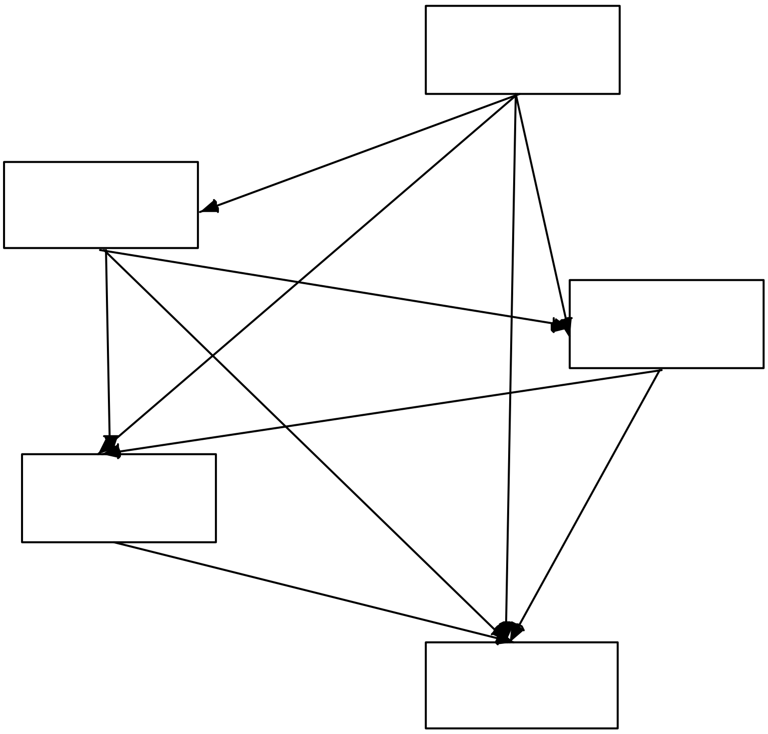

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Interactions of travel behaviour, accessibility and personal characteristics: The case of the Upper Austria Region

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Kurzfassung

Dieser Aufsatz untersucht die Auswirkungen räumlicher Strukturen und persönlicher Merkmale auf das individuelle Verkehrsverhalten, insbesondere auf die Verkehrsmittelwahl, wobei die räumlichen Strukturen unter anderem durch Errreichbarkeitsmasszahlen beschrieben werden. Mit Hilfe von SEM (Structural Equation Modelling) werden Modelle zur Analyse dieser Beziehungen geschätzt. Die Modelle basieren auf der Verkehrserhebung Oberösterreich 1992.

Die Ergebnisse zeigen, dass das Verkehrsverhalten vor allem von den Faktoren Autobesitz, Geschlecht und Art der Tätigkeit beeinflusst wird. Die Anzahl von Einrichtungen, die ein Haushalt fussläufig erreichen kann, ist die wichtigste räumliche Variable. Die Variablen, die die Struktur einer Gemeinde auf Gemeindeebene beschreiben, und die Erreichbarkeitsmasszahlen besitzen im Vergleich dazu eine relativ geringe Erklärungskraft. Gründe hierfür werden aufgezeigt. Obwohl die Ergebnisse den Schluss nahelegen, dass die räumliche Struktur weniger bedeutend für das Verkehrsverhalten ist, geben die Ergebnisse doch wichtige Hinweise für mögliche Planungsalternativen.

Schlagworte

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Abstract

This paper explores the impacts of personal characteristics and the spatial structure on travel behaviour, especially mode choice. The spatial structure is described among other things by accessibility measures. The models are estimated using structural equation modelling (SEM). The models are based on the 1992 Upper Austrian travel survey and the Upper Austrian transport model.

The results highlight the key roles of car ownership, gender and work status in explaining the observed level and intensity of travel. The most important spatial variable is the number of facilities which can be reached by a household. The municipality based variables and the accessibility measures have rather little explanatory power. Reasons for these low explanatory power are considered. Although the findings in this study indicate that the spatial structure is not a decisive determinant of traffic, the results provide useful hints for possible policy alternatives.

Keywords

Upper Austria – structural equation modelling – accessibility – travel behaviour – spatial structure

1. Introduction

The personal travel environment can be described in terms of such dimensions as

- Location
- Access to the central-place system of the region (Christaller, 1933)
- Access to work, shopping and leisure facilities
- Provision of infrastructure facilities
- Public transport supply
- Settlement structure and density
- Topography

but also in terms of certain configurations, such as suburban subdivision, urban blocks or detached house-settlements. As an outcome of this differentiation and of the functional separation in general, the individual environments offer different opportunities with regards to work, shopping or leisure activities.

This paper analyses the interactions between these spatial dimensions, the individual characteristics of the travellers and the observed travel behaviour. Travel behaviour – as understood here – is a complex web of long-term and short-term choices which results in the observed time-space traces. Central elements of this web are car ownership, mode choice, destination choice and the long term location choice. The aim of this paper is to detect spatial factors which determine or at least influence travel behaviour, especially mode choice.

In the literature, there is no consensus about the impact of the spatial structure on travel behaviour. At a very general level, there are two positions: On the one hand studies come to the conclusion that the impact is rather small (e.g. Bagley and Moktharian, 2000; Schmiedel, 1984; Petersen and Schallaböck, 1995). On the other hand, researchers, such as e.g. Holz-Rau (1990), Wiederin (1997) or Sammer, Fallast, Lamminger, Röschel and Schwaniger (1990) find that the modal split and the amount of traffic are dependent on the spatial structure. For a wider review see Bagley, 1999.

The reason for this contradiction is not a basic difference in the approaches used or the assumptions accepted, but rather the selected spatial variables, the selected variables describing travel behaviour and the selected personal variables.

- **Spatial structure** : For example, some investigations concluding space-independence of travel behaviour characterise the spatial structure of areas only by the number of inhabitants – a variable known to have little explanatory power in other investigations, either. According to other studies the accessibility of facilities is one of the most important spatial variables (e.g. Kitamura, Akiyama, Yamamoto and Golob, 2001, Handy and Niemeier, 1997, or Simma, 2000).

- **Travel behaviour**: Generalising across the many studies of travel and the built environment, trip frequencies appear to be primarily a function of socio-economic characteristics of travellers and secondarily a function of the built environment, whereas trip lengths are primarily a function of the built environment and secondarily of socio-economic characteristics (Ewing and Cervero, 2001).

- **Personal variables:** Studies which consider next to the spatial variables also personal variables mostly come to the result that the personal variables are more important than the spatial variables (see Bagley and Moktharian, 2000; Simma 2000). But this result does not answer the question if persons with specific characteristics choose different residential areas. Therefore longitudinal studies which control for changes in the demographic characteristics would be necessary.

The remainder of the paper is organised as follows: First, the study area and the computation of accessibility measures is described followed by a description of the data source used for the analysis. Then the modelling approach – Structural Equation Modelling – is briefly outlined. The core of the paper is the discussion of disaggregate person-level models for two main trip purposes (shopping and working). The results are summarised and interpreted in the discussion.

2. Study area: Upper Austria

The general focus of the study, i.e. the interactions between the spatial structure, personal characteristics and travel behaviour, cannot be investigated without a specific spatial frame. In this case, the Austrian province (*Land*) Oberösterreich was selected for two main reasons.

- **Availability of suitable travel survey data**: The provincial government of Upper Austria conducted a very detailed and quantitatively rich travel survey in 1992, whose data was available for the study. Additional spatial variables for each municipality were added.

- **"Small Austria"**: Upper Austria can be regarded as a scale model of Austria. All regional types which can be found in Austria also can be found in Upper Austria – a big agglomeration from an Austrian perspective, alpine regions, industrial areas and less developed rural regions.

2.1 General description

Upper Austria is one of the nine Austrian provinces. It is located west of Vienna, east of Munich and south of Prague. It has a size of 12.000 km² and about 1.3 million inhabitants. At a very general level Upper Austria can be divided into three parts:

- **Böhmisches Massiv** in the north of Upper Austria
- **Alpenvorland** in the centre of the province
- **Alps** in the south

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 the Czech Republic was closed for the five decades of the Cold War. As a result, the opportunities for industrial development after World War II were limited. The situation is different in the other parts of Upper Austria. The Alpenvorland is the centre of agriculture and industry, including a number of large scale factory complexes in the main cities. Half of the population lives in the Alpenvorland, and 13 of the 15 largest towns are situated here. The Alps, especially the Salzkammergut with its lakes and the skiing areas are dependent on tourism, including second-home ownership.

Upper Austria consists of 15 districts, three cities with district status (Linz, Steyr and Wels) and 445 incorporated municipalities. The respective district capitals are both centres of the local administration, as well as of shopping and industrial location for their area. Linz is the capital of the province and by far its largest city. The 445 municipalities are very different in their spatial, socio-demographic and economic characteristics. The province's overall structure can be characterised as follows (see **Table 1** for a more detailed description of the spatial attributes).

- **Distribution of the inhabitants**: 26% of the municipalities have less than 1.000 inhabitants, 40% of the municipalities have between 1.000 and 2.000 inhabitants and further 18% of the municipalities have between 2.000 and 3.000 inhabitants. Only one municipality has more than 100.000 inhabitants – Linz.

- **Location of the municipalities**: The location of a municipality can be described by two distance-variables – the distance to the relevant district capital and the distance to Linz. For the districts along the border to the Land Salzburg, Salzburg is the relevant main centre for employment and shopping. The distance to Salzburg replaces the distance to Linz for all municipalities, where more residents recorded trips to Salzburg than to Linz.

- **Number of accessible facilities**: The number of accessible facilities is a measure for the supply of activity opportunities for a particular household. It is high if a household can reach a shop, a supermarket, a bank, a post-office, a kindergarten, school, a pharmacy and a doctor in walking-distance (ten minutes). It equals zero, if the household cannot reach any facility within this time. Only three municipalities are without all of these facilities, but in every municipality there are at least some households which cannot reach any facility within a reasonable walking distance.

- **Share of working women**: Between 25 and 50% of the women in a municipality are working. This variable characterises the importance of the traditional nuclear family and the sex-specific division of labour within the municipalities.

- **Commuting**: Because workplaces are mainly concentrated in Linz and the district capitals, people in the small villages often have to commute. In some municipalities more than 80% of the working adults are commuters.

- **Share of farms:** In some communities, the agriculture is still dominant indicating a relatively low state of development. The importance of the agriculture may not only be shown by its share of employees, but also by the share of farms among all buildings. The latter variable is especially interesting because many farms are run by farmers on a part-time basis.

Table 1 Descriptive statistics for the municipalities of Upper Austria

	Mean	Standard deviation	Minimum	Maximum
Number of inhabitants	3 081	10 530	245	208 727
Distance to district capital	17	10	0	59
Distance to Linz (Salzburg)	46	21	0	143
Number of reachable facilities (municipality level)	2.6	1.4	0	7.2
Number of reachable facilities (household)	3.9	3.2	0	8
Share of farms	19	12	0	69
Share of commuters	62	11	15	84
Share of working women	36	4	25	50

These figures are calculated for each single municipality without considering the neighbouring municipalities and their attributes. Statements across municipal borders can be made by applying accessibility-measures.

2.2 Accessibility measures

There is a wide range of possible definitions for the term accessibility, such as ‘the potential of opportunities for interaction’, ‘the ease of spatial interaction’ or ‘the attractiveness of a node in a network taking into account the mass of other nodes and the costs to reach those nodes via the network’ (see Rietveld and Bruinsm, 1998). These definitions raise the questions for whom, for which mode, for which area and for which purpose accessibility should be measured.

In addition to these general definitions, there are several approaches to operationalise accessibility for analysis.

> „Accessibility measures can be loosely organized into three types: cumulative opportunities measures, gravity-based measures, and utility-based measures. All three types incorporate both a transportation element and an activity element, although they differ in the sophistication with which they reflect travel behavior.“ (Handy and Niemeier, 1997, 1177)

Here gravity-based measures are used. In contrast to the cumulative measures these measures weight opportunities, e.g. the size of a facility by impedance, in contrast to the utility-based measures these measures are easier to understand and sufficient for the purpose of this paper. One possible definition is:

$$Acc1_i = \sum_{j=1}^{j=444} A_j * e^{-a * c_{ij}}$$

$Acc1_i$	accessibility of facilities in the municipality *i*
A_j	the opportunities for work and shopping in the municipality *j*
c_{ij}	travel time by a specific mode between municipality *i* and any other municipality *j* (*j* = 1...444)
α	constant reflecting the intensity of travel for a specific purpose

This formula takes into account the supply side, only, and leaves out the demand side. This is especially critical if there is a competition between the users of the supply – as it is the case for employees. Therefore Wang (2001) proposes an extended definition which was originally developed by Shen (1998):

$$Acc2_i = \sum_{j=1}^{j=444} \frac{J_j * d_{ij}^{-b}}{\sum_{k=1}^{k=444} W_k * d_{kj}^{-b}}$$

$Acc2_i$	Accessibility of possible workplaces in the municipality *i*
J_j	number of workplaces in the municipality *j*
d_{ij}	distance between municipality *i* and any other municipality *j* (*j* = 1...444)
d_{kj}	distance between municipality *j* and any other municipality *k* (*k* = 1...444)
β	constant reflecting intensity of travel
W_k	number of employees

The added job proximity index rescales the accessibility of a job location by the job competition intensity of the particular location. This is measured by its proximity to all employees.

These two formulas were taken as the basis for the computation of several accessibility-measures in Upper Austria. The measures differ in the choice of the purpose and the mode, in the consideration of the supply in a specific municipality, in the derivation of the alpha (α) respectively the beta (β) and in the computation-formula.

- **Choice of purpose and mode**: Two different purposes – working and shopping – and two different modes – public transport and private car – were distinguished.

- **Consideration of the supply**: Most studies about accessibilities only consider the supply in the other municipalities, because the interactions of two municipalities are the focus of these studies. In this paper the explanation of the individual travel behaviour is of interest. Therefore it was decided to take into account not only the supply in the other municipalities, but also the supply in the respective municipality, which is decisive for choices concerning travel behaviour.

- **Computation**: The first formula was used for the purposes shopping and work, the second formula only for the purpose work. It was assumed that competition is only important in the job-market.

- **Derivation of the alpha** (see Table 2): The frequency-distributions of the travel times for the two different purposes (work and shopping), for the two different modes (public transport and car) and for two different types of area (main cities – Linz, Wels, Steyr – and remaining area) were used to compute the alphas. The calculation of the alphas was based on the Upper Austrian travel survey. The alphas were computed with the help of a regression analysis (without constant and residual):

  $c_{ij} = \alpha * \log(\text{frequency of time-interval})$

- **Derivation of the beta** (see Table 2): The computation of the beta was based on a gravity model using the loading of the routes (only car) and the distances between the municipalities which came from a transport model developed by the PTV AG (VISUM). The beta was computed with the help of regression analysis (without constant and residual):

$$\log \frac{loading}{population * workplaces} = b * \log(d_{ij})$$

The accessibility measures were computed on the basis of this beta and these alphas, whereby the different area-alphas were combined for each accessibility measure. The descriptive statistics of the accessibility measures are shown in Table 3. Figure 1 shows the distribution of the accessibility measure (β) for work by car, Figure 2 shows the distribution of the accessibility measure for shopping by public transport. The main cities – Linz, Wels, Steyr – and the district capitals can be identified. In the work figure the importance of the axis Linz-Wels as the dominant work area becomes clear, in the shopping figure a second area is additional important – the tourism dominated area around Gmunden.

Table 2 The derivation of the different alphas and the beta for the accessibility measures

Purpose	*Dependent variable*	*Data base*	*Sample size*	*Gradient*	R^2		R^2
Work	Distance	VISUM	7 592	$\beta = 0.4$	0.18		
				Gradient for the main cities		*Gradient for the remaining area*	
Work	Travel time by public transport	Travel survey	48 223	$\alpha_{11} = 0.4$	0.19	$\alpha_{12} = 0.5$	0.25
	Travel time by car	Travel survey	145 875	$\alpha_{21} = 0.5$	0.20	$\alpha_{22} = 0.6$	0.39
Shopping	Travel time by public transport	Travel survey	11 423	$\alpha_{31} = 0.3$	0.08	$\alpha_{32} = 0.4$	0.13
	Travel time by car	Travel survey	103 546	$\alpha_{41} = 0.4$	0.14	$\alpha_{42} = 0.5$	0.26

The different accessibility measures for the two purposes were compared by means of a correlation analysis. Because the correlations were very high within a specific purpose (between 0.95 and 0.99), it was decided to use the second accessibility (β) measure for the purpose working and the accessibility by public transport for the purpose shopping. Additionally the ratio between the accessibility by public transport and the accessibility by car was computed to distinguish areas with and without a relatively good public transport supply.

Table 3 The descriptive statistics of the accessibility measures

Accessibility measure	*Distance or mode*	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*
Acc2 – Work	Distance	1.98	6.08	0.79	119
Acc1 – Work[1]	Public transport	772	6 362	1.21	130 964
	Car	3 406	43 410	8.02	900 507
Acc1 – Shopping[2]	Public transport	1 682	10 146	0.00	154 364
	Car	8 967	80 271	2.73	1 490 929

[1] number of employees
[2] m^2 of sales area

Figure 1 Spatial distribution of the work accessibility measure

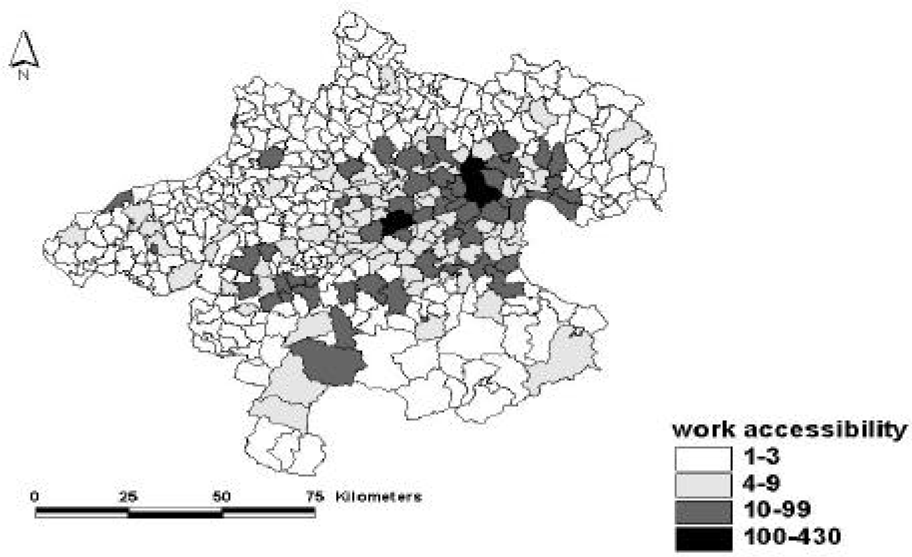
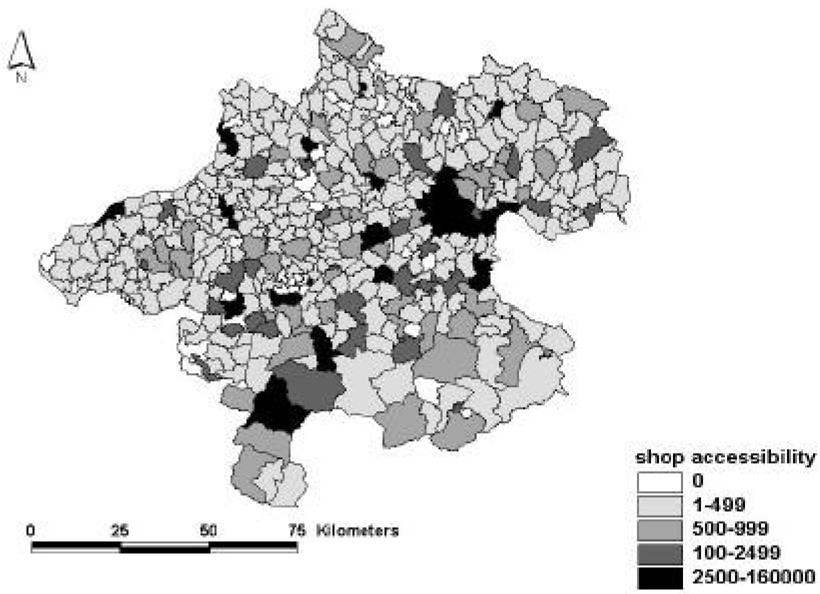


Figure 2	Spatial distribution of the shop accessibility measure



3. The 1992 Upper Austrian Travel Survey

The government of Upper Austria conducted a travel survey during the autumn of 1992 (Amt der Oberösterreichischen Landesregierung, 1995). The survey design and protocol mainly followed the well known example of the German KONTIV survey (Axhausen, 1995). A postal questionnaire was used to collect the information. Responses were expected from persons aged older than five years. Every third household was sampled from the official and mandatory local registers of residents and households. On average, 70% of the households returned the questionnaires.

The result of the 1992 Survey was a database with 898 552 trip records, 328 242 person records and 123 628 household records including information about the household, the household-members older than five years and their travel behaviour on a given weekday. Additional variables were created, mostly aggregates, such as the distances travelled on the reporting day or the number of pupils living in a household. This database was complemented with further municipality-based spatial variables.

For the investigations of this paper, only respondents were considered who were mobile and reported their behaviour fully and correctly (177.760 persons). Non-mobile persons were excluded because only out-of-home activities were of special interest, here. Nonetheless, it is interesting to have a closer look at the distribution of mobile and non-mobile persons (approximately 20% of the sample). To address this question a SEM-model of the likelihood to be mobile on the reporting day was estimated. The probability mainly depends on the socio-demographic variables: age, work-status, gender, and the number of workers in the household. Additionally some spatial variables were found to be significant, e.g. the number of accessible facilities increasing and the share of farms decreasing the likelihood of leaving the house (Simma, 2000).

4. 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 (see Maruyama, 1998, Mueller, 1996, Bollen, 1989). SEM is a confirmatory method which should be guided by prior theories about the structures to be modelled. A SEM-model is a set of simultaneous equations specified by direct links between variables which can be latent. A SEM-model without latent variables has only one component – the 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 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, G and Y 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. The total effects of the exogenous and endogenous variables on the endogenous variables are given by the so-called reduced-form equations:

$$\eta \rightarrow \eta: \quad (I - B)^{-1} - I$$
$$\xi \rightarrow \eta: \quad (I - B)^{-1}\Gamma$$

The estimation of a SEM-model can be accomplished in several ways. The methods are based on matching model-replicated variance-covariances with the observed variance-covariances. Instead of covariances also correlations can be used. Here the Maximum Likelihood-method is used in conjunction with a correlation matrix, because the Maximum Likelihood-method provides fast efficient estimators and is relatively robust against violations of the multivariate normality assumption (Maruyama, 1998, 281).

5. Analysis

The models analysed during the study possess the following basic form. They consist of the variables describing the spatial structure (municipality-based variables and accessibility measures) and the person variables on the exogenous side, and travel behaviour on the endogenous side. Two disaggregate models based on the observed persons and their behaviour are described here. The difference between the two models is that one contains only work trips, the other only shopping trips. The models are restricted to a specific purpose, because the explanation of mode choice is the main focus.

5.1 Hypotheses

SEM is a confirmatory method. Therefore hypotheses about the model structure must guide the modelling process. The following assumptions about possible impacts on the endogenous variables are posed.

- **Car-ownership**: It is assumed that car-ownership is mainly influenced by personal characteristics.

- **Mode choice**: It is assumed that mode choice is influenced by the commitment to a mode and by the travel situation expressed by the accessibility measures.
- **Travelled distances**: It is assumed that a good supply of activity opportunities in the home-municipality is connected with a locally orientated behaviour and low average distances. Contrary – inhabitants in municipalities with nearly no work-places and without shops (there are several such municipalities in Upper Austria) are forced to travel long distances, especially if the respective district capital is far away.

5.2 Structure of the model

The variables included in the models were selected by theoretical considerations. Because the attention of this paper is directed towards the impact of the spatial structure, only a few socio-demographic variables were used – namely gender, work-status and the number of pupils respectively infants in the household. The spatial variables have already been introduced in chapter 2. Travel behaviour is described by car-ownership, by the number of trips with different means of transport (walk, public transport, car) and by the travelled distances on the reported day. Car-ownership represents the mobility-chances, the number of trips the mobility-level as well as mode choice and the travelled distance the mobility-intensity.

Table 4 shows the postulated relationships between the selected variables, whereby the β's describe the existence of a relationship between the endogenous variables, the γ's the existence of a relationship between the exogenous and the endogenous variables. The free parameters represented by the β's and γ's are chosen based on the hypotheses and on earlier results in related studies (e.g. Simma, 2000). The assumptions within the Γ-matrix are first best guesses which are open for modifications guided by the first results and further considerations.

5% random samples of all mobile persons older than 17 with shopping respectively working trips were used as data base for the models. The sample for the purpose work had a size of 4.418 observations, the sample for the purpose shopping a size of 3.007 observations. An age-limit of 18 years was introduced because travellers under 18 do not have access to a car. The models including these relationships were estimated based on a correlation-matrix with the Maximum likelihood-method. The initial models were then refined within the Γ-matrx.

Table 4 Initially postulated direct effects of the two models

From	To: Car-ownership	Walk trips	Public transport trips	Car trips	Distance travelled
Endogenous					
Car-ownership		-β	-β	β	β
Walk trips			-β	-β	-β
Public transport trips				-β	β
Car trips					β
Exogenous: Person and household					
Employed	γ				
Male	γ				
Number of infants	-γ				
Number of pupils	-γ				
Number of reachable facilities	-γ				
Exogenous: Spatial structure					
Distance to district capital	γ				γ
Share of farms	γ				-γ
Share of working women	γ				
Share of commuters	γ				γ
Size of shop base	-γ	γ			-γ
Accessibility measure	γ		-γ	γ	
Pt-Supply/car-supply			γ	-γ	

5.3 Results

Models with clearly improved and relatively good fits (see Table 6) were the result of a modification-process which was based on theoretical considerations and the first model results (t-values and modification indices). The relatively high chi²-values and the low probabilities are not an indication for model-misspecification, but they are caused by the relatively big sample-sizes (chi²-value dependent on sample-size).

The fit of the work model is slightly better than the fit of the shopping model, but the multiple correlation coefficients of the endogenous variable (comparable to the R^2s of a regression analysis) are better in the shopping model (see Table 5 and Table 7). In both models, car-ownership can be explained best, whereas the usage of public transport is the worst explained variable. The relatively low R^2s can be explained by the fact that only few exogenous variables were considered and variables with high explanatory power, but little theoretical power like licence-ownership were not; The differences between the R^2s within a model (structural equations – reduced form) can be explained by the fact that the reduced form only considers the influence of the exogenous variables.

The total effects of the B-matrix and the G-matrix are shown in the Table 5 and Table 7. Because the models were very similar, it was possible to generate generalised path-diagrams with the direct effects – one with the effects between the exogenous and endogenous variables (see Figure 3), one with the effects between the endogenous variables (see Figure 4). The parameters of the B-matrix corresponded with the model-assumptions. Many postulated paths had to be changed within the G-matrix – especially the relationships between the variables describing the spatial structure and travel behaviour were wrongly postulated.

Table 5 Total effects of the work model – significant at the 0.001 level

From	**To** Car-ownership	Walk trips	Public transport trips	Car trips	Distance travelled
Car-ownership		-0.24	-0.36	0.35	0.14
Walk trips			-0.20	-0.26	-0.16
Public transport trips				-0.34	0.12
Car trips					0.12
Male	0.59	-0.33	-0.01**	0.30	0.27
Number of infants	-0.05	0.07	-0.03**	-0.02*	-0.02
Number of pupils	-0.05	0.01	0.02	-0.02	-0.01
Number of reachable facilities	-0.09	0.21		-0.08	-0.04
Distance to district capital			0.05	-0.02	0.10
Share of farms					0.09
Share of working women					-0.05
Share of commuters		-0.12	0.02	0.03	0.02
Number of workplaces					
Accessibility measure	-0.04*	-0.11	0.17	-0.03*	0.03
R^2s for structural equations	0.36	0.21	0.13	0.34	0.18
R^2s for reduced form	0.36	0.17	0.02	0.11	0.13

* only significant at the 0.01 level ** only significant at the 0.1 level

Table 6 Goodness-of-fit of the two modified models

	Goodness-of-fit of work model	Goodness-of-fit of shopping model
Sample-size	4 418	3 007
Degrees of freedom	41	53
Chi²-value	81 (P = 0.00)	102 (P = 0.00)
Goodness-of-Fit Index (GFI)[1]	1.00	1.00
Normed Fit Index (NFI)[2]	1.00	1.00
Critical N (CN)[3]	3 544	2 362

[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 7 Total effects of the shopping model – significant at the 0.001 level

From	**To** Car-ownership	Walk trips	Public transport trips	Car trips	Distance travelled
Car-ownership		-0.17	-0.26	0.38	0.11
Walk trips			-0.09	-0.43	-0.17
Public transport trips				-0.23	0.02*
Car trips					0.18
Male	0.61	-0.22	-0.03*	0.17	0.21
Full-time employed	0.25	-0.13	-0.06	0.03	0.25
Part-time employed	0.09	-0.02	-0.02	0.03	0.01
Number of infants					
Number of pupils					
Number of reachable facilities	-0.07	0.32	-0.01	-0.22	-0.07
Distance to district capital					0.09
Share of farms					
Share of working women					
Share of commuters				-0.05	-0.01
Size of shop base					
Accessibility by car			0.25	-0.06	0.00*
Pt-Supply/car-supply				-0.06	-0.01
R^2s for structural equations	0.52	0.20	0.10	0.34	0.20
R^2s for reduced form	0.52	0.19	0.07	0.08	0.15

* only significant at the 0.01 level

Figure 3 Generalised direct effects between the exogenous and endogenous variables

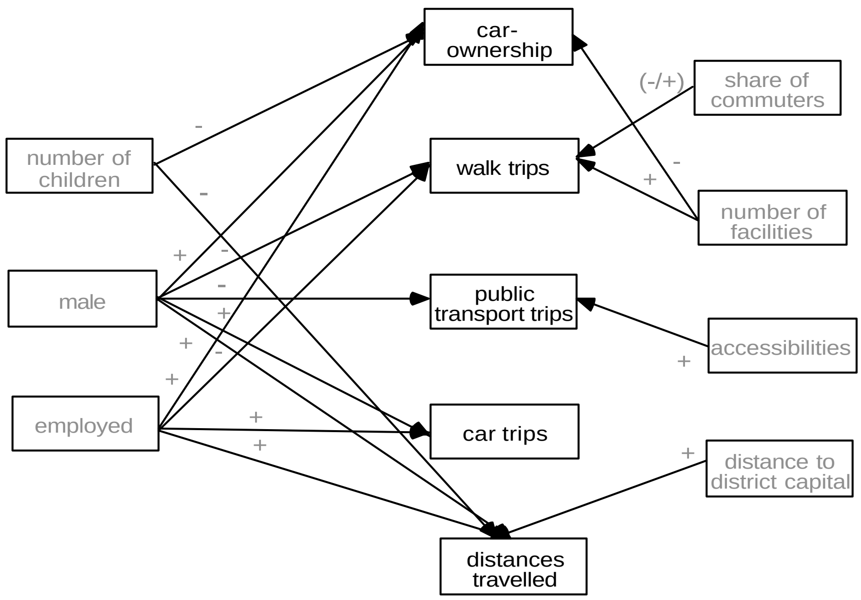
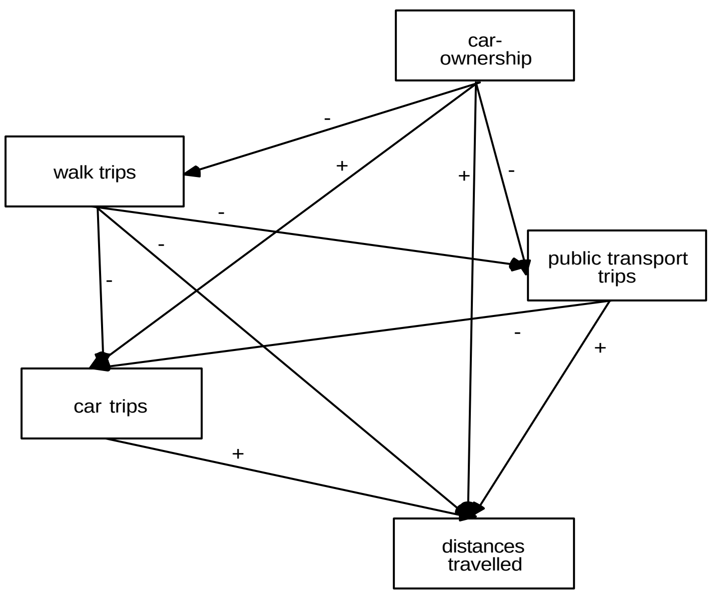


Figure 4 Generalised direct effects between the endogenous variables



5.4 Interpretation of results

The B-matrices of both models show that car-ownership strongly influences mode choice. This choice in turn has an impact on the travelled distances. Car-owners make fewer trips on foot respectively by public transport and more trips by car. The consequence of those car-trips are comparatively long distances. There are substitutive relationships between the number of trips with a specific mode.

The G-matrix conveys the relationships between the exogenous and endogenous variables which can be described and interpreted as follows. Generally it can be stated that the personal factors have more explanatory power than the spatial factors.

- **Gender**: Gender is a variable with high explanatory power in both models. Men usually own more often a car, make more trips by car and travel longer distances than women.

- **Work status**: This variable was only included in the shopping model and not in the work model, because work trips are normally made by employees only. The effects of being employed on travel behaviour are similar to the effects of being male. People who are not employed use public transport more often than employees, but employees travel longer distances by public transport.

- **Number of children**: The impact of children on the travel behaviour is rather small or non-existent.

- **Number of accessible facilities**: This variable shows the importance of the surrounding residential area. If a household can reach a range of facilities within walking distance, the probability of a locally orientated behaviour with low distances and a high number of walk trips increases.

- **Distance to the district capital**: If a municipality is far away from the respective district capital, the respondents have to travel longer distances – in the case of the work model public transport is comparatively often used.

- **Share of commuters**: There is an interesting difference between the models. The share of commuters has an positive impact on the trips made by car and the travelled distances in the work model and a negative impact on the trips made by car and the travelled distances in the shopping model.

- **Accessibility measures**: A good accessibility of work places respectively shopping facilties is connected with an increase of trips made by public transport and a decrease of trips made by car or on foot (only in the work model).

6. Discussion

The results of the models can be used to assess the hypotheses. Most of them were confirmed.

- **Car-ownership**: Car-ownership is mainly depending on personal characteristics – especially on gender and work-status. Additionally the surrounding residential area plays a decisive role.

- **Mode choice**: Car-ownership strongly influences all other endogenous variables, whereby car-ownership has a positive impact on the trips made by car and negative impacts on the trips made by the other modes. Unfortunately, it was not possible to investigate the influence of season ticket-ownership on mode choice because of data restrictions. Other investigations have shown that it is important to include both commitment-variables (see Axhausen, Simma and Golob, 2000 or Simma and Axhausen, 2001).

  Additionally, mode choice is influenced by the personal variables. The travel situation expressed by the accessibility measures is rather unimportant. A good supply tends to increase the use of public transport

- **Travelled distances**: This hypothesis is true for the variable describing the number of reachable facilities, but false for the accessibility measures. A possible explanation is that especially the surrounding residential area is important for travel behaviour.

Additional findings could be drawn from these models.

- **Similarities between the models**: One interesting finding was that mode choice for the two different purposes is influenced by similar variables to a similar extent. This means that the factors influencing mode choice are relatively independent of the purpose, but there exist differences in the absolute values.

- **Importance of personal characteristics**: Personal attributes have much more and stronger effects on travel behaviour than the chosen spatial variables. This finding indicates that travel behaviour is a very individual matter – at least in a cross-sectional model.

- **Effects of the accessibility measures**: A high accessibility of work places respectively shops only promotes the usage of public transport. This finding can be explained by the fact that especially the larger cities with a great supply have a good public transport system.

7. Conclusions and recommendations

Both models have highlighted the importance of the personal characteristics of the travellers for their travel behaviour compared to the moderate effects of the spatial structure. Although the statistical results presented in this study tend to indicate that accessibility affects travel only marginally, generalising this conclusion may not be warranted for two reasons. First, the historical development is not considered. Second, the municipality-based indices mostly adopted here may not be the adequate measures for the investigation of the relationship between the spatial structure and travel behaviour.

Nevertheless, the results give hints how travel behaviour could be directed in a more environmentally friendly direction by changes in the spatial structure. The following policy variables could be identified:

- number of reachable facilities
- distance to the district capital
- share of commuters respectively the accessibility of workplaces

Increasing the first and reducing the second and third variable would increase the number of trips on foot or by public transport and reduce the distances travelled.

At the moment local communities do not have specific policies to encourage the presence of shopping facilities, but given the general trend to centralisation it might be worthwhile for them to subsidise some of the costs of these facilities to retain them not only for transport, but also for community building reasons. Additionally the choice of plots for public facilities like school or kindergarten should be considered carefully.

While it is not easily possible to increase the number of district capitals for historical and budgetary reasons, it is possible to bring some of the functionality of such centres closer to the users though electronic means, in particular certain types of administrative visits, but also some services, such as banking, insurance etc. The positive effect of the distance to the district capital on the trips made by public transport indicates that it could be fruitful to promote the public transport connections between the district capitals and the municipalities.

The third obvious policy variable is rather difficult to address because industrial structure is mostly outside of the control of local and regional government. In addition, the urban-rural nexus of commuting helps to maintain the liveability of many peripheral communities in Upper Austria and elsewhere. The inherited house, the role as part-time farmer or vintner, the social networks, for example, keep people in place, which is the currently desired outcome further supported through policies encouraging commuting: tax deductability of commuting expenses, low cost public transport season tickets, maintenance of services on unprofitable branch lines etc. In spite of these policies and ties, peripheral communities continue to loose population for the suburban areas around the urban centres. The successful tourism areas are an exception to this trend.

Current policies are helping to maintain the status-quo, but they seem unable to reverse the trends or to give them new directions. Initiatives to promote mixed land-use at a fine resolution, to provide suitable and flexible public transport, if necessary demand-led, to offer discounted season-tickets, to mobilise already developed building land through taxation of unused building rights etc. can reduce the impacts of car dependency, but they cannot avoid them. Radical policies, such as consistent marginal (social) cost pricing of infrastructure services or tight urban growth boundaries, might be more effective, but have not been tried in Austria or elsewhere.

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