<tr>
<td>Gender</td>
<td>0.31 ***</td>
<td>0.05 ***</td>
<td>0.08 ***</td>
</tr>
<tr>
<td>Work-status</td>
<td>0.19 ***</td>
<td>0.03 ***</td>
<td>0.18 ***</td>
</tr>
<tr>
<td>Distance to the district-capital</td>
<td></td>
<td></td>
<td>0.11 ***</td>
</tr>
<tr>
<td>Infrastructure- facilities</td>
<td>0.09 **</td>
<td>0.02 **</td>
<td></td>
</tr>
<tr>
<td>Share of commuters</td>
<td></td>
<td></td>
<td>0.11 ***</td>
</tr>
<tr>
<td>Share of agricultural-employment</td>
<td>-0.08 **</td>
<td>-0.01 **</td>
<td></td>
</tr>
</tbody>
</table>

** = significant at 0.05 level  
*** = significant at 0.01 level

### 4.4 Household-model of location type, household structure and mobility

#### 4.4.1 Factor-analysis

The aim of the factor analysis is to reduce the dimensionality of the description of the mobility behaviour of the households, ideally matching the results for the persons. The same analysis was performed to find the mobility factors - the selection of the variables, an explanatory factor-analysis and a confirmatory factor analysis. The variables retained are very similar to the variables in the person-level model – with only one exception: the analysis uses the household-sums of the variables number of trips, number of car-trips, number of journeys, distances travelled, time spent travelling, average speed and day-area. The result of the explanatory factor-analysis was a two factor-model, which was very similar to that used in the person model. The results were confirmed by the confirmatory factor analysis.
4.4.2 Model Specification

Variables describing the household and the spatial variables are used on the exogenous side of the household model. The variables describing the household encompass the household size, the number of drivers, the share of the different age-groups, of women and of workers respectively non-workers on all household members. The spatial variables are the same as in the person model. The endogenous variable-side consists of three latent variables – car-ownership, mobility-level and mobility-intensity which were generated in the factor analysis.

The assumed effects should reflect the circumstances and the spatial situation in Upper Austria. It is postulated that the household-structure has an effect on car-ownership and through car-ownership on the mobility-variables and that the spatial variables only have an effect on the mobility-variables. The B-matrix is assumed to be recursive, that is to say that there are no feedback-effects between the
endogenous variables. Effects only exist from car-ownership to the mobility variables and from mobility-level to mobility-intensity.

4.4.3 Results
Some variables had very little explanatory power. They were therefore excluded from the model. It was noticeable that especially the spatial variables did not have an effect on the mobility variables at the household level. The final model has seven exogenous variables, five describing the household and two describing the spatial structure, plus three endogenous variables (See Table 6).

Table 6 Household dataset: Estimated total effects between exogenous and endogenous variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of cars</th>
<th>Mobility level</th>
<th>Mobility intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of persons</td>
<td>0.12 **</td>
<td>0.35 ***</td>
<td>0.47 ***</td>
</tr>
<tr>
<td>Number of children under six years</td>
<td>0.27 ***</td>
<td>-0.78 ***</td>
<td>-0.97 ***</td>
</tr>
<tr>
<td>Number of drivers</td>
<td>0.69 ***</td>
<td>0.17 ***</td>
<td>0.39 ***</td>
</tr>
<tr>
<td>Share of young people</td>
<td>-0.39 ***</td>
<td>0.69 ***</td>
<td>0.85 ***</td>
</tr>
<tr>
<td>Share of non-workers</td>
<td>-0.08 ***</td>
<td>-0.10 ***</td>
<td>-0.13 ***</td>
</tr>
<tr>
<td>Infrastructure-facilities</td>
<td>-0.05 *</td>
<td></td>
<td>0.00 *</td>
</tr>
<tr>
<td>Distance to the district-capital</td>
<td></td>
<td>0.08 **</td>
<td></td>
</tr>
</tbody>
</table>

* = significant at 0.10 level  
** = significant at 0.05 level  
*** = significant at 0.01 level

In the household model the socio-demographic variables are more important than in the person model. A greater number of socio-demographic variables have a significant explanatory power, and the variables influence number of cars as well as mobility-level directly. The spatial variables play a subordinate role. Mobility-intensity is not well explained through the model. The endogenous side of the model is also different from that of the person-level model. The effect from number of cars to the mobility-intensity was not significant at all, the effect from number of cars to the mobility-level had less explanatory power than in the person-level model.

According to goodness-of-fit indices the results were highly significant.

- Chi-square: $\chi^2=137.74$ with 41 degrees of freedom, $p=0.00$
- Root mean square residual: $RMR=0.030$
- Goodness-of-fit index: $GFI=0.96$
- Adjusted goodness-of-fit-index: $AGFI=0.91$
The paper has highlighted, that the different aspects of mobility: level and intensity are related in different ways to the main background variables. While the spatial location and structure influences mobility intensity and the mobility level, it does not influence car-ownership. The socio-demographic variables influence both, working mostly through car-ownership. At the household level a regression-to-the-mean effect across the household members blurs the influence of the spatial variables.

The results reported here are only those of a first analysis of the data. It is planned to extend the analysis in a number of directions, e.g.:

- Making spatial choices endogenous, in particular to test, if different household types prefer different spatial location
- Testing for differences between different types of region within the Land, between different types of household etc.
- Testing for differences between different types of life-styles and mobility-styles
- Developing models for the different roles in the household (adults versus non-adult, male versus female head)

Clearly, it would be interesting to compare these results with data from different countries, especially the US with its vastly different scale and its different spatial structures. The main emphasis of such an exercise would be to construct matching spatial indicators, in particular for the distances to the different types of locations and centres.

The results should encourage survey designers to enrich their survey data with detailed spatial indicators both for the characteristics of the immediate environment of the respondent, but also for the accessibility to resources at different levels of scale. The merger of GIS and travel-behaviour data should be accelerated.

**Acknowledgements**

The authors wish to thank the provincial government of Upper Austria for making the data available to us, in particular the additional data describing the municipalities of the province. Especially helpful was Mr. H. Kubasta of the Transport Planning Division of the Amt der Oberösterreichischen
Thanks also to Mr. W. Dantine (Fessel-GfK, Vienna) for the purchasing power data at the municipal level.

The ESF/NSF Transatlantic Research Conference on Social Change and Sustainable Transport (Berkeley, 1999) provided the first opportunity to present the ideas of this paper. The authors wish to thank organisers for the opportunity.

The work of the first author is supported by the Fonds für Wissenschaftliche Förderung, Vienna through a research grant.

7 REFERENCES


Golob, T.F. (1997) Structural equation modeling for transportation research, Lecture Notes, Institute of Transportation Studies, University of California, Irvine.


Hanson, S. und G. Pratt (1988) Gender, class and space, Environment and Planning D: Society and Space, 6, 15-35.

Hanson, S. und P. Hanson (1981) The travel-activity patterns of urban residents: Dimensions and relationships to sociodemographic characteristics, Economic Geography, 57 (4) 332-347.


