Far, far away – trip distances and mode choice in the context of residential self-selection and the built environment

Joachim Scheiner

PD Dr Joachim Scheiner, Technische Universität Dortmund, Faculty of Spatial Planning, Department of Transport Planning, 44227 Dortmund, Germany

phone ++49-231-755-4822, fax ++49-231-755-2269, e-mail joachim.scheiner@tu-dortmund.de

This is a author produced version of the following book chapter:

Scheiner, Joachim (2010): Far, far away – trip distances and mode choice in the context of residential self-selection and the built environment. Geller, Paul S. (ed.): Built Environment: Design, Management and Applications. New York: Nova Science Publishers. pp. 215-237.

Please reference this paper as shown above.

key words: trip distance, travel mode choice, residential location choice, residential self-selection, structural equation modelling

abstract

Access to activity opportunities depends, among other factors, on land-use mix and density at an individual's place of residence. Travel mode choice varies considerably depending on distances to facilities as well as on realised trip distances. This chapter presents findings from an empirical study conducted in the region of Cologne. Standardised data collected from 2,000 residents are used for an in-depth analysis of the interrelation between trip distances and mode choice. Based on structural equation modelling, life situation (sociodemographics), car availability, location preferences and the built environment are taken into account. In addition, lifestyles receive consideration in the study of leisure trips. The findings show the impact life situation, car availability and the built environment have both on trip distances and mode choice, as well as the interrelation between the latter two. What is more, significant effects of lifestyles and residential self-selection on travel behaviour are found. The chapter closes with discussion of consequences for urban planning, making a case for more balanced, mixed-use patterns in urban development.

1 Introduction

Recent years have seen considerable scholarly interest in the effects the built environment has on travel behaviour. Transport researchers have highlighted the importance of a number of key attributes of the built environment in this context: density, land-use, distance to the nearest centre, and the connectivity of transport networks (see overviews in Boarnet and Crane, 2001; Stead and Marshall, 2001; Cervero, 2006). The spatial determinants of travel have been summarised using keywords such as the 'three D's' – density, diversity, design (Cervero, 2002).

The built environment has a particularly strong impact on two elements of travel behaviour: trip distances and travel mode choice. A dense, mixed-use urban structure allows residents to make short trips due to the proximity of housing to other activities. As a consequence, a comparatively large proportion of the trips may be undertaken by non-motorised transport modes (NMT, i.e. by bicycle or on foot). The impact of the built environment on mode choice is thus in this case indirect: mode choice depends on trip distance, and trip distance depends on distance to facilities (i.e. on the least required distance). These interrelations have been found in numerous empirical studies (see for overviews and empirical studies Cervero, 2002; Schwanen et al., 2004; Guo and Chen, 2007 and other papers in the same issue).

However, there is also a direct interrelation between the built environment and travel mode choice. As well as NMT, public transport (PT) accounts for a relatively high share of trips in dense, mixed-use structures for two reasons. Firstly, high population density and/or activity density often goes along with restrictions for the private car, such as lack of parking space, high traffic density, and low travel speed, and therefore reduces the comparative disadvantage of PT against the private vehicle (in some cases even producing the opposite effect). Secondly, the high demand density encourages an attractive PT system.

The interrelations between the built environment and trip distances as well as between the built environment and travel mode choice have been investigated in detail in numerous studies. However, the same is not true for the interrelations between trip distances and mode choice. This chapter aims to shed light on this issue by simultaneously studying trip distances and mode choice for maintenance trips, leisure trips, and all trips a person makes put together. Life situation variables, the built environment, accessibility preferences and car availability are taken into account as determinants. Lifestyles are considered additionally when leisure trips are studied. The following section provides a brief literature overview, followed by some hypotheses. The data and methodology employed are introduced subsequently, followed by the results. The chapter concludes with discussion of consequences for urban planning and research.

2 Trip distances, mode choice and the built environment: the state of the research

2.1 Travel mode choice and distance to the nearest facility

In contrast to realised trip distances, minimum necessary distances to nearest facilities such as shopping centres, leisure opportunities or schools can be directly affected by spatial planning concepts. Available research fairly consistently suggests that the provision of activity facilities in the neighbourhood may result in more walking and/or bicycle use and thus indeed affects mode choice (see references cited above). However, there is no common understanding of the details of these interrelations, e.g. with respect to distance thresholds.

One reason for this may be that many studies work with rather generalised distance categories. For instance, the German state North Rhine-Westphalia implemented a programme intended to promote rail-oriented housing schemes. This programme was largely based on the observation that car use among those living in a catchment area of one kilometre around a railway station was slightly lower than outside this radius (ILS, 1999). However, the possible existence of a decline in car use within the 1-km-radius has not been explored. Such a decline is highly likely. E.g., based on German data Scheiner (2009c) found that 94 percent of trips shorter than 200 m are undertaken on foot, whereas in the distance band 800-1,000 m walking holds a share of no more than 38 percent.

Holz-Rau (1991) examined shopping trips in a Berlin neighbourhood on a micro-spatial basis. His results show that car use for shopping increases rapidly among motorised households from a distance of 325 m or more to the nearest grocery store. For distances exceeding 670 m motorised households hardly use any transport modes other than the car. Individuals without access to a car tend to switch to the bicycle when the distance exceeds 325 m.

Holz-Rau et al. (1999) found considerably longer, but less frequent shopping trips in poorly served (mono-functional) residential neighbourhoods, as compared to mixed-use neighbourhoods with good shopping facilities. The proportion of car trips among all shopping trips was markedly higher in mono-functional neighbourhoods, although in absolute terms the differences were less pronounced due to the lower trip frequency. Owing to the longer distances in the mono-functional neighbourhoods, the car is in any case used much more for shopping.

For the U.S., Handy & Clifton (2001) found that proximity to shopping facilities did not seem to reduce car travel. Yet, in another study distance to the nearest facility turned out to be an important factor influencing the frequency of shopping trips on foot (Cao et al., 2006).

The same study, however, shows that the subjective importance individuals assign to the accessibility of shopping facilities increases the likelihood of walking as well, suggesting that people sort themselves into the environments they prefer. For shopping trips the effect of self-selection is stronger than for strolling (Cao et al., 2006). Scheiner and Holz-Rau (2007) carried out a similar study on the basis of structural equation modelling. The results confirm the important effect of residential self-selection on travel mode choice, even when objective attributes of the neighbourhood are being controlled for. These papers contribute to the recent debate about residential self-selection. They suggest that the conditions of the built environment, which are reflected in distances to certain destinations, should not be regarded as a fixed pre-condition of life (see also Bohte et al., 2009, Cao et al., 2009).

To sum up, results from existing studies are not entirely consistent although there is general agreement that proximity to facilities is associated with more NMT and less motorised travel (particularly, less car travel). It should also be noted that not all trip purposes are equally suited for use in such studies because for some types of activity there is a lack of clarity about the extent of the appropriateness of opportunities for certain requirements. It is usual to assume that a shopping centre or a grocery store suits the needs of all. However, the same assumption may not be valid for specialised retail branches, and certainly cannot be made with relation to the appropriateness of the nearest workplace or of a particular location for a stroll.

2.2 Travel mode choice and realised distance

Transport planning commonly assumes that walking is the fastest travel mode for distances under one kilometre, the bicycle for distances between one and six kilometres, and the car for distances over six kilometres; access and egress time being taken into consideration (Zumkeller and Nakott, 1988).

The effect of realised trip distances on mode choice is, if at all, mostly examined in rather coarsely meshed distance categories. The lowest category typically includes trips of up to about one to two kilometres, or one mile (Kloas and Kunert, 1993; Bahrenberg, 1997; Schlossberg et al., 2006; DfT, 2006). Working with these relatively broad categories may mask considerable variation within the categories and (in longitudinal studies) important shifts over time. Exceptions include Vågane (2007) who provides differentiated analyses for Norway, and Scheiner (2009c) who does the same for Germany.

Distance thresholds vary between regions and countries (Badland and Schofield, 2005, p. 186). This may have cultural, economic, topographic or climatic reasons. In many highly motorised countries the car is the preferred mode of transport even for short trips, while in developing countries very long distances are covered on foot. Among the more developed countries there are considerable differences as well. In the UK 76 percent of trips up to one mile (1.6 km) are undertaken on foot (DfT, 2006, p. 15-16). In Germany the equivalent figure is only 60 percent for trips up to one kilometre in length (calculated from DIW/INFAS, 2003), and in Norway it is 53 percent (Vågane, 2007). Methodological differences may also play a role here.

There are also marked international differences in bicycle use. While the proportion of short trips undertaken on foot is lower in Germany than in the UK, this is largely compensated by the bicycle. Generally, the bicycle is widely used in the Netherlands and in Denmark, in Germany less so, in the UK, France and the US even less so (EU, 2000; Giuliano and Dargay, 2006; Gatersleben and Appleton, 2007). Among other factors this has to do with the bicycle being seen as a serious transport mode. There are also clear inter-urban differences within individual countries which seem to suggest the existence of 'bicycle cultures', but may also indicate different socio-demographic compositions. For instance, in the German university towns of Freiburg, Munster and Erlangen the bicycle plays a much more significant role in daily travel than in most other German cities (BMVBW, 2002). However, I am not aware of any comparisons that take trip length categories into consideration.

To the best of my knowledge, there are hardly any spatially differentiated studies on this topic concerning trends over time. The results found by Scheiner (2006, 2009c) point towards an increasing divide in travel mode choice between cities and smaller communities: in cities, car use increases more slowly and from a lower level than in smaller communities.

The decision in favour of a certain travel mode obviously does not only depend on trip distance. Important factors affecting the propensity to walk are individual motivation, available resources (transport means, financial resources, health), the attractiveness of the route, and social roles and needs, which are reflected in employment, gender and age, among other variables. For instance, adolescents cover considerable distances to school on foot (Schlossberg et al., 2006). The socio-demographic factors may be summarised under the term life situation (Scheiner and Holz-Rau, 2007)[1]. The availability of a car plays a central role in this respect, because the speed that can be achieved by car is a precondition for long trips under a restricted time budget. Car availability consequently turns out to be an important pre-decision for an individual's travel behaviour, which has a notable impact on his or her activity spaces, trip distances and travel mode choice (Simma and Axhausen, 2001; Scheiner and Holz-Rau, 2007).

In addition, trip purpose has an important influence on the propensity to walk. This is self-evident with respect to trips with an intrinsic motivation to walk, such as strolling or hiking. The requirement of carrying (shopping) goods impacts or even determines the chance of walking. In addition, the high economic cost of travel time (job trips, business trips) may limit the acceptability of slow travel.

2.3 Hypotheses and study approach

Travel behaviour is always based on a number of interrelated decisions an individual has to make, including decisions about the activity, an activity location (and the distance he or she has to cover to get there), a travel mode, and a date and time of activity/travel. What is more, travel behaviour is characterised by considerable social interdependencies, e.g. when it comes to decisions concerning shared trips and activities. To put it simply, one has to decide: what, where, when, how, and with whom? This framework does not assume that transport participants actually make deliberate decisions on a day-by-day basis. Employees clearly do not decide on the location of their workplaces every day. However, they all have made a decision about their particular workplace location at a certain point in time in the past. It thus seems obvious to study various elements of travel behaviour simultaneously rather than separately.

This said, it may not sound particularly spectacular to say that travel mode choice corresponds closely to travel distances. Nevertheless, the interrelation between realised or necessary trip lengths on the one hand and travel mode choice on the other hand has not yet been conclusively determined.

Before examining this interrelation, it is important to note that there is no clear causal relationship between trip length and travel mode choice from a theoretical point of view. It seems plausible that increasing trip lengths may cause a shift towards the car. However, the causality might also be the other way round. Given a travel time budget which is by and large stable over time, the increase in car use may allow for longer trips. The study by Ye et al. (2007) may serve to support the former direction of causality. They model the interrelation between trip chain complexity and transport mode, and conclude that models in which chain complexity affects mode choice outperform models which assume reverse causality. This is true both for work trips and non-work trips. Although trip chain complexity and trip length are certainly two different things, this result suggests that mode choice might be an outcome of what somebody has to do and where he or she has to do it.

This interpretation is further supported by the findings of Lanzendorf (2001, p. 205ff) on the sequence of decisions about activities, activity places and travel modes in leisure travel. His findings indicate that in the overwhelming majority of cases people first decide on the destination, before they decide on the travel mode. Taken together, these findings might be interpreted as an indication that people decide on a certain destination (and thus, implicitly, on a certain trip length) and the mode choice decision tends to be 'at the end of the pipeline', even if there are certainly trips for which it is the other way round, e.g. trips to the countryside without a predetermined destination. Hence, in this chapter mode choice is treated as dependent on travel distance.

Explanatory variables considered for modelling include various measures of life situation, location preferences, the built environment, and the availability of a car. For the study of leisure trips, lifestyles are taken into account as well. For work and maintenance trips lifestyles have been

---

[1] In transport studies these factors are usually denominated as socio-demographics, though this is just a formal term that does not say anything about the reasons why the underlying variables should influence travel behaviour, whereas life situation explicitly points to an individual's personal circumstances (e.g. social roles, social contact) relevant for his or her travel.

found to be of minor or no relevance in extensive analyses of the same data (see Scheiner, 2009b, 2010). All variables represent standard knowledge and/or more recent developments in transport research, as derived from the literature review above. The analysis is stratified by trip purpose. The general model structure used is shown in Figure 1, and more theoretical considerations are outlined elsewhere (Scheiner and Holz-Rau, 2007, Scheiner, 2009b, 2009d).

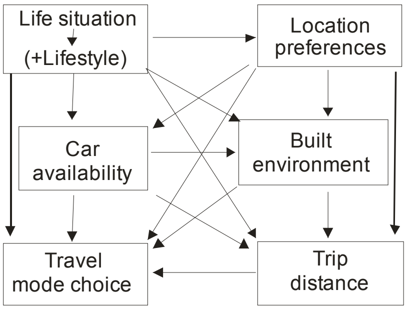

Figure 1: Model structure

Source: own concept

3 Methodology

3.1 Data used

The data used in this chapter were collected in a standardised, cross-sectional household survey within the framework of the project StadtLeben[2]. The survey was undertaken in ten study areas in the region of Cologne in 2002 and 2003. 2,691 inhabitants took part in extensive face-to-face interviews about their travel behaviour, housing mobility, life situation, lifestyle, location preferences and residential satisfaction. The response rate was 27 percent of those asked. This appears to be a reasonable rate, given the high respondent burden (the average interview duration was 58 minutes).

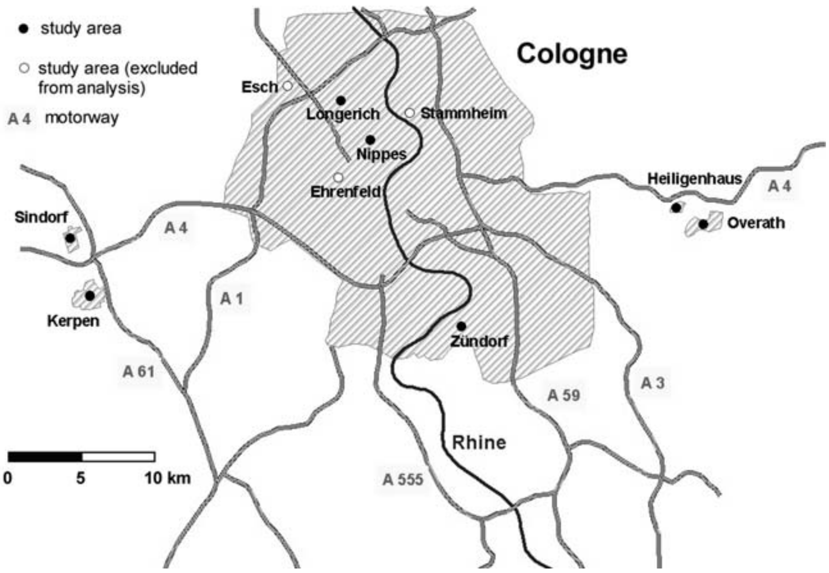

Figure 2: Location of the study areas in the region of Cologne

Source: own concept of project group StadtLeben

[2] "StadtLeben – Integrated approach to lifestyles, residential milieux, space and time for a sustainable concept of mobility and cities" (2001-2005). Project partners: RWTH Aachen, Institute for Urban and Transport Planning (coordination); FU Berlin, Institute of Geographical Sciences, Department of Urban Research; Ruhr-University of Bochum, Department of Cognition and Environmental Psychology; Dortmund University of Technology, Department of Transport Planning (see http://www.isb.rwth-aachen.de/stadtleben/).

Due to reasons of project flow some of the relevant variables were recorded using different questionnaires in some of the study areas. The analysis is therefore based on seven study areas only, all of which were surveyed in 2003. Depending on the model, the resulting net samples have a value of about n=2,000. The working samples have a size of about n=1,000 due to the split of the sample (see below). The sampling procedure was based on random route. The sample is representative for the general population aged 16 and older in the study areas.

The five types of area are each represented by two study areas (Figure 1, study areas excluded from analysis in squared brackets): high density inner-city quarters of the 19th century ('Wilhelminian style': Nippes, [Ehrenfeld]); medium density neighbourhoods dating from the 1960s ('modern functionalism') with flats in three- or four-story row houses (Longerich, [Stammheim]); former villages located at the periphery of Cologne which since the 1950s have experienced ongoing expansion with single-family row houses or (semi-) detached single occupancy houses (Zündorf, [Esch]); small town centres in the suburban periphery of Cologne (Kerpen-Stadt, Overath-Stadt); and suburban neighbourhoods with detached single occupancy houses (Kerpen-Sindorf, Overath-Heiligenhaus). The four suburban neighbourhoods are all about 30 km away from Cologne.

As each of the two areas belonging to one type is clearly different, the areas are very varied with regard to spatial location, transport infrastructure, central place facilities and socio-demographic structure. Nonetheless it has to be noted that spatially or socially 'extreme' areas were not purposely targeted. There are no obvious high income areas, and only one distinct low income area (Stammheim; excluded from the analysis).

Heiligenhaus represents the most peripheral neighbourhood. There are no retail facilities or services worth mentioning, and PT is limited to an irregular bus service. However, one has to keep in mind that even this area is located within the outskirts of the city of Cologne. It is thus not particularly remote when seen in the context of the spatial variety of the whole of Germany.

The region of Cologne is a polycentric agglomeration with the clearly dominating centre of Cologne. The population trend is slightly positive, and the housing market is largely supply dominated. The opportunities for different population groups as defined by lifestyle or life situation to realise a specific location choice that meets their needs and wishes are thus limited. This is an important condition for the interpretation of the results.

3.2 Variables

Travel mode choice and trip distances are studied in this chapter in the context of life situation, lifestyle, location preferences, and car availability. These concepts can be specified with a low or high degree of complexity. Because of the many interdependencies, an attempt is made to keep the degree of complexity in the model components as low as possible. This is achieved by using dimensions of lifestyle, preferences and the built environment that seem relevant for mode choice and/or trip distances from a theoretical point of view, rather than including all available dimensions. The following components are used:

Life situation was measured by a set of seven observed variables, namely gender, age, number of children in the household, total household size, education level, per capita household income (with children counting as 0.8 persons) and employment. Some transformations of the ordinal-level variables education level and employment were undertaken in order to achieve metric variables. Education level was transformed into an estimated number of years in school. Employment (full-time, part-time, marginal, none) was similarly transformed into an estimated number of working hours per week.

In extensive attempts, a measurement model of life situation was developed in which household size, number of children, age and income were allowed to load on one latent variable, which was called 'family'. It should be noted that this variable refers to individuals living in a certain household type (family) rather than to households as units, as all analyses are based on individuals. Education level, employment, income and age are allowed to load on a second latent variable called 'social status'. Gender operates as an exogenous variable and rendering its binary scale unproblematic.

Lifestyles are presented in the data by four domains: leisure preferences, values and life aims, aesthetic taste, and frequency of social contacts. These were represented by a total of 34 items measured by five-point Likert-type answer scales. The scales were constructed so that they came as close to an interval scale as possible (see Rohrmann, 1978). In order to keep the models as simple as possible, only a few items are selected to represent lifestyle. What is more, the use of lifestyles is limited to the leisure trip models, as noted above. As some respondents are more inclined than others to generally agree with items, the answers were normed by subtracting a respondent's mean answer to all the items from the respective value. This results in normalised variables that take any individual tendency to generally agree or disagree into account.

Lifestyle is represented in the leisure models by the strength of out-of-home leisure preferences, a latent variable based on the items 'going to the movies/theatre/concerts' and 'attending training/education courses'. This latent variable is assumed to be related to a large variety of out-of-home leisure needs, relatively long trips and, thus, low shares of NMT, but high shares of motorised modes. In earlier attempts, the 'familial leisure preference' was used as a second lifestyle dimension. This was based on the two items 'play with children' and 'engage with my family'. However, it was found to be of minor importance for mode choice as well as trip distances. It was therefore excluded from the models for the sake of parsimony.

Individual *location preferences* were measured using subjective importance ratings of neighbourhood and location attributes, again measured by five-point Likert-type answer scales. Information was gathered as part of the survey by asking 'How important are the following features of the neighbourhood for your personal decision in favour of a certain place of residence?' The attributes were then listed, for instance 'accessibility of the city centre' or 'access to public transport'. Again, the scales are normalised in order to take any individual inclination to generally agree or disagree into account.

Travel mode studied	All trip purposes	Maintenance trips	Leisure trips
	Location preferences: importance of proximity to...		
Car	PT	shopping	leisure facilities
PT	PT	shopping	leisure facilities
NMT	shopping	shopping	leisure facilities
	Built environment: quality of...		
Car	PT	shopping	leisure facilities
PT	PT	shopping	leisure facilities
NMT	shopping	shopping	leisure facilities

Table 1: Measurement of location preferences and the built environment in the models

Source: author's concept.

Specifically, when examining maintenance trips, the importance of proximity to shops and services is used as an indicator of location preferences, while in the leisure models, the importance of proximity to leisure facilities is used (see overview in Table 1). The former was measured by a latent variable based on two observed variables: 'proximity to shops' and 'proximity to services'. In the latter, a single item measuring the importance of proximity to leisure facilities for adults is used. When examining the sum of all recorded trips, general measures of urbanity and/or transport service seem to be more appropriate than proximity to a certain type of facility. Hence, when examining car use and PT use, the importance of proximity to PT is used ('importance of PT'). For NMT, the quality and quantity of local activity opportunities is more important than the quality of the local PT system. Thus, the subjective importance of proximity to retail and services is used here.

The *built environment* at the place of residence is studied with regard to specific attributes of the neighbourhood that are selected in accordance with the location preferences. In the maintenance trip models, the supply of retail and services is used. Similarly, the supply of leisure opportunities is used in the leisure trip models. Both indicators are measured as the number of opportunities within a straight-line distance of 650 m around the place of residence. These indicators are calculated separately for all individuals[3]. In the models of all trips taken together, I use the quality of the local PT system when car share or PT share is studied. When the dependent variable is the share of non-motorised modes, the built environment is measured by the supply with shopping opportunities and services again.

Car availability was measured as an ordinal variable which can take on four values (see Table 2). This ordinal variable could be interpreted as metric once the distances between the four values were equal. Actual car use in the four groups suggests that *cum grano salis* this is approximately true (Table 2). None of the groups are either extremely close together or extremely far apart.

Car availability	car use per week distance	car use per week frequency	n
no car in household	12.2	0.8	305
car in household, but not available	34.9	2.2	88
car in household, partly available	67.0	4.8	273
car in household, available at any time	104.3	6.7	1,454
All	83.2	5.4	2,120

Table 2: Car use by car availability (means)

Source: author's analysis. Data: StadtLeben.

Travel behaviour was recorded by applying the frequent activities method. Activity frequency, usual travel mode, destination and travel distance were surveyed for selected activities including work, education, daily grocery shopping, weekly shopping, event shopping, personal errands at public authorities, private visits, sports, visits to restaurants or pubs, cultural events and sport events, discos and concerts, walks, and excursions.

Trip distances were examined on the basis of mean values for selected activities an individual reported having made. Maintenance activities include daily grocery shopping, weekly shopping, event shopping and administrative transactions at public authorities. Leisure trips include all other activities noted above except for work and education. Job trips and education trips are not studied separately, as the data only include discrete measures of the usual travel mode for these two travel purposes, preventing the construction of metric variables.

Travel mode use was examined here with respect to relative shares of various travel modes among all trips reported by an individual in the respective activity category. Three transport modes are considered: the private car (including marginal shares of motorcycles), PT, and NMT (bicycle and walking). A related paper (Scheiner, 2009d) focuses on absolute frequencies of mode use. However, these not only depend on an individual's inclination to use a given mode, but also on his or her level of mobility, i.e. on activity frequency. In any case, comparative studies of absolute frequencies v. relative shares of mode use generally yield similar results (see Scheiner, 2009a).

It should also be noted that mode use is considered here on an individual rather than a trip level. Thus, mode choice is treated not as discrete choice, as one would normally assume, but as continuous variables. Likewise, trip distances are studied here as mean distances covered by an individual for certain purposes. This means that the interrelation between distance and mode choice is blurred to a certain extent by aggregating trips and, thus, this interrelation is likely to be underestimated.

3.3 Methodology of structural equation modelling

The interrelations discussed above can be studied with structural equation modelling. This method is being increasingly used in transportation studies (Golob, 2003). Structural equation modelling can be described as a combination of factor analysis and a generalised form of

[3] The mapping of opportunities was undertaken by the RWTH Aachen and the Ruhr Universität Bochum. Leisure opportunities include sites of informal activity, such as chance meeting points in public space. I extended this survey beyond the borders of the study areas to meet the full radius of 650 m even for respondents living close to the border of an area.

regression analysis. The technique used is not described in detail here due to lack of space (see Scheiner and Holz-Rau, 2007 for more details).

There is much debate about the conditions under which the classical Maximum Likelihood (ML) approach can be regarded as superior to non-parametric procedures even when the normality assumption is violated (e.g., Hoogland and Boomsma, 1998, see also Golob, 2003 for transport applications). The available sample of about n=2,000 seems well appropriate for a robust application of the ML procedure, even if the sample is split into two halves (see below). The asymptotically distribution-free (ADF) procedure then reaches the limit of reliability, but seems still to be acceptable. Ultimately, a rather rigorous approach was applied. First, the sample was split into two halves by a random procedure. Then each model was estimated in four versions:

1. ML estimation of a theoretical model with the main sample
2. Empirical fitting of the model to the data
3. ADF estimation of the theoretical model
4. ML estimation of the theoretical model with the second sample for validation.

Version 2 only serves to verify the coefficients in the theoretical model version when fitted to the data, while my substantial interest lies in the theoretical models. Each of the four model versions was compared to the others with respect to the strength and sign of the effects. The results for each four versions turn out fairly stable and may clearly be interpreted in terms of the sign and strength of the effects. By contrast, modelling all trip purposes together without taking more than one measure of travel behaviour simultaneously into account resulted in considerable variations of effects between each of the four versions.

The interpretations are based on direct as well as total effects. Total effects of one variable on another are calculated as the sum of direct and indirect effects, the latter being mediated by intervening variables. Taking total effects into account allows for a more thorough interpretation of interrelations. An example for the calculation can be found in the text below Figure 3. The analyses were undertaken with the programme AMOS 5.0 to 7.0 (Analysis of Moment Structures).

	indicator of goodness-of-fit				df	
	RMSEA		Hoelter (p=0.05)			
	decision rule <0.05 good >0.1 n.a.		≥ 200 good			
model	figure	best (version 2)	figure	best (version 2)	figure	best (version 2)
car share, all trips	0.127	0.035	84	678	34	26
car share, maintenance	0.119	0.044	91	505	46	33
car share, leisure	0.111	0.043	102	499	48	41
PT share, all trips	0.112	0.043	107	505	34	28
PT share, maintenance	0.118	0.046	93	469	45	34
PT share, leisure	0.133	0.047	77	477	34	25
NMT share, all trips	0.117	0.039	93	582	46	34
NMT share, maintenance	0.117	0.028	94	857	45	30
NMT share, leisure	0.112	0.036	102	616	48	39

Table 3: Goodness-of-fit and degrees of freedom for the models

n.a.: not acceptable
The table gives values for two goodness-of-fit indicators as well as the degrees of freedom (df) for the model shown in the following figures and for the empirically fitted 'best' model version.
RMSEA (Root Mean Square Error of Approximation) measures discrepancy between the model implied and the true population covariance matrix, in relation to degrees of freedom. This ratio is related to sample size. In cases of close fit, RMSEA approaches zero. Values smaller than 0.05 indicate a close fit. The Hoelter statistics specifies the required sample size (critical n) to reject the model at a given significance level. Large values indicate a close fit. Values larger than 200 can be regarded as good. The table gives decision rules for the two indices.
Source: Author's analysis. Data: Project StadtLeben.

4 Results

There are a number of heuristic indicators to assess the goodness-of-fit of structural equation models. For most of these indicators there are decision rules available and they have been tested in methodological studies. The indicators are based on different principles, for instance on discrepancies between theoretical and empirical covariance matrices, or on mean differences between expected and estimated values of various parameters. Two of these indicators, along with the corresponding decision rule, are given in Table 3 for the models shown in the figures below and for the respective best model version (i.e. the ones that have been empirically fitted to the data, see above). The fit values of the theoretical models fail to meet a satisfactory level, but the values of the fitted models are satisfactory to close.

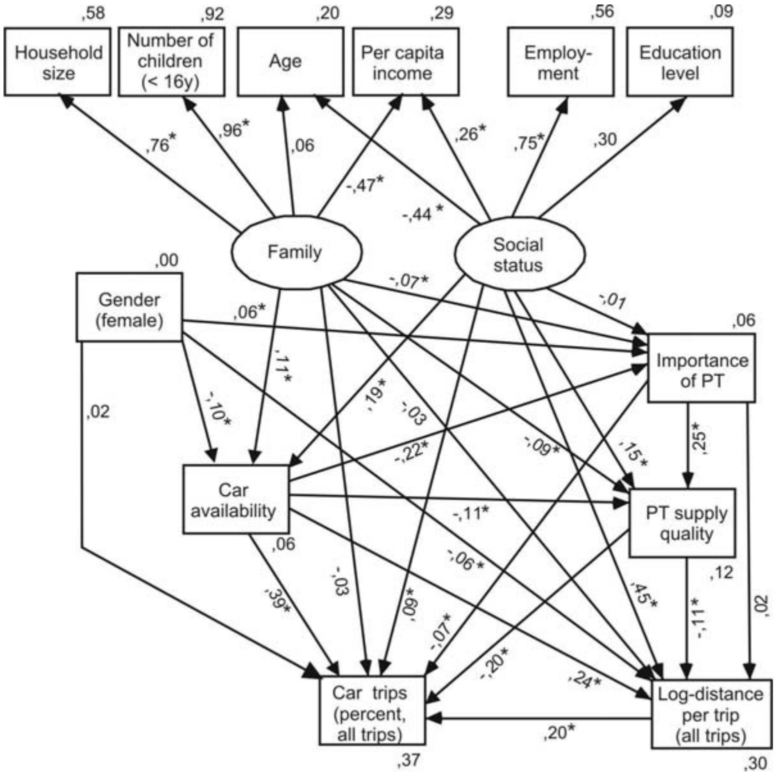

Figure 3: Model of trip distances and car share – all trip purposes

Theoretical model (version 1, ML estimation).
This and the following figures show the estimated standardised path coefficients and the proportion of explained variance of the endogenous variables, the latter being indicated next to the variable boxes. Significant coefficients (p=0.05) are marked with an asterisk. The rectangles are observed variables, the ovals are latent constructs.
The total effect a variable has on another variable is calculated as the sum of direct and indirect effects. For instance, the total effect of 'importance of PT' on 'car trips' equals -0.07 + 0.25*-0.20 + 0.25*-0.11*0,20+0,02*0,20 = -0.12.
Source: Author's analysis. Data: StadtLeben.

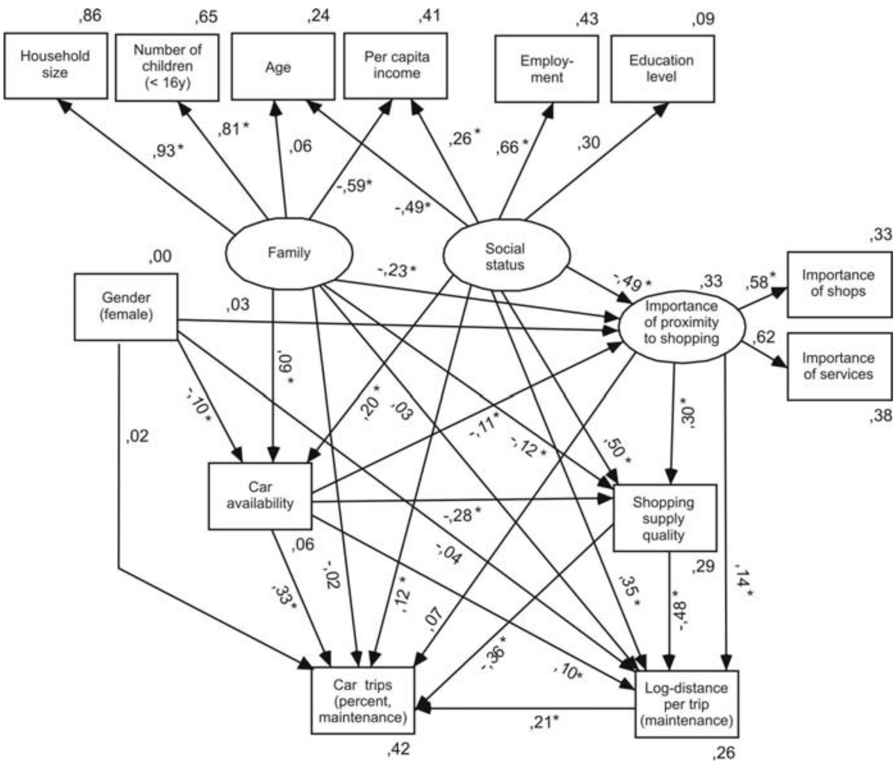

Figure 4: Model of trip distances and car share – maintenance trips

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

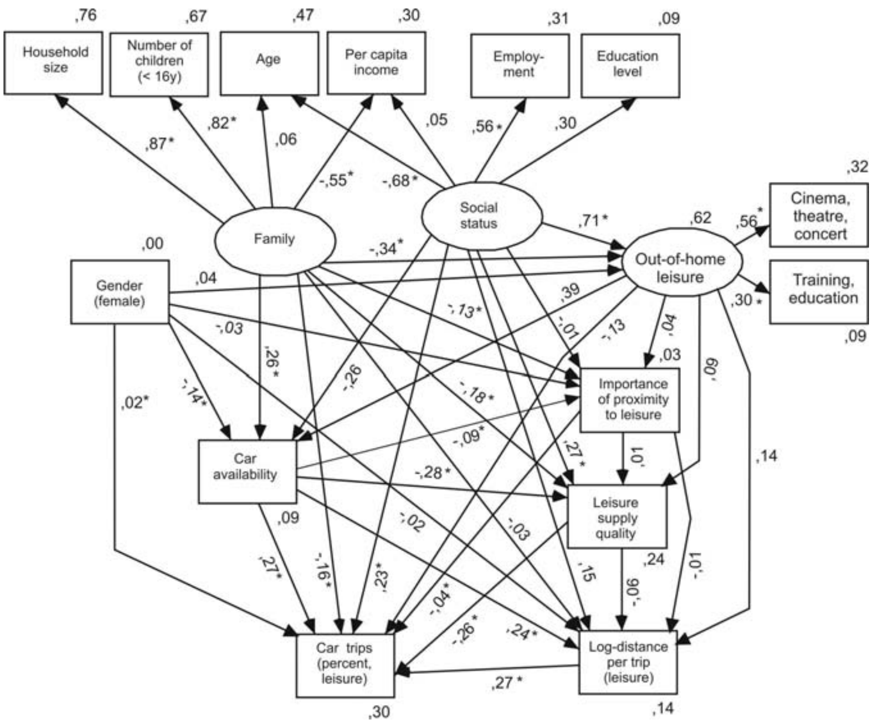

Figure 5: Model of trip distances and car share – leisure trips

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

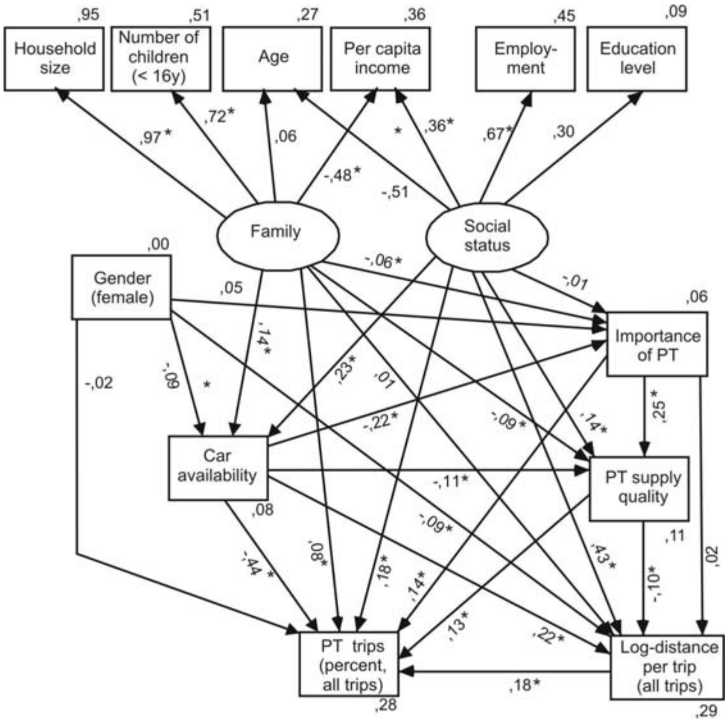

Figure 6: Model of trip distances and PT share – all trip purposes

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

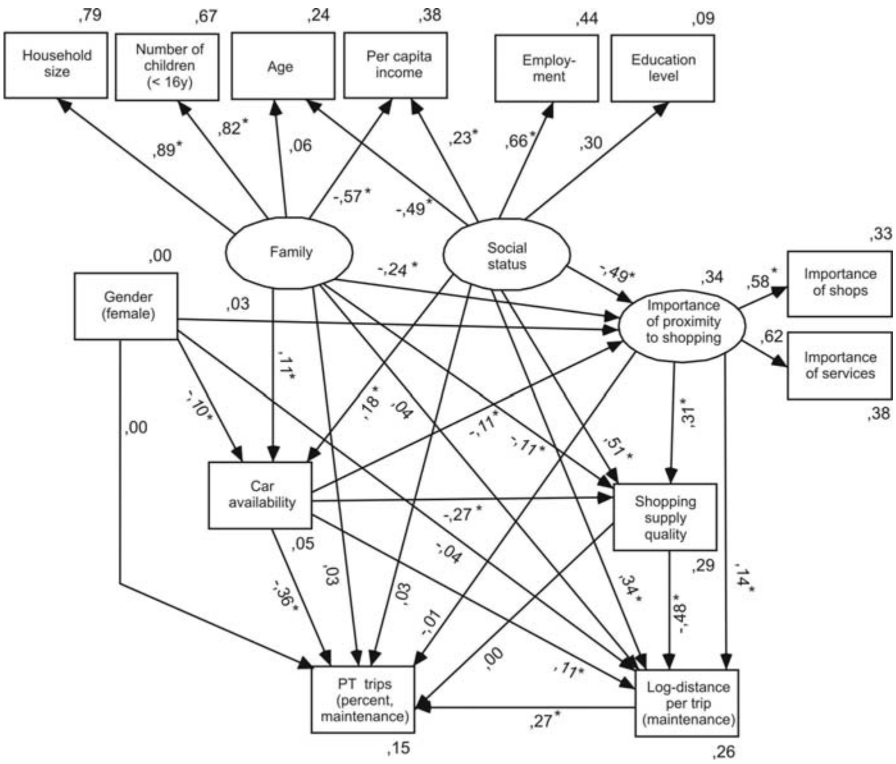

Figure 7: Model of trip distances and PT share – maintenance trips

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

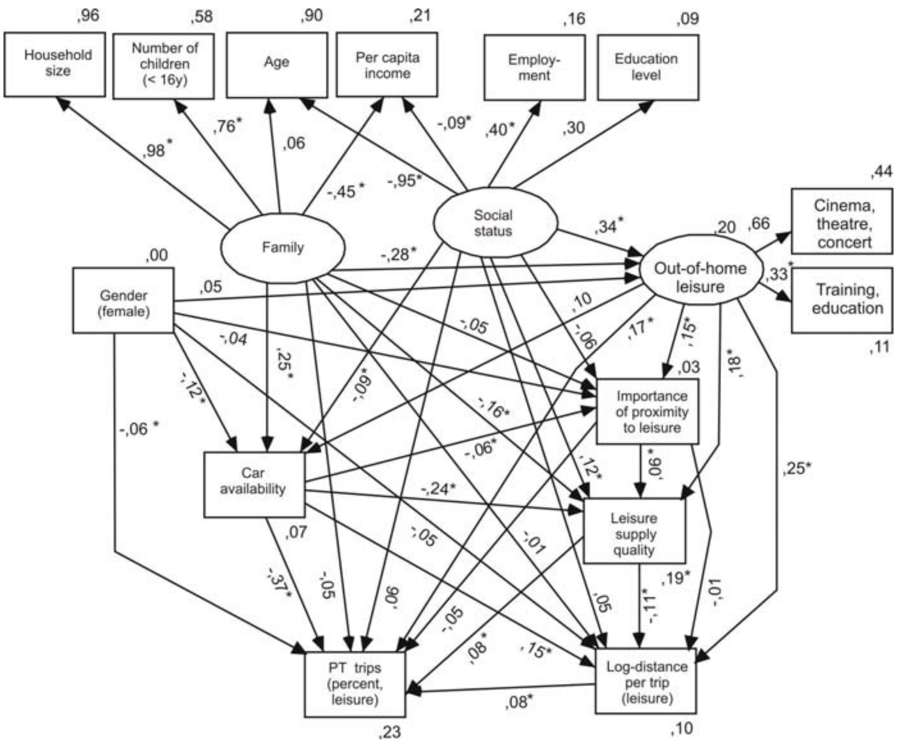

Figure 8: Model of trip distances and PT share – leisure trips

Theoretical model (version 4, ML estimation, validation sample).
Source: Author's analysis. Data: StadtLeben.

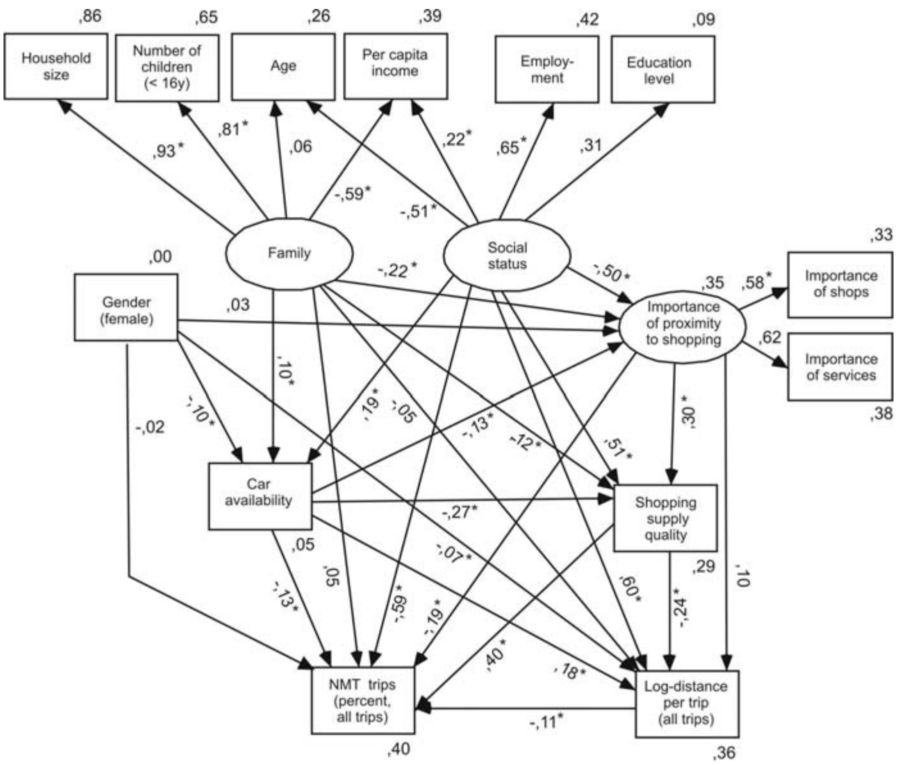

Figure 9: Model of trip distances and NMT share – all trip purposes

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

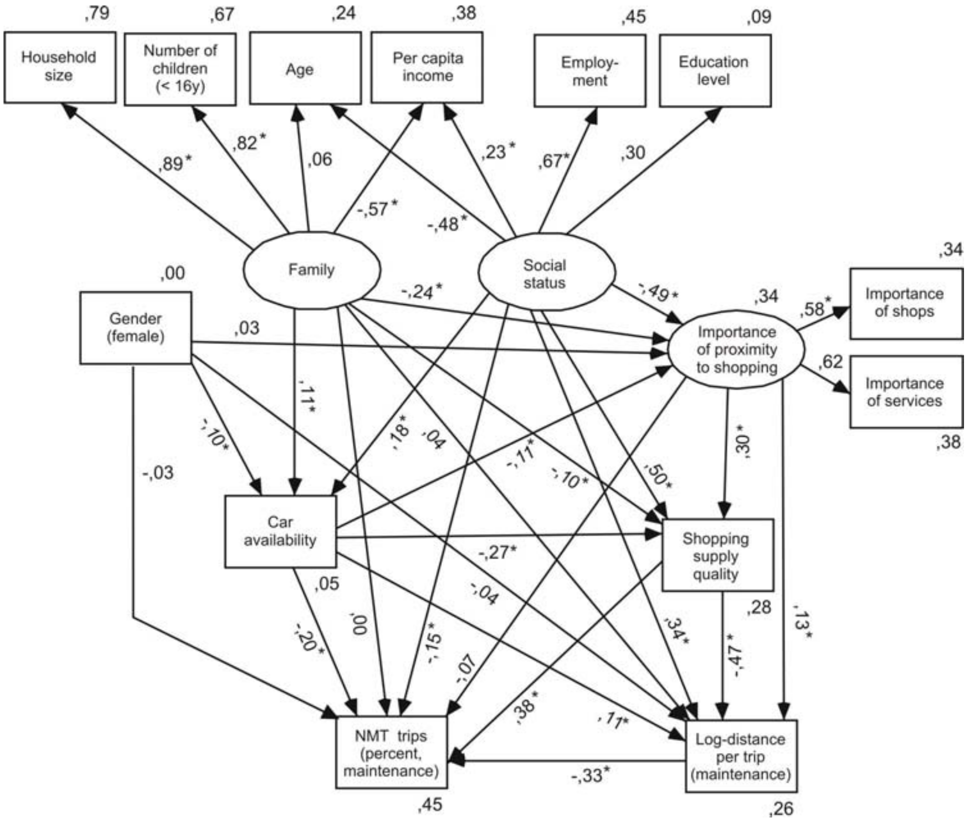

Figure 10: Model of trip distances and NMT share – maintenance trips

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

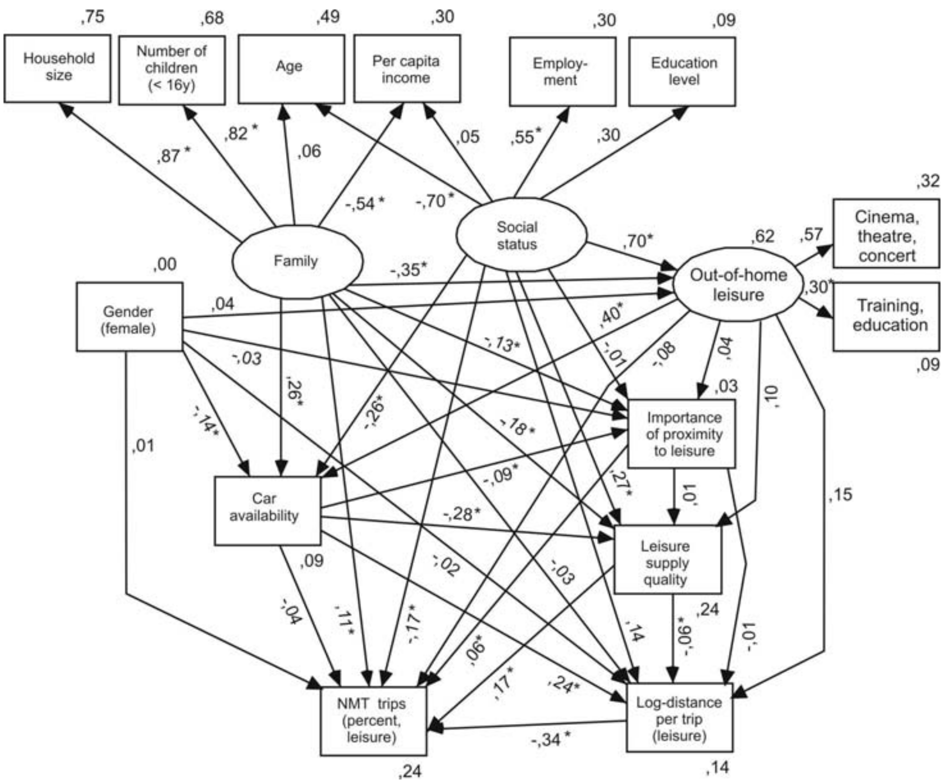

Figure 11: Model of trip distances and NMT share – leisure trips

Theoretical model (version 1, ML estimation).
Source: Author's analysis. Data: StadtLeben.

Turning our attention to the effects found in the models, social status is generally the most important element of life situation. High social status is associated with markedly longer trips and higher shares of car use *as well as* PT use (Figure 3, Figure 6). At the same time, individuals with high social status have lower NMT shares (Figure 9). These findings are true for maintenance trips and for leisure trips as well as for all trips put together. The effects of social status on travel mode choice are a result of direct effects as well as indirect effects mediated by trip distances and residential location choice. Individuals with high social status tend to locate in central areas. These residential location decisions encourage PT and NMT use and counterbalance car use to a certain extent, but without fully offsetting the positive relationship between status and car use.

As far as gender is concerned, women make slightly shorter trips than men. This mainly relates to the models that include all trip purposes (Figures 3, 6, 9), less to the maintenance models (Figures 4, 7, 10), and even less to the leisure models (Figures 5, 8, 11). Women's shorter job trips account for a large part of the significant gender difference when all trip purposes are considered. Gender does not have much of an impact on travel mode choice. Thus, gender differences seem to be more a matter of activity spaces.

The household type family is associated with longer than average maintenance trips. This finding corresponds with the high mode share of the private car among individuals living in a family. PT use (particularly for leisure trips) is slightly weaker among individuals living in family households than among others.

Lifestyle is one of the strongest impact factors for leisure trip distances (Figures 5, 8, 11), besides social status and car availability. A strong out-of-home leisure orientation is associated with markedly longer trips and, accordingly, with low shares of NMT and high shares of motorised modes. Concerning the latter, the effect of lifestyle on PT use (Figure 8) is considerably stronger than its effect on car use (Figure 5). It is perhaps surprising that a strong out-of-home leisure orientation seems to strengthen PT use more than car use. However, one has to note that individuals with this lifestyle are often young adults such as students and trainees, many of whom do not have access to a car. The positive effect of lifestyle on trip distances exists despite the tendency of individuals with strong out-of-home leisure preferences to locate in neighbourhoods with good leisure supply. In other words, although these individuals tend to live in neighbourhoods that match their preferences they tend to make long trips to fulfil their diverse leisure needs. This means that without the mediating residential location effect their leisure trips would be even longer.

The availability of a car also strongly increases trip distances and, obviously, car use, but decreases the use of PT as well as NMT. The impact the car has on PT use is considerably stronger than its impact on NMT. In the leisure sector the *direct* effect of the car on NMT is actually negligible. Even so, the overall effect of the car is negative in any case. This is mainly a result of the tendency for motorised individuals to locate in peripheral locations and to undertake longer trips.

With respect to the built environment, a well-developed supply of retail outlets and services is strongly associated with relatively short trips and lower proportions of car use among all maintenance trips (Figure 4). The low car share is both a direct and an indirect effect mediated by trip distance. Similarly, a good leisure supply structure leads to shorter leisure trips (Figures 5, 8, 11), although the effect is not as marked as for maintenance trips. What is more, a large number of leisure opportunities in the neighbourhood leads to markedly less car use (Figure 5) and a higher NMT share (Figure 11).

When all recorded activities are considered together, the quality of PT supply is used as the built environment indicator in the models of car use and PT use. PT supply corresponds with relatively short trips (Figure 3), which is likely to be an effect of the generally higher urbanity found at residential locations with a good PT system than of the PT system per se. The effect PT has on travel mode choice is even stronger than its effect on trip distances: living at a place with a good PT system leads to more PT use and less car use (Figures 3, 6).

A high subjective preference for PT affects PT use more strongly than the objective quality of the system (Figure 6). Thus, the subjective importance of PT appears to be even more important than the PT system itself. Residential self-selection according to specific location preferences is particularly pronounced in this case.

On the other hand, a high preference for proximity to shopping or leisure facilities does not lead either to short maintenance trips or short leisure trips, nor does it have significant effects on mode choice. Although such proximity preferences are clearly associated (particularly in the case of shopping preferences) with residential location choice, their total effects on travel behaviour are negligible.

Last but not least, there is a clear and strong relationship between trip distance and travel mode choice: the longer the trips, the greater the car use and the PT use (Figures 3, 6), and the weaker the use of NMT (Figure 9). Thus, the interrelation between distance and mode choice does indeed capture the two different elements outlined in section 2. Firstly, mode choice depends on realised trip distances. These may be affected at best indirectly by urban policy concepts, e.g. by impacting on the monetary or generalised costs of travelling. Secondly, the *necessary* distances to potential destinations – i.e. to opportunities – may be affected directly by land-use planning. It should be encouraging for policy makers and planners that land-use does indeed seem to have a strong independent impact on travel behaviour, irrespective of people's attitudes and social background. The data analysed in this chapter reveals the effect of the built environment in terms of the number of opportunities in the respondents' neighbourhoods. The effects found are particularly strong for maintenance trips, but are also significant for leisure trips as well as for all trips recorded when put together.

5 Conclusion

The built environment matters. This is the key result of the analysis presented in this chapter. The built environment plays a substantial role in terms of people's travel distances as well as in terms of their mode choice. Social inequalities may be even more important – an observation which has been made before (Hanson and Schwab, 1995; Stead et al., 2000) –, but it seems nonetheless that the provision of a range of shopping and leisure facilities and a decent PT system has substantial potential to make people use environmentally friendly travel modes and undertake relatively short trips. It has been shown that in such urban contexts even car owners may choose to leave their car at home and walk more than elsewhere (Scheiner, 2009c).

On the other hand there are at least four caveats worthy of note.

Firstly, residential self-selection may play an important role for travel. It seems that people tend to choose a place of residence that matches their travel and accessibility preferences, and while the above findings do not support the notion of self-selection effects on trip distances with respect to shopping or leisure preferences, they suggest that PT preferences may indeed be more important for PT use than the actual PT system. Residential self-selection, however, is not only a matter of location attitudes. People also tend to sort themselves according to their life situation and lifestyle. Social status has been identified as being one of the strongest impact factors for mode choice and trip distances. In the leisure sector, lifestyle is among the most prominent impact factors for trip distances as well. These social inequalities in travel behaviour are partly indirect effects mediated by residential sorting. One has to note, however, that the existence of residential self-selection does not mean that the built environment is irrelevant. In order to give people the chance to choose between different locations, these differences have to exist. That is, residential self-selection effects are themselves evidence that the built environment matters (Naess, 2009).

Secondly, short trip distances and high shares of environmentally friendly modes can be found mainly in the inner districts of large cities, i.e. in spatial contexts that are extremely over-supplied with central place facilities. These districts do not only serve their own population with shopping and leisure opportunities, but large numbers of incoming consumers as well. This means that the lessons learned from these urban districts cannot be directly transferred to other contexts, such as small towns or suburban neighbourhoods, as the over-provision of facilities in the central locations of core cities and the under-provision in the surrounding suburbs are two sides of the same coin – they are mutually dependent.

Thirdly, this notion also implies that it does not make much sense to blame peripheral locations for high per-capita car travel volumes and at the same time praise urban locations for their low car travel volumes, as exactly the same urban locations may be blamed for their potential to attract incoming commuters, shopping and leisure consumers who are exactly those who live in the suburbs and cover long distances to the centres which attract them.

This mutual dependency, however, appears to be a dilemma only at first glance. The solution would be to aim for a spatial structure that attempts to avoid the under-supply *and* the over-supply of opportunities. For workplaces (as one particular example of opportunities) it has been shown that a spatially balanced job-housing mix is associated with less job travel (Cervero and Duncan, 2006 for the US, Holz-Rau and Kutter, 1995 for Germany).

Fourth, perhaps the most salient problem with small-scale, neighbourhood-oriented spatial distributions of opportunities is the level of specialisation required for economic viability in individualised, affluent societies. Even for retail outlets such as groceries it has been argued that neighbourhood-scale 'walk-to shops' may have limited chances of survival (Bartlett, 2005). This may be even truer for more specialised opportunities such as leisure and cultural facilities, or workplaces.

However, the question of economic viability should not lead us to conclude that there is no point in encouraging people to undertake short trips by providing relatively small-scale opportunities and a relatively balanced spatial distribution of land-uses. The chances to do so may be very limited under the current economic and societal conditions, but they do exist. And what is more, one clearly has to recognise that the current economic and societal conditions are unlikely to remain stable in the near future. Energy and, thus, transport prices are likely to further increase substantially. More than any urban policy, this may foster more balanced, mixed-use spatial patterns and a more 'traditional' development of neighbourhoods and cities. A principal task for urban policy could well be to recognise and take advantage of this opportunity to provide the conditions to facilitate more balanced, mixed-use patterns in order to be prepared for future challenges.

Acknowledgement: The research in this chapter was funded by the German Research Foundation (DFG) as part of the project 'Wohnstandortwahl, Raum und Verkehr im Kontext von Lebensstil und Lebenslage' (Choice of residential location, built environment and transport in the context of lifestyle and life situation, 2006-2008).

6 References

Badland, H., & Schofield, G. (2005). Transport, urban design, and physical activity: an evidence-based update. Transportation Research D 10 (3), 177-196.

Bahrenberg, G. (1997). Zum Raumfetischismus in der jüngeren verkehrspolitischen Diskussion. In U. Eisel, & H.-D. Schultz (Eds.), Geographisches Denken. Urbs et Regio 65 (pp. 345-371). Kassel: Universität.

Bartlett, R. (2003). Testing the 'popsicle test': realities of retail shopping in new 'traditional neighbourhood developments'. Urban Studies 40(8), 1471-1485.

BMVBW (Federal Ministry of Transport, Building and Housing, ed.) (2002). National cycling plan 2002-2012: ride your bike! Berlin: BMVBW.

Boarnet, M., & Crane, R. (2001). Travel By Design. Oxford: Oxford University Press.

Bohte, W., Maat, K., & van Wee, B (2009). Measuring attitudes in research on residential self-selection and travel behaviour: a review of theories and empirical research. Transport Reviews 29(3), S. 325-357.

Cao, X., Handy, S. L., Mokhtarian, P. L. (2006). The influences of the built environment and residential self-selection on pedestrian behavior in Austin, Texas. Transportation 33(1), 1-20.

Cao, X., Mokhtarian, P., & Handy, S. (2009). Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. Transport Reviews 29(3), 359-396.

Cervero, R. (2002). Built environments and mode choice: toward a normative framework. Transportation Research D 7(4), 265-284.

Cervero, R. (2006). Alternative approaches to modeling the travel-demand impacts of smarth growth. Journal of the American Planning Association 72(3), 285-295.

Cervero, R., Duncan, M. (2006) Which reduces travel more: Jobs-housing balance or retail-housing mix? Journal of the American Planning Association, 72(4), 475-490.

DfT (Department for Transport, ed.) (2006). Transport statistics bulletin. National travel survey 2005. London: DfT.

DIW/INFAS (2003). Mobilität in Tabellen. Tabellenprogramm zur Erhebung Mobilität in Deutschland 2002. Berlin: DIW.

EU (ed.) (2000). Transport in figures 2000. Luxembourg: European Commission.

Gatersleben, B., & Appleton, K.M. (2007). Contemplating cycling to work: attitudes and perceptions in different stages of change. Transportation Research A 41(4), 302-312.

Giuliano, G., & Dargay, J. (2006). Car ownership, travel and land use: a comparison of the US and Great Britain. Transportation Research A 40(2), 106-124.

Golob, T. F. (2003). Structural equation modeling for travel behavior research. Transportation Research B 37(1), 1-25.

Guo, J. Y., & Chen, C. (2007). The built environment and travel behavior: making the connection. Transportation 34(5), 529-533.

Handy, S. L., & Clifton, K. J. (2001). Local shopping as a strategy for reducing automobile travel. Transportation 28(4), 317-346.

Hanson, S., & Schwab, M. (1995). Describing Disaggregate Flows: Individual and Household Activity Patterns. In S. Hanson (Ed.), The Geography of Urban Transportation (pp. 154-178). New York, London: The Guilford Press.

Holz-Rau, C., & Kutter, E. (1995). Verkehrsvermeidung. Siedlungsstrukturelle und organisatorische Konzepte. Materialien zur Raumentwicklung 73. Bonn: BfLR.

Holz-Rau, C., Rau, P., Scheiner, J., Trubbach, K., Dörkes, C., Fromberg, A., Gwiasda, P., & Krüger, S. (1999). Nutzungsmischung und Stadt der kurzen Wege: Werden die Vorzüge einer baulichen Mischung im Alltag genutzt? Bonn: Bundesamt für Bauwesen und Raumordnung.

Holz-Rau, H.-C. (1991). Verkehrsverhalten beim Einkauf. Internationales Verkehrswesen 43(7-8), 300-305.

Hoogland, J. J., & Boomsma, A. (1998) Robustness studies in covariance structure modeling. Sociological Methods and Research 26(3), 329-367.

ILS (Institut für Landes- und Stadtentwicklungsforschung Nordrhein-Westfalen) (1999). Baulandentwicklung an der Schiene. Dortmund: ILS.

Kloas, J., & Kunert, U. (1993). Vergleichende Auswertungen von Haushaltsbefragungen zum Personennahverkehr (KONTIV 1976, 1982, 1989). Forschungsprojekt im Auftrag des Bundesministers für Verkehr (FE-Nr. 90361/92). Berlin: DIW.

Lanzendorf, M. (2001). Freizeitmobilität. Unterwegs in Sachen sozial-ökologischer Mobilitätsforschung. Materialien zur Fremdenverkehrsgeographie 56. Trier: Universität.

Naess, P. (2009). Residential self-selection and appropriate control variables in land use: travel studies. Transport Reviews 29(3), 293-324.

Rohrmann, B. (1978). Empirische Studien zur Entwicklung von Antwortskalen für die sozialwissenschaftliche Forschung. Zeitschrift für Sozialpsychologie 9(1), 222-245.

Scheiner, J. (2006). Does individualisation of travel behaviour exist? Determinants and determination of travel participation and mode choice in West Germany, 1976-2002. Die Erde 137(4), 355-377.

Scheiner, J. (2009a). Sozialer Wandel, Raum und Mobilität. Empirische Untersuchungen zur Subjektivierung der Verkehrsnachfrage. Wiesbaden: VS Verlag.

Scheiner, J. (2009b). Objective and subjective socio-spatial inequalities in activity patterns. Swiss Journal of Sociology 35 (accepted for publication)

Scheiner, J. (2009c). Interrelations between travel mode choice and trip distance: trends in Germany 1976–2002. Journal of Transport Geography 17 (in print, DOI: 10.1016/j.jtrangeo.2009.01.001)

Scheiner, J. (2009d). Is travel mode choice driven by subjective or objective factors? In C. Holz-Rau, & J. Scheiner (Eds.), Subject-Oriented Approaches to Transport. Dortmunder Beiträge zur Raumplanung, Verkehr 6 (pp. 53-69). Dortmund: IRPUD.

Scheiner, J. (2010). Social inequalities in travel behaviour: trip distances in the context of residential self-selection and lifestyles. Journal of Transport Geography (accepted for publication)

Scheiner, J., & Holz-Rau, C. (2007). Travel mode choice: affected by objective or subjective determinants? Transportation 34(4), 487-511.

Schlossberg, M., Greene, J., Phillips, P. P., Johnson, B., & Parker, B. (2006). School trips: effects of urban form and distance on travel mode. Journal of the American Planning Association 72(3), 337-346.

Schwanen, T., Dijst, M., & Dieleman, F. M. (2004). Policies for urban form and their impact on travel: the Netherlands experience. Urban Studies 41(3), 579-603.

Simma, A., & Axhausen, K. W. (2001). Structures of commitment in mode use: a comparison of Switzerland, Germany and Great Britain. Transport Policy 8(4), 279-288.

Stead, D., & Marshall, S. (2001). The relationships between urban form and travel patterns. An international review and evaluation. European Journal of Transport and Infrastructure Research 1(2), 113-141.

Stead, D., Williams, J., & Titheridge, H (2000). Land Use, Transport and People: Identifying the Connections. In K. Williams, E. Burton, & M. Jenks (Eds), Achieving Sustainable Urban Form (pp. 174-186). London: E & FN Spon.

Vågane, L. (2007). Short Car Trips in Norway: Is there a potential for modal shift? Paper presented at the European Transport Conference, Leiden, Netherlands, 17-19 October, 2007.

Ye, X., Pendyala, R. M., & Gottardi, G. (2007). An exploration of the relationship between mode choice and complexity of trip chaining patterns. Transportation Research B 41(1), 96-113.

Zumkeller, D., & Nakott, J. (1988). Neues Leben für die Städte: Grünes Licht fürs Fahrrad. Bild der Wissenschaft 5, 104-113.