Transportation (2016) 43:243–271
DOI 10.1007/s11116-014-9574-x

Moving between mobility cultures: what affects the travel behavior of new residents?

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Published online: 4 January 2015

Abstract This paper analyzes the complex interdependencies between residential relocation and daily travel behavior by focusing on modal change. To help explain changes in daily travel patterns after a long distance move between cities the concept of urban mobility cultures is introduced. This comprehensive approach integrates objective and subjective elements of urban mobility, such as urban form and socio-economics on the one hand, and lifestyle orientations and mode preferences on the other, within one socio-technical framework. Empirically, the study is based on a survey conducted among people who recently moved between the German cities Bremen, Hamburg and the Ruhr area. Bivariate analyses and linear multiple regression models are applied to analyze changes in car, rail-based and bicycle travel. This is done by integrating variables that account for urban mobility cultures and controlling for urban form, residential preferences and socio-demographics. A central finding of this study is, that changes in the use of the car and rail-based travel are much more dependent on local scale, such as neighborhood type and residential preferences, whereas cycling is more affected by city-wide attributes, which we addressed as mobility culture elements.

Keywords Attitude · Built environment · Mobility culture · Mode choice · Regression model · Residential relocation

Introduction

A predominant debate within recent travel behavior research is whether travel behavior is more influenced by objective characteristics such as built environment and socio-

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economics, or whether it is more related to subjective criteria such as attitudes and lifestyles (Scheiner and Holz-Rau 2007). This dichotomy has become particularly crucial for studying the interdependencies between housing mobility and daily travel behavior. Several authors have focused on built environment and its potentially routine-breaking character, e.g. by adjusting travel behavior to the new urban form parameters after a residential relocation. Other studies examine the relative persistence of established mobility-related attitudes and orientations which themselves influence the location choice before a residential relocation (Cao et al. 2009; Scheiner 2006 for reviews of the research field). In this view, movers tend to choose neighborhoods that are most appropriate for a continuation of their preferred travel behavior, a process which has become well-known as 'residential self-selection' (for many Schwanen and Mokhtarian 2005a, b).

The residential self-selection debate leads to the question whether travel behavior of new residents is more influenced by built environment characteristics or by travel-related attitudes. The evidence provided by related work varies widely from showing urban form influences to more attitude-related impacts. These diverse results are a consequence of a vast range of different ways to implement the concepts of urban form, attitude and travel behavior. The diversity of employed variables and statistical models has been documented by comprehensive review studies (Cao et al. 2009; Ewing and Cervero 2010). However, most of this work has concentrated on regional changes of residence, such as moving from an urban core to a suburban area or vice versa and the related consequences for daily travel. Accordingly, the urban form and attitude variables implemented in these studies are mostly related to the neighborhood-scale. Few studies have analyzed the interdependencies between long-distance moving and daily travel behavior. Furthermore, indicators on the aggregated geographical level have rarely been regarded as factors influencing individual travel behavior of new residents (Burbidge 2012 is a rare exception). This is especially striking because of the growing importance of long-distance moving as a worldwide phenomenon. Besides the well-documented effects of neighborhood characteristics, we assume that long-distance movers are more sensitive to city-wide transport attributes than regional movers are. For example, the predominance of cycling as a mode of transport in a city is unlikely to affect the travel behavior of residents moving between neighborhoods of the same city. On the other hand, a strong cycling culture might capture the attention and affect the travel behavior of a new resident for whom an abundance of cyclists is a new phenomenon. In this study the city-wide attributes are addressed by the concept of urban mobility cultures (Deffner et al. 2006), which includes both objective components—such as urban form and infrastructure supply—and more subjective factors, such as lifestyle and mobility patterns of a city's population.

Departing from the concept of urban mobility cultures, we ask what factors affect the travel behavior of long-distance movers at the new place of residence. Thus, this study aims to improve our understanding of travel behavior in three ways. First, we add the consideration of inter-city movers to the debate of residential self-selection based on the assumption that this group behaves differently from their regional counterparts. Second, we include the influence of aggregated, city-wide characteristics (such as mode-specific infrastructure networks and modal split) to the analysis. By adding neighborhood characteristics, the superimposition of these spatial levels can be controlled. Third, the concept of urban mobility cultures (Deffner et al. 2006) is employed to include both objective and subjective elements within one conceptual model affecting travel behavior changes after a residential relocation.

For the purpose of this study, in May 2011 we surveyed people who moved 2006–2011 between three urban regions: Bremen, Hamburg and the Ruhr area (represented by the

cities of Bochum, Dortmund and Essen). Employing a quasi-longitudinal and partly retrospective design, we asked for the respondents' travel behavior before and after the residential relocation and their attitudes towards different components of mobility cultures in both cities. We assessed the impact of the change in mobility culture with ordinary least squares (OLS) regression models controlling for changes in the built environment, household composition and socio-demographics.

The paper is structured as follows. The next two sections summarize earlier research on urban form, attitudes and lifestyle and their impact on travel behavior throughout the process of residential relocation. "Methodology" section presents the methodology, whereas "Statistical analysis and findings" section displays the empirical results. "Discussion and policy implications" section discusses the results and draws some conclusions on policy implications. Finally, the key findings are summarized, some limitations of the study are discussed and an outlook to further research directions is given.

Integrating urban form and attitudes—the concept of urban mobility cultures

Transportation research is characterized by an objective-subjective divide in explaining travel behavior (Scheiner and Holz-Rau 2007; De Vos et al. 2012). On the one hand, 'hard factors' such as urban form and socio-economic factors are understood as being influential for various aspects of travel behavior. For analyzing the impact of the built environment, the concept of the 3 D's—density, diversity and design (Cervero and Kockelman 1997)—has become an important orientation for several studies (Newman and Kenworthy 1989, 1999; Næss 1996, 2011 for density-related analyses, Cervero 1996; Frank and Pivo 1994; van Wee 2002 for discussing land use mix and diversity, Boarnet and Crane 2001; Chatman 2009; Fehrs and Peers 1992; Friedman et al. 1994; Handy et al. 2005, Krizek 2003 for assessing neighborhood design indicated by, for instance, the outline of the street network, the average block size or the sidewalk coverage). However, it has also been argued that the impact of urban form diminishes when controlled for socio-economic characteristics of the inhabitants (McNally and Kulkarni 1997; Holz-Rau and Kutter 1995, see Wegener and Fürst 1999 for an early review). In this context it is important to note that gender (Best and Lanzendorf 2005; Scheiner and Holz-Rau 2012), household composition, represented e.g. by the number of adults and children per household (Hearst et al. 2013; Lee et al. 2007) and life cycle stage (Beige and Axhausen 2012; Grimsrud and El-Geneidy 2014; Verhoeven et al. 2005) have also been identified as relevant factors influencing travel behavior.

On the other hand, by paying attention to social trends such as modernization (Giddens 1990) and pluralization (Beck 1992) travel behavior research is increasingly implementing so called 'soft factors' (De Vos et al. 2012, p. 1) such as attitudes and preferences towards particular modes of travel or neighborhood characteristics (Fujii and Gärling 2003; Gatersleben 2007; Salomon and Ben-Akiva 1983). Some research has categorized people into different 'mobility styles' (Lanzendorf 2002) and 'travel behavior segments' (Anable 2005) both using factor and cluster analysis based on socio-demographics, attitude and travel-related variables (see also Götz and Ohnmacht 2011; Hunecke et al. 2010; Prillwitz and Barr 2011; Pronello and Camusso 2011; Steg 2005). Furthermore, it has been argued that individual attitudes and preferences can form patterns of collective values and social norms indicated, for instance, by an unequally distributed environmental awareness across Europe (Pronello and Camusso 2011, p. 1306). These value patterns and aligned mobility orientations may, in turn, influence individual travel behavior. Goetzke and Rave (2011) have conceptualized this process as 'social network effect'.

It has been shown that both urban form and attitude-related factors contribute to an understanding of travel behavior. However, focusing only on spatial and infrastructural characteristics tends to disregard the reality of individual perception, evaluation and decision. On the other hand, too much focus on the individual can obscure the fact that an individual's travel behavior is still linked to objective factors such as urban form and infrastructure (Hunecke et al. 2007, p. 278). As discussed above, urban transport policy and mobility-related discourses also impact people's daily travel patterns.

As a result of analyzing these different strands of research, we argue that both the built environment and attitudes inform the broader socio-cultural context of community-based priorities, values and beliefs. We chose urban mobility cultures (Deffner et al. 2006) as a theoretical framework because of its link to the built environment, travel-related attitudes and urban-level transport policy. The socio-cultural setting can be interpreted as a complex configuration of different preferences and lifestyles represented by a city's population. An urban population can even develop specific social conventions and habits. In this view, spatial characteristics such as urban form and transport infrastructure are a physical extension of cultural priorities. Rammler (2008) has exemplified this strong interdependence between social norms and spatial structures for automobile culture. Similarly, the concept of urban mobility cultures is based on the assumption that objective and subjective factors for explaining urban mobility are interconnected and dependent on each other. Hence, urban mobility cultures can be understood as integrative, which incorporates travel behavior and underlying mode-specific preferences. Additionally, rather objective and structural components such as infrastructure and spatial characteristics are included. Moreover, mobility- and city-related discourses and urban transport policy are added to the concept of urban mobility cultures (Fig. 1). This is adequate, given that various works have revealed the impact of strategic funding decisions and policy processes (Bratzel 1999; Haefeli 2005; Stone 2009) and the influence of urban discourses and storylines that may strengthen one form of urban mobility and marginalize others (Cresswell 2010; Freudendal-Pedersen 2009; Vigar 2002). Both approaches are also central to the 'new mobilities' paradigm that has become very influential in social sciences (Cresswell 2010; Jensen 2009, Sheller and Urry 2006).

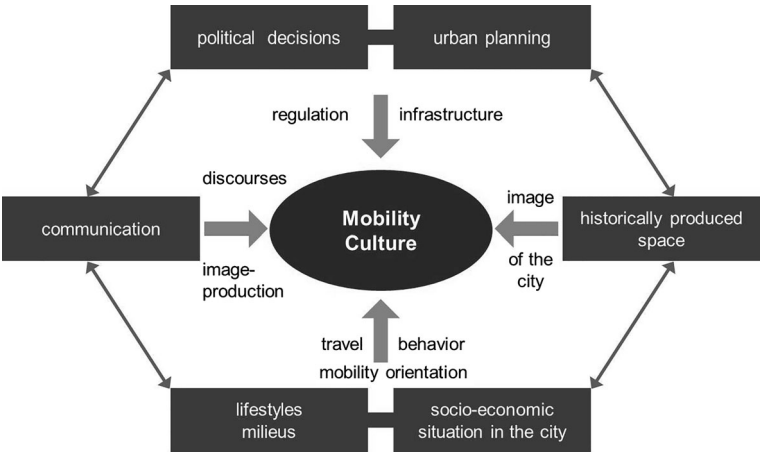

Fig. 1 Concept of urban mobility cultures. *Source* Götz and Deffner 2009, p. 41, authors' translation and modification

It is important to note that the concept is not fixed and homogenous. Instead the model reflects urban mobility culture as a set of dynamic processes, competing interests and conflicts. Consequently, mobility cultures are variable over time and space. Deffner et al. (2006) define culture as commonly shared knowledge which facilitates the organization of day-to-day life by accepting particular practices and norms as well as excluding others. In sum, although urban mobility cultures are changeable, they are rather inertial and long-lasting structures with a high level of path dependence. This is especially true since they are often developed along a predominant mode of transport. These 'backbone modes' (Deffner et al. 2006) usually entail long-lasting infrastructural and cultural configurations.

Residential relocations as a key event for travel behavior change

Applying a life course perspective has been helpful in improving the understanding of the link between urban form, attitudes and travel behavior. The 'mobility biographies' approach has illustrated that mobility orientations tend to be relatively robust and highly habitualized as long as the context remains stable (Axhausen 2008; Lanzendorf 2003; Scheiner 2007). Once biographical key events such as a residential relocation, the birth of a child or a job change take place, the greater the chance for a change in mobility-related attitudes and travel behavior. During this period of adjusting to new circumstances, travel-related habits become conscious and the resulting open-mindedness towards new mobility options opens up a window of opportunity for synchronization of attitudes and travel behavior (De Vos et al. 2012; Stanbridge et al. 2004, p. 1), and behavioral change (Bamberg 2006).

As mentioned above, a wide range of studies have highlighted the correlation between urban form and travel behavior (for reviews see Crane 2000; Ewing and Cervero 2001). Critics of this approach have shown that the choice of residential location itself is influenced by travel-related attitudes and habitualized travel behavior (Aditjandra et al. 2012, p. 23; Bothe et al. 2009; Cao et al. 2007, p. 536; Handy et al. 2005). People sort themselves into particular categories of neighborhoods which most fit their preferred travel mode, an approach which has become known as residential self-selection (for many Bagley and Mokhtarian 2002; Handy et al. 2005). Scheiner (2006) was able to show how daily travel patterns of people who were planning to relocate differ from the travel behavior of their neighbors not intending to move. This indicates that even after a residential relocation past travel dispositions are an adequate predictor for current travel behavior, an idea well-known as state dependency (Beige and Axhausen 2012; Krizek 2003; Prillwitz et al. 2007). In this view, modal changes at the new residential location are not determined by the changed built environment but are an expression of a more adequate realization of travel-related preferences which already existed latently at the previous residential location, but was not fully implemented due to constraints such as local accessibilities. Several studies have focused on this mismatch between actual and preferred travel behavior often reflected by a dissonance between the current and the desired neighborhood type (De Vos et al. 2012; Schwanen and Mokhtarian 2005a, b; Van Acker et al. 2010).

The concept of self-selection on the other hand can be criticized insofar that a better realization of travel preferences is insufficient to fully explain behavioral changes. Residential choices are rarely motivated by travel preferences alone. Instead, a choice to relocate is the outcome of a dynamic and complex decision-making process that is based on housing, economic and travel-related realities (Chatman 2009). If residential

choice is understood as a trade-off, there is still evidence of the direct influence of the built environment on travel behavior, even in studies controlling for residential self-selection through the inclusion of travel and neighborhood-related preferences. Needless to say, this observation is only valid insofar as there are a variety of built environments from which new residents can choose. Consequently, Næss (2009) argues that suburban dwellers drive more and walk less than inner-city residents, even while controlling for self-selection.

Table 1 summarizes empirical findings of relocation studies regarding the impact of the built environment and attitudes towards travel behavior which have been identified in these studies. Most studies found two directions of causality at different magnitudes. On the one hand, neighborhood spatial characteristics influence travel behavior, on the other hand travel preferences impact residential choice and eventually travel behavior, as well. This indicates that both dimensions are strongly interwoven (Aditjandra et al. 2012; Cao et al. 2007, 2009; Ewing and Cervero 2010; Handy et al. 2005; Scheiner and Holz-Rau 2013). However, we found only one study addressing travel behavior change of long distance movers. The exchange students, surveyed by Burbidge (2012), significantly changed their modal choice when living abroad.

Nonetheless, to our knowledge there is no study that addresses long distance moving between cities or regions that are characterized by contrasting mobility orientations of both transport policy and inhabitants. The relevance of middle and long distance moving is indicated by the fact that 50.1 % of all people who moved within Germany in 2012 relocated over a distance of more than 50 km (BBSR 2014). This is by no means to say that the impact of urban mobility cultures is limited to this group of people. Instead, they potentially influence all persons getting in touch with those socio-cultural contexts, e.g. because they grew up and were socialized there. Nonetheless, a survey of long distance movers is particularly appropriate for our analysis, since the adaptation process caused by socio-cultural differences is rather apparent and limited to a relatively short period of time for this group of people. Hence, this group is relatively easy to identify and to analyze. Such socio-cultural differences have been described by Deffner et al. (2006) with the term ‘urban mobility cultures’. Consequently, we aim to identify the relative impact of built environment and attitude measures when analyzing different mobility cultures, based on perceptions by new residents.

Methodology

In an explorative study (Klinger et al. 2013) we categorized 44 German cities by using a set of indicators representing the components of the ‘urban mobility culture’ concept. By applying factor and cluster analysis we received 6 different groups of cities representing different mobility cultures: cycling cities, transit metropolises, auto-oriented cities, transit cities with multimodal potential, walking cities with multimodal potential and transit cities.

Starting from this pre-study, we intended to choose city-pairs representing different city clusters in order to survey people who recently moved between contrasting urban mobility cultures. Besides this research-oriented consideration, we had to pay attention to pragmatic criteria such as availability of registration data and a sufficient number of people moving between the selected urban areas. We eventually collected data from people who moved from 2006 to April 2011 between the cities of Bremen (representing ‘cycling cities’) and Hamburg (‘transit metropolises’) as well as the Ruhr area represented by the cities of Bochum (‘transit cities with multimodal potential’), Dortmund (not included in Klinger

Table 1 Significant influences of built environment and attitudes in studies analyzing travel behavior of residential movers

	Data	Travel behavior variable (dependent variable)	Significant BE variables (independent variables)	Significant attitude variables (independent variables)
Aditjandra et al. (2012)	Quasi-longitudinal survey, 219 respondents in Tyne and Wear area (UK), which have moved between 1999 and 2007, two structural equation models	Changes in car ownership	Changes in safety, changes in shopping accessibility (−)	Positive utility of travel attitude (−)
		Changes in driving behavior (frequency)	Changes in safety, changes in shopping accessibility (−), changes in travel accessibility (−), change in social factors (−)	Pro-public transport attitude (−), pro-walking attitude (−), dislike cycling (−), positive utility of travel attitude (−)
Cao et al. (2007)	547 inhabitants of 8 Northern Californian neighborhoods, who moved within 2002 and 2003, four structural equation models (two with dependent variables related to travel behavior)	Changes in automobiles	Changes in 'spaciousness'	Accessibility preference (−), spaciousness preference (−)
		Changes in driving	Changes in spaciousness, changes in accessibility (−), socializing in neighborhood (−), distance to nearest fast food, no. of leisure businesses (−)	Travel minimizing attitude (−), safety of car attitude, car dependent attitude, accessibility preference (−), spaciousness (−)
Cervero and Day (2008)	Quasi-longitudinal survey of 900 households, moved within Shanghai, approx. between 2000 and 2006	Mode change from non-motorized modes (NMT) to bus for commuting	Change in job accessibility index (−), street connectivity index,	–
		NMT to metro	Moved to rail-served districts	–
		NMT to auto	Road length (−)	
		Bus to metro	Moved to rail-served district, road length (−)	–
		Bus to auto	Job accessibility index, prior residence more central, prior residence more peripheral (−)	–
		Monthly commuting duration (household head)	Change in job accessibility index (−), changed job location (−), forced relocation	–

Table 1 continued

	Data	Travel behavior variable (dependent variable)	Significant BE variables (independent variables)	Significant attitude variables (independent variables)
Chatman (2009)	Survey of 999 persons in San Diego and San Francisco metropolitan areas conducted in 2003/2004, 74 % of respondents moved in the previous 10 years, besides others three linear regression models	Trips made by auto (after move)	Residents per road mile within 1-mile radius (−)	Sought transit and walk/bike access during residential relocation (−)
		Trips made by transit (after move)	Retail employees within 1-mile radius (−), heavy-rail station within ½-mile, distance to downtown (−)	Sought transit access
		Trips made by walk/bike (after move)	Four-way intersections in ¼-mile radius	Sought walk and/or transit access
Handy et al. (2005)	1,490 inhabitants of 8 Northern Californian neighborhoods, movers and non-movers, ordered probit model, relocation implemented as change in neighborhood characteristics	Change in driving	Groceries within 1,600 m (−), pharmacies within 1,600 m (−), change in accessibility factor (−), change in safety factor (−)	Car dependent attitude, pro bike/walk attitude (−)
Krizek (2000)	Data taken from the Puget sound transportation panel, before-and-after survey of 550 households moving within study period, 6 paired-samples *t* tests for travel behavior characteristics before/after the move	Mean trip distance (vehicle kilometer traveled, vkt)	Moving from medium to low LADUF[c], low to medium (−)	–
		Mean tour distance (vkt)	As above	–
		% trips with alternative modes (public transit, bike, walk)	High to medium (−)	–
Krizek (2003)	Data taken from the Puget sound transportation panel, n = 6,144 households, incl. 430 which moved within study period, linear regression models	Vehicle miles traveled	NA[a] (−), RA[b] (−), change in NA (−), change in RA (−), change in workplace RA (−)	–

Table 1 continued

	Data	Travel behavior variable (dependent variable)	Significant BE variables (independent variables)	Significant attitude variables (independent variables)
Prillwitz et al. (2007)	Data taken from the German Socio-economic panel (GSOEP), waves 1998 and 2003, n = 3,188 daily commuters, linear regression model, relocation captured as explanatory variable	Change in commuting distance (1998–2003)	Commuting distance 1998 (−), move from core to non-core area, easy access to public transport 2003 (−), move to single-family house	–
Scheiner and Holz-Rau (2013)	791 Movers in Cologne region, quasi-longitudinal survey in 2002/2003 (project StadtLeben), four structural equation models	Car use change	Outward relocation, public transit quality change (−)	Public transit satisfaction change (−)
		Public transit use change	Outward relocation (−), public transit quality change	Public transit satisfaction change
		Bicycle use change	Outward relocation (−), shopping quality change	Shopping satisfaction change
		Walking change	Outward relocation (−), shopping quality change	Shopping satisfaction change

Source as indicated in the table

Table displays only independent variables which are significant at the 0.05 level, negative impacts are indicated by (−)

[a] NA = neighborhood accessibility, measured as factor of housing unit density, land use mix and block size

[b] RA = regional accessibility, measured as accessibility of a neighborhood within the larger region using gravity model calculation

[c] LADUF = Less auto dependent urban form, factor of density, land use mix and intersections per area

Table 2 Study cities: socio-economic and transportation key data. *Sources* EPOMM 2014 and Klinger et al. 2013

	Population size	Population density[a] (pers./km^2)	Household income (av., €)	Modal share (%)				Mobility culture cluster (Klinger et al. 2013)
				Car	Transit	Cycling	Walking	
Hamburg	1,772,100	3,982	1,987	41	19	9	31	Transit metropolises
Bremen	547,360	2,891	1,784	41	12	16	29	Cycling cities
Bochum	378,596	3,940	1,466	53	14	4	28	Transit cities with multimodal potential
Dortmund	584,412	3,626	na	50	22	10	18	–
Essen	579,759	4,208	1,539	54	12	1	33	Auto-oriented cities

[a] number of inhabitants per square kilometer of urbanized land

et al. 2013) and Essen ('auto-oriented cities'). Even if the Ruhr cities were included in different clusters, all three are characterized by a rather strong auto-orientation, as indicated along with other city characteristics in Table 2.

Altogether we received a gross sample of 11,308 people from the municipal registration offices, which collect both the current postal address and the previous one. Furthermore, they provide the date of registration at the current address, which can be interpreted as a proxy for the time of the residential move. Due to cost considerations we were limited to mailing out 5,185 8-page questionnaires in May and June 2011. The participants were asked to send back the completed questionnaire in an enclosed, addressed envelope. One week later a reminder letter was sent out and participants were given the chance to participate in a lottery for two shopping vouchers. Church (1993) found that these measures increase the response rate without biasing the sample. The number of returned questionnaires totaled 1,450 giving an overall response of 28.0 % of which 27.4 % provided valid data for the analysis. The sample can be divided into six subgroups representing the different city-relations that the residential relocations are based on. The size of the subsamples is summarized in Fig. 2.

The comparison of our sample with the overall German population reveals that the participants of our survey are on average younger, better educated and less affluent. Moreover, they are more likely to be female, unmarried, employed and live in a single person household. Our sample and the proportion of the German population which moved in the last 5 years show many similarities with regard to age, professional status and household size. Altogether these socio-demographic characteristics presumably indicate that students and young professionals are overrepresented in our sample. This is confirmed by the relatively high level of education in combination with a rather low income (Table 3).

From the questionnaire we derived variables measuring travel behavior, urban form, residential preferences and the perception of urban mobility cultures in both cities. Travel behavior is measured by the frequency of car travel, rail transit (tramway, subway or light rail) and bicycle use, since these modes are considered as backbones of the transport systems (Deffner et al. 2006) in the Ruhr area, Hamburg and Bremen, respectively. We

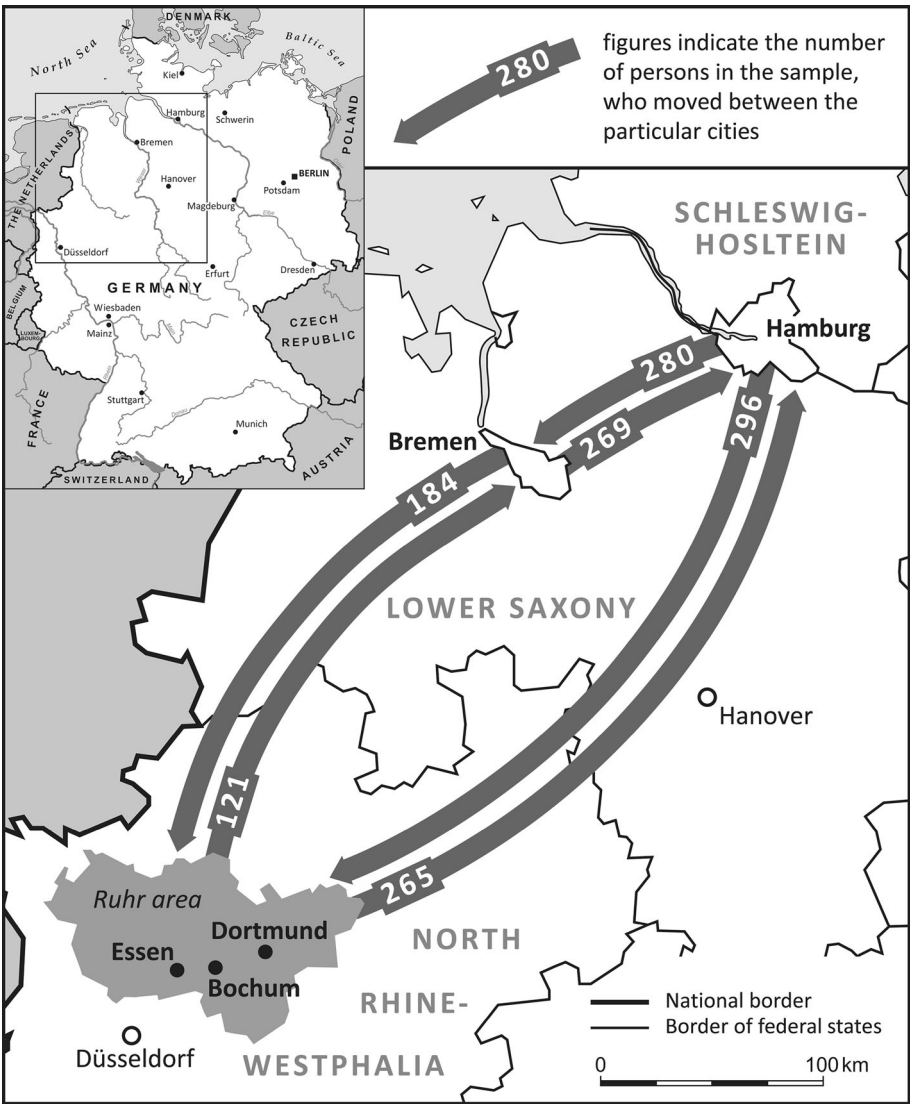

Fig. 2 Study area in Northern Germany. *Source* Authors' concept, map created by Elke Alban, Department of Human Geography, Frankfurt/Main

asked for the frequencies of mode use directly before the relocation and at the time of the survey, using categories which were drawn from the national travel survey 'Mobility in Germany' from 2008 (Infas and DLR 2010). Moreover, we created two change variables. For bivariate statistics we used a simple ordinal figure, indicating whether mode use frequency decreased, continued on the same level or increased after the move by simply comparing the frequencies before and after the relocation. For implementation in ordinary least squares regression models (OLS) we created a metric variable, converting each of the five response categories to an average number of days per week this mode is used. This

Table 3 Distribution of socio-demographic attributes in German population and study sample (in percent)

		German population (all)	German population (only movers) (residential relocation in last 5 years)	Sample
Sex	Female	51.4	51.0	57.8
Age	18–29 years	16.7	38.8	35.1
	30–44 years	23.3	32.9	49.6
	45–59 years	28.8	20.4	8.9
	≥60 years	31.2	7.9	6.0
Highest school certificate	Abitur (university entrance)	24.1	36.0	84.4
	No abitur	75.9	64.0	15.6
Professional status	Employed (full time)	42.9	52.7	54.2
	Employed (part time)	14.4	13.0	11.5
	Not employed	42.7	34.3	30.0
Marital status	Married, couple	57.3	39.1	55.1
	Unmarried	25.8	46.7	39.8
	Other	16.9	14.2	5.1
Household size	Single	21.7	28.2	28.2
	≥2 Persons	78.3	71.8	71.8
Net household income per month	<2,000 €	42.6	[a]	50.0
	≥2,000 €	57.4	[a]	50.0

Source ALLBUS 2010, see also Terwey (2000)

[a] Insufficient number of cases

transformation is based on assumptions and therefore should be considered only as a proxy for the real distributions and changes. Furthermore, in this context it is important to note that changes within the same frequency category, for example from two to three days a week, have been captured as continuous mode use. In light of the idea of state dependency, according to which actual travel behavior is most heavily influenced by previous travel behavior (Beige and Axhausen 2012; Krizek 2003; Prillwitz et al. 2007), we also included the frequency of mode use before the relocation in our models. The remaining explanatory variables can be classified into six categories: urban form and activity space, residential preferences, perceived urban mobility cultures, city-relation, mode availability and socio-demographics (Table 4).

Urban form and activity space

Two urban form related change variables were derived. Firstly, the postal codes of residential locations before and after the move were categorized into three different neighborhood types, which were defined by the German planning authority BBSR: 'inner city', 'traditional neighborhood, close to inner city' and 'edge of the city' (BBR 2007). From this categorization in both cities we derived change variables indicating if the move was directed towards downtown or towards the edge of the city, in comparison to the former residential location (Table 4). That means that, for instance, a move is directed towards downtown if someone, who previously lived at the edge of the city, chose her/his new place of residence in the inner city or traditional neighborhood. This approach is in

Table 4 Overview of variables to predict mode use after a residential relocation

Variable	Items	Definition
Dependent variable		
Travel behavior (change)		
Change in car use Change in rail transit use Change in bicycle use	Bivariate analysis: Ordinal: decreased, same level, increased Multivariate analysis: Metric: change in number of days per week the mode was used	Frequency of mode use was collected by a five-point scale: (almost) daily, 1–3 days per week, 1–3 days per month, less often, (almost) never) and transformed to a metric variable assuming an average number of days per week for each category. Consequently, change variables were calculated by subtracting both frequency figures before and after the move
Independent variable		
Travel behavior (base)		
Car use before move Rail transit use before move Bicycle use before move	Metric: number of days per week the mode was used before the move	Frequency of mode use was collected by a five-point scale: (almost) daily, 1–3 days per week, 1–3 days per month, less often, (almost) never) and converted to a metric variable assuming an average number of days per week for each category
Urban form and activity space (change)		
Change of activity space with residential relocation (change)	Extended (1), not extended (0)	Spatial orientation (neighborhood person lives in, other neighborhood, other city/town) was collected for five activities (work/education, grocery shopping, going to a pub/restaurant, visiting friends, accompanying other people) before and after the move and converted into a change measure
Change of regional accessibility (change)	Multivariate analysis:outwards (1), not outwards (0)	Places of residence before and after the move have been classified (inner city, close to inner city traditional neighborhood, edge of the city)[a] and a change variable has been derived
Residential choice preferences (base)		
Accessibility of highways Availability of parking space Accessibility of public transit Accessibility of city center	Important (1), not important (0)	Respondents were asked if these characteristics had been important for their residential choice at the city of destination
Perception of urban mobility cultures (change)		
7 factors of perceived mobility cultures	Metric, positive values (negative values): this attribute is more associated with the city of destination (origin)	Respondents were asked to indicate whether particular attributes of urban mobility apply more to the city of origin or more to the city of destination (five-point scale from 'more at city of origin" to 'more at city of destination'. Consequently, these 37 items were reduced to seven factors (Table 5)
City-relation of the move (change)		
5 directions of moving	Nominal variable with five possible values, converted into five binary dummies (Bremen to Ruhr and vice versa, Hamburg to Ruhr and vice versa, Bremen to Hamburg)	Current and previous city of residence were provided by the cities' registration offices

Table 4 continued

Variable	Items	Definition
Availability of transport modes (change)		
Car availability Transit availability Bicycle availability	Availability increased (1) Availability not increased (0)	As indicated by respondents before and after the move (yes/no for bike and transit season ticket, always/sometimes/never for car), converted into binary change variables (dummies)
Socio-demographics (base/change)		
4 base variables:		
Sex	Female (1), male (0)	As indicated by respondents, converted into binary dummies
Education level	Student, graduated (1), other (0)	
Age	30 years and older (1), younger (0)	
Employment	Employed (1), other (0)	
3 change variables:		
Income	Increased (1), not increased (0)	As indicated by respondents, converted into binary dummies (income) and change variables (no. of persons)
Number of adults/children per household	Metric	

Source own questionnaire and own calculation

[a] Intra-urban spatial categories defined in BBSR (2010) and BBR (2007). *Source* Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), intra-urban monitoring, data provided by the statistical departments, cities of Bochum, Bremen, Dortmund, Essen and Hamburg

line with other studies that measure the built environment indirectly by defining typical neighborhood categories (Schwanen and Mokhtarian 2005a, b; Khattak and Rodriguez 2005). Our understanding of the different neighborhood types is oriented on Scheiner and Holz-Rau (2013) stating 'that the spatial scope from urban to suburban represents a continuous spectrum rather than a discrete choice'.

The second urban form indicator is derived from peoples' responses to questions about locations they regularly visit for particular activities such as working and shopping. The responses were measured on a four-point-scale including the categories "I do not carry out this activity", "I carry out this activity in the neighborhood I live in", "I carry out this activity in another neighborhood of the city I live in" and "I carry out this activity in another municipality". We compared these categories for the time before and after the move and then transformed them into a binary change variable that can take the values 'extended activity space' or 'not extended activity space' (Table 4). Schönfelder and Axhausen (2010, p. 129) define activity spaces as 'geographic indicators of observed travel patterns over prolonged periods.'

Even if this variable is primarily behavior and preference-related, it also reflects the spatial distribution of facilities around the place of residence that may constrain the individual activity space (Hägerstrand 1970). In this view, the variable indicates a strong relation to urban form features such as density and diversity. A large activity space, for instance, points towards a low density of the built environment.

Residential choice preferences

We integrated preferences towards a particular neighborhood type and accessibility attributes into multivariate models in the form of four binary variables. We asked whether

accessibility to highways, availability of parking space, accessibility to public transit and accessibility to the city center were important for choosing the actual residential location (Table 4). These variables are used as indicators for residential self-selection. Self-selection here is expressed by a residential choice related to preexisting neighborhood and transport mode preferences.

Perceived mobility cultures and city-relation of the residential relocation

Furthermore, we included variables that are inspired by the concept of urban mobility cultures and therefore are related to the cities as a whole. With a set of 37 items we aimed to implement the mobility culture approach (Deffner et al. 2006) introduced above. We asked for the respondents' perception of various mobility aspects in both the city of origin and the city of destination, reflecting all four key elements of the concept, namely: travel behavior and underlying preferences; infrastructure and built environment; transport policy; mobility-related discourses. We assessed travel behavior and built environment in detail whereas policy and discourses are measured in a more compact way (for an overview of all items see Table 5). To reduce complexity and minimize the existing intercorrelation between the items, we conducted a factor analysis using principal component analysis and varimax rotation. The analysis resulted in 7 factors of comparative mobility culture perception with an Eigenvalue higher than 1 (Kaiser criterion) (Table 5). The variance explained by the factor model is 64.2 %. Factor loadings illustrate that grouping of variables is mainly structured by transport mode. Interestingly, cycling orientation is pooled with environmental-friendly policy and media coverage (Factor 1), whereas transit-related items are associated with a vibrant street life (Factor 2). High car use is combined with negative agglomeration effects like high prices and aggressive atmosphere (Factor 5). Particularly, the responses to items related to transport policy and discourses are characterized by high shares of missing values (varying between 4.1 and 10.2 %). This suggests a relatively low awareness towards these topics. Additionally, the idea of contrasting mobility cultures is also accounted for by integrating the inter-city direction of the residential relocation (city of origin and city of destination) in terms of binary dummy variables. This is of particular interest since we aimed at highlighting the impact of city-wide characteristics compared to neighborhood-scale attributes. We expected, for example, that a move towards the edge of the city has different impacts on mode use depending to which city it is directed. This is because we hypothesize that travel behavior of new residents is shaped by local mobility cultures. We assume that this impact is at least as strong as the one of the urban form characteristics of the new neighborhood. Additionally, we accounted for the importance of city-wide characteristics by including the city-relation the move was based on. Subsequently, a multinomial variable with five values that refers to the reference category 'move from Hamburg to Bremen' was included in the multivariate analyses.

Mode availability and socio-demographics

Items measuring availability of particular means of transport and socio-demographic attributes of the respondents complete the set of variables. Both groups of variables had substantial power in previous studies of travel behavior. Access to specific modes is often understood as a proxy for a person's actual travel behavior. Consequently, Beige and

Table 5 Factors of mobility culture perception—loadings of items

Mobility culture perception factors	Items: Where…	Loadings[a]
1. Cycling orientation and environment- friendly transport policy	… do people cycle more often?	0.834
	… are cyclists more accepted by other road users?	0.826
	… are cycle paths and bike racks of higher quality?	0.821
	… is cycling more fun?	0.807
	… is peoples' travel behavior more environment-friendly?	0.706
	… is cycling more dangerous?	−0.627
	… do people use the car more often?	−0.594
	… does transport policy focus more on environment-friendly modes?	0.559
	… do local media focus more on environment-friendly modes?	0.514
	… does transport policy focus more on car users?	−0.464
2. Transit orientation and street life	… public transit supply more attractive?	0.842
	… do people use public transit more often?	0.756
	… is public transit use more dangerous?	0.723
	… do people combine different modes more often?	0.610
	… do people spend more time on streets and public places?	0.599
	… is transport policy more innovative and advanced?	0.468
	… is live on streets more bustling?	0.441
3. Walking orientation	… is walking more convenient?	0.726
	… are pedestrians more accepted by other road users?	0.712
	… is walking more fun?	0.685
	… are walking paths and connections more attractive?	0.635
	… is walking more dangerous?	−0.609
	… do people walk more often?	0.567
	… are cyclists more considerate?	0.453
4. Car orientation	… is car use more convenient?	0.855
	… is car use more fun?	0.846
	… are car users more accepted by other road users?	0.711
	… are roads and parking lots of higher quality?	0.577
	… is car use more dangerous?	−0.519
	… does transport policy focus more on car users?	0.401
5. Agglomeration effects and lack of safety	… is transport more reasonably priced?	−0.699
	… is life on streets more bustling?	0.525
	… is the atmosphere on streets more aggressive?	0.511
	… is car use more dangerous?	0.478
	… is public transit use more dangerous?	0.460
	… do people use the car more often?	0.421
6. Media coverage of transport issues	… do transport issues have a higher weight in public discourse?	0.806
	… do transport issues have a higher weight in conversations with friends and colleagues?	0.762

Table 5 continued

Mobility culture perception factors	Items: Where…	Loadings[a]
	… do local media focus more on car use?	0.641
	… is the development of the transport system more often blocked by political conflicts?	0.411
7. Advanced transport policy	… is transport policy more continuous?	0.669
	… is transport policy more innovative and advanced?	0.661
	… is the development of the transport system more often blocked by political conflicts?	−0.508
	… does transport policy focus more on environment-friendly modes?	0.490

Source own data and own calculation

[a] Positive loadings indicate that this feature is perceived to be more true at the city of destination, whereas negative loadings point towards a higher occurrence at the city of origin

Axhausen (2012) labeled them as 'mobility tools'. In the context of the complex process of residential moving (Chatman 2009; Stanbridge et al. 2004) we interpret the acquisition or abandonment of mobility tools as reaction to or anticipation of travel requirements after the relocation (Scheiner and Holz-Rau 2013). Based on levels of car, bike and public transit season ticket availability before and after the relocation, three ordinal change variables were created. In terms of socio-demographics we added four status-related dummy variables measuring sex (female), education level (university degree, student), age (30 years or older) and professional status (employed). The socio-demographic assessment is completed by three change variables, two metric ones related to the varying number of adults and children per household and a dummy indicating an increase in monthly income.

Statistical analysis and findings

Bivariate analysis

For a first insight into the effects of a residential relocation between cities of contrasting mobility cultures we conducted Chi square-tests to identify variations in mode use change by destination city. The results summarized in Table 6 confirm our expectations in terms of the 'backbone mode' in each city and are in line with findings from earlier work on aggregate analysis of urban mobility cultures in German cities (based on a set of 23 objective and subjective indicators, for details see Klinger et al. 2013). Car use increased most clearly after a move to the Ruhr area whereas it does not significantly differ between people who moved to either to Bremen or Hamburg. Similarly, the increase of rail transit use of movers to Hamburg exceeded that of people relocating to Bremen and the Ruhr. In these two cities again the transit use of new residents does not differ significantly from each other. Bicycle use was somewhat different since the increase of cycling is higher for persons moving to Bremen compared to those moving to Hamburg, whereas cycling orientation in the Ruhr area lags behind Hamburg. In total, the differences between destination cities are significant for all three modes of transport. This finding indicates that there is a city-specific influence on the mode choice of new residents. However, it is necessary to

Table 6 Crosstabulation and Chi square-tests for mode use change and city of destination. Source: own data and own calculation

Change in mode use (%)		Destination		
		Bremen	Hamburg	Ruhr
Car use	Decreased	34.3	33.3	21.6
	Unchanged	42.1	42.8	35.8
	Increased	23.6	23.9	42.6
n = 1,338/Chi square = 48.7 (sign. 0.000)				
Rail transit use	Decreased	41.0	28.1	41.4
	Unchanged	36.5	38.9	34.3
	Increased	22.5	33.0	24.3
n = 1,348/Chi square = 27.9 (sign. 0.000)				
Bicycle use	Decreased	16.3	30.9	47.4
	Unchanged	36.6	44.1	41.8
	Increased	47.2	25.0	10.8
n = 1,361/Chi square = 165.4 (sign. 0.000)				

conduct multivariate analyses in order to reveal which particular city-wide characteristics have an impact on mode choice and to find out if this impact is still valid when controlled for other aspects such as urban form, residential preferences and socio-demographic aspects.

Multivariate analyses

Aiming to verify the results of the bivariate analyses, we conducted three multivariate linear regression models in order to predict the impact of particular mobility culture components by controlling for urban form, residential self-selection and socio-demographics. Table 7 shows the results for each variable including non-standardized and standardized regression coefficients. The non-standardized coefficients can be interpreted as the change of days per week the particular mode is used if all other independent variables remain constant. Furthermore, Table 7 shows the variance inflation factors, which indicate to what extent the variance of this variable increases in consequence of intercorrelation with other explanatory variables. As other relocation studies have done, (Cervero and Day 2008; Prillwitz et al. 2007) we implemented Ordinary Least Squared models including change in mode use as endogenous variable. Therefore, mode use change was implemented as a metric variable measuring the difference in the number of days per week the specific mode is used before and after the move. Unlike many other studies we included all independent variables in our models, since this approach is recommended for theoretically-driven studies as an adequate way to include an argument-based set of variables (Backhaus et al. 2011). In sum, the models for change in car, rail transit and bicycle use include ten metric and nineteen binary variables as exogenous variables (see above). Assumptions dependent on OLS models have been tested by graphic and mathematical measures. The results of these tests, as shown at the bottom of the same table, indicate that not all assumptions are completely met which is not unusual for models based on 'soft' data such as attitudes and perceptions. Linearity is mainly given apart from slight non-monotonic deviations that do not show a definite curvilinear form. These deviations can be accepted since they do not invalidate the analysis although they might marginally weaken the model fit (Tabachnick and Fidell 2007, p. 127). Not all models complied with

Table 7 OLS regression models explaining change in car, rail transit and bicycle use. *Source* own data and own calculation

Variables	Model 1—change in car use[a]			Model 2—change in rail transit use[a]			Model 3—change in bicycle use[a]		
	Beta[d]		VIF	Beta[d]		VIF	Beta[d]		VIF
	Unst.	Stand.		Unst.	Stand.		Unst.	Stand.	
Constant	0.874**			1.329**			1.294**		
Base travel measure									
Car/rail transit/bike use before move	−0.568	−0.531**	1,4	−0.673	−0.560**	1,3	−0.498	−0.461**	1.3
Socio-demographics (base)									
Sex (female)	−0.115	−0.021	1,1	−0.132	−0.022	1,1	−0.034	−0.006	1.1
Degree, student	−0.221	−0.034	1,1	−0.003	0.000	1,1	*0.300*	*0.045***	*1.1*
Age: 30 years and older	0.335	0.060**	1,2	−0.587	−0.094**	1,2	−0.119	−0.021	1.2
Employed	0.560	0.099**	1,3	−0.146	−0.023	1,3	−0.026	−0.005	1.3
Socio-demographics (change)									
Increase in income	0.230	0.043**	1,2	−0.164	−0.027	1,2	*−0.240*	*−0.044***	*1.2*
Change in number of adults	0.003	0.002	1,0	0.014	0.006	1,0	−0.043	−0.022	1.0
Change in number of children	0.290	0.062**	1,1	−0.274	−0.052**	1,1	0.12	0.003	1.1
Mode availability (change)									
Increase of car availability	1.119	0.170**	1,2	−0.502	−0.068**	1,1	−0.468	−0.070**	1.1
Increase of transit availability	−0.783	−0.111**	1,1	1.130	0.142**	1,2	−0.359	−0.050**	1.1
Increase of bicycle availability	0.032	0.004	1,1	0.217	0.022	1,1	0.694	0.078**	1.2
Residential choice preferences (base)									
Highway accessibility	0.618	0.087**	1,2	−0.376	−0.047**	1,2	−0.559	−0.077**	1.2
Parking availability	0.708	0.104**	1,2	−0.609	−0.079**	1,2	−0.041	−0.006	1.2
Transit accessibility	−0.931	−0.164**	1,3	0.995	0.155**	1,3	−0.019	−0.003	1.3
City center accessibility	−0.274	−0.049**	1,3	0.582	0.092**	1,3	0.165	0.029	1.3
Urban form (change)									
Extended activity space	*0.291*	*0.054***	*1,1*	0.166	0.027	1,1	−0.026	−0.005	1.1

Table 7 continued

Variables	Model 1—change in car use[a]			Model 2—change in rail transit use[a]			Model 3—change in bicycle use[a]		
	Beta[d]		VIF	Beta[d]		VIF	Beta[d]		VIF
	Unst.	Stand.		Unst.	Stand.		Unst.	Stand.	
Move towards edge of city[b]	0.079	0.013	1,2	0.001	0.000	1,2	0.016	0.003	1.2
Mobility culture perception (change)									
Factor 1—cycling orientation, environment-friendly transport policy	−0.072	−0.027	2,9	−0.110	−0.037	2,9	0.607	0.223**	3.0
Factor 2—transit orientation and street life	−0.232	−0.087**	2,4	0.445	0.148**	2,5	0.058	0.021	2.4
Factor 3—walking orientation	−0.061	−0.023	1,1	0.039	0.013	1,1	*0.109*	*0.041**	*1.1*
Factor 4—car orientation	0.086	0.032	1,2	*−0.127*	*−0.042***	*1,2*	−0.026	−0.009	1.1
Factor 5—agglomeration effects, lack of safety	0.134	0.050**	1,6	−0.019	−0.006	1,6	−0.089	−0.033	1.6
Factor 6—media coverage of transport issues	0.071	0.026	1,1	−0.056	−0.019	1,1	0.012	0.004	1.1
Factor 7—advanced transport policy	−0.059	−0.022	1,1	0.126	0.042**	1,1	−0.14	−0.005	1.1
City-relation of the move (change)[c]									
From Bremen to Hamburg	0.252	0.037	4,1	−0.453	−0.059	4,2	0.049	0.007	4.1
From Ruhr to Bremen	0.145	0.018	1,7	*−0.456*	*−0.051***	*1,7*	*0.407*	*0.050**	*1.7*
From Bremen to Ruhr	*0.333*	*0.034*	*2,4*	0.134	0.012	2,4	−0.298	−0.030	2.4
From Hamburg to Ruhr	0.740	0.109**	2,5	0.224	0.029	2,5	−0.698	−0.101**	2.5
From Ruhr to Hamburg	0.176	0.027	3,4	−0.242	−0.033	3,5	−0.245	−0.037	3.4
Summary statistics									
N	1,333			1,342			1,356		
Adjusted R^2	0.494			0.496			0.432		
F/p	45.79/0.000			46.45/0.000			36.59/0.000		

Table 7 continued

Variables	Model 1—change in car use[a]			Model 2—change in rail transit use[a]			Model 3—change in bicycle use[a]		
	Beta[d]		VIF	Beta[d]		VIF	Beta[d]		VIF
	Unst.	Stand.		Unst.	Stand.		Unst.	Stand.	
Model assumptions									
Linearity (graphic)	(yes)			(yes)			(yes)		
Normality of residuals (graphic/mathematical)	yes/no			no/no			no/no		
Homoscedasticity (gr./math.)	no/no			yes/yes			yes/no		
No multicollinearity (VIF < 10)	yes			yes			yes		

Italic variable becomes (in)significant after testing with heteroscedasticity-consistent standard errors

[a] Measured in change of days per week the mode is used

[b] Calculation based on intra-urban spatial units, defined in BBSR (2010) and BBR (2007). *Source* Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), intra-urban monitoring, data provided by the statistical departments, cities of Bochum, Bremen, Dortmund, Essen and Hamburg

[c] Reference category: From Hamburg to Bremen

[d] *Unst.* unstandardized, *Stand.* standardized

* Significant at 0.1 level; ** significant at 0.05 level

the requirement of normality of the residuals, which has been accepted since large samples ($n > 40$) are robust to a violation of this assumption, which means that the significance of the regression coefficients is not biased by the distribution of the residuals (Backhaus et al. 2011, p. 96, Mendenhall and Sincich 2012, p. 411). Heteroscedasticity of the residuals has been found for car use and cycling models, which means that the standard errors of prediction are not equal for all scores of the dependent variables. Since this violation of the homoscedasticity assumption leads to model inefficiency, we additionally tested regression models with heteroscedasticity-consistent standard error estimators proposed by MacKinnon and White (1985) and implemented into SPSS software by Hayes and Cai (2007). In Table 7, originally significant variables that became non-significant after correcting for heteroscedasticity and vice versa are written in italic. Multicollinearity does not appear for any of the models, given that for none of the models variance inflation factors (VIF) exceed the critical value of 10 (Mendenhall and Sincich 2012, p. 364) in terms of decreasing the precision of the predicted regression coefficients. For some coefficients related to mobility culture perception and city-relation VIF are higher than 4, which points to an intercorrelation or interaction between these groups of variables. In order to reveal characteristic interaction among the independent variables we excluded those variable groups showing particular many significant influences that are mainly the mode availability, residential choice preferences and the mobility culture perception. Subsequently, we analyzed in what way the remaining variables responded to these changes. In sum, all three eliminations primarily led to changes in the significance levels of socio-demographics and city-relation variables. Additionally, the exclusion of mode availability and residential choice preferences produced significance changes in the perception of mobility cultures. Among the results two are of special interest. As already indicated by the VIF-values, eliminating perceived mobility culture leads to a rising importance of the origin–destination-relation, most apparently in the cycling model that then shows significant influences for four out of the five tested city-relations. Secondly, the exclusion of the residential choice preferences is followed by considerable significance changes among the socio-demographic variables. For instance, after deleting mode availability, employment has a significant influence on cycling and rail transit use. The same is true for its impact on cycling after eliminating residential choice preferences. This confirms expectations that mode availability and residential choice are clearly interrelated with socio-demographic characteristics.

Another challenging aspect of model construction was a high number of missing values for some independent variables, such as the policy and discourse-related factors of the mobility culture concept and the dummy variable ‘move towards the edge of the city’. The missing values have been replaced by applying multiple imputation method, which estimates missing values by using all other independent variables as predictors in regression models (Ortúzar and Willumsen 2011, p. 89). The remaining missing values in the models conducted stem from the dependent variables.

All models offer a decent quality of fit, indicated by R^2-values higher than 0.4. The highest proportion of the explanatory power is caused by the baseline travel variables, showing that high frequencies of mode use are unlikely to be further increased after the move. This finding indicates both saturation effects and a high propensity to maintain established behavior patterns even in the context of biographical key events, known as state dependency (Krizek 2003; Prillwitz et al. 2007). Socio-demographic variables only moderately impact mode use change. Although rail transit use and cycling are more affected, gender and change in number of adults in household are insignificant for all models, whereas rise in both, age and number of children has opposite effects on car

usage (reinforcing) and rail transit (diminishing), which points to a combination of family formation and car use. Similarly, increasing income leads to a higher level of car use and a lower level of cycling. Further socio-demographic influences lead to positive relationships between employment and driving as well as between studying/graduating and cycling.

Impacts triggered by varying mode availability follow roughly our expectations. Whereas car availability reinforces car use and reduces use of rail transit and bikes, better access to a transit system leads to less driving, more rail transit use and more cycling. Bicycle availability is only significant in predicting the level of cycling.

All four variables representing residential choice preferences towards various accessibility attributes are significant predictors for change in driving and rail transit use, whereas cycling is negatively affected only by the preference towards highway accessibility. An extended activity space as an indicator for a less dense and diverse urban form pattern on neighborhood-scale is only relevant for estimating modifications in car change. The missing influence of changes in the regional accessibility confirms the findings of bivariate analysis presented above.

The influence of the perceived change of mobility culture, the centerpiece of our study, and the impact of the particular city-pairs is in line with our expectations. Car use is negatively influenced by a perceived increase of transit orientation and positively affected by higher agglomeration affects. Furthermore, it rises significantly when moving from Hamburg to the Ruhr area. The use of tramway and subway benefits from a more transit-oriented mobility culture as well as from a more advanced transport policy whereas car orientation has a negative impact on the use of rail transit. Moreover, rail transit use decreases significantly when moving from the Ruhr to Bremen. Cycling is also strongly influenced by a bicycle-oriented cultural setting and somewhat less explicitly by an orientation towards walking. Furthermore, bicycle use increases by moving from the Ruhr to Bremen and is clearly reduced when moving from Hamburg to the Ruhr.

Discussion and policy implications

Our analysis of changes in mode use after a residential relocation offers some insights into the differences and correlation between three major modes of transport. For this purpose we analyzed the factors influencing the mode use after moving to another city including a new urban mobility culture, defined here as travel-related socio-physical context. In comparing the three analyzed modes, the private automobile is most dependent on objective socio-demographic indicators such as income, employment or age of the respondent. Moreover, car travel is the only one of the three means of transport which is influenced by urban form and accessibility at the local level as indicated by an extended activity space. This finding confirms earlier work on driving (Cao et al. 2007; Handy et al. 2005). In contrast, changes in bicycle use are nearly independent from socio-economic and urban form-related influences, with the exception that current and former students are more likely to cycle. The changes in bicycle use are more likely to be caused by the overall cycling and walking orientation as one dimension of the overall mobility culture. Subsequently, an increase in cycling and walking among new residents can be interpreted as a result of observing and reproducing the mobility patterns, which other local residents have already successfully realized. Similar relationships have been called ‘social spillover effects’ in the context of modal choice (Goetzke and Rave 2011) and ‘neighbor effect’ with regard to preferences for new vehicle technologies (Mau et al. 2008). This somewhat

simplified comparison of driving and cycling points to important policy implications. Efforts to reduce car use in urban contexts are more likely to succeed if they are directed to socio-economics, urban form and infrastructure constraining daily travel patterns. Examples for such measures are road pricing or a more local-oriented provision of shopping and leisure facilities. Cycling, in contrast, seems to be more influenced by soft factors such as the modal choice of peers or the perceived acceptance of cyclists. This finding is supported by the commonly shared experience of a cycling boom which has been taking place in many German and European cities over the last decade without substantial investments in infrastructure or cycling oriented neighborhood design. Rather, it emerged as a socio-cultural movement which attached positive values and attitudes such as environmentalism or coolness with riding a bike (Lanzendorf and Busch-Geertsema 2014). At the same time, this finding illustrates the fragility of this cycling orientation, since it might be associated with negative values and interests in the same way. Some German media illustrate such tendencies by reporting about 'cycling rambos' and uncivilized cycling behavior (Der Spiegel 2011). This relatively strong sensitivity towards attitudes and discourses could be interpreted as an effect of bike use not yet being embedded in an established, stable and long lasting socio-physical framework as, for instance, car use is. Therefore, a cycling-oriented transport policy should stabilize a positive image of urban cycling among citizens and decision-makers (e.g. through campaigning and travel demand management).

Another interesting finding is the contrasting impact of some variables towards car use and rail transit use. For example, increases in age and number of children lead to more car use and less transit use. The opposite is true for a transit-oriented mobility culture. The diminishing impact of a vibrant street life (a variable loading highly on the transit orientation factor) towards private car use confirms findings of a UK-based study (Aditjandra et al. 2012, p. 30). From this perspective, reconsideration of travel behavior in case of a residential move could, in a somewhat simplified way, be understood as a trade-off between car and transit use. At first glance, cycling seems to be rather independent from this major dichotomy since the model for cycling does not show directly opposing influences to the other two modes. Interestingly, though cycling is influenced by the availability of all three modes at the new place of residence. Generally, in a policy context, planners and operators may be well advised to better understand how measures of transport supply or travel demand management targeted towards a particular means of transport also have effects on the use of other modes of travel.

The last important aspect of our study is the different degree to which the three modes of travel are affected by residential choice preferences. Whereas car use and rail transit use show significant influences for all four implemented residence and accessibility-related preferences, cycling is only affected by the subjective importance of highway accessibility. In other words, cycling seems to be less dependent on processes of residential self-selection. At the same time, no direct urban form influences have been proven. It can be argued instead that cycling is influenced foremost by the new socio-cultural setting after the move, expressed by dominant behavior and policy settings as well as the built extension of a bicycle culture in the form of cycling-related transport infrastructure.

Conclusion and future research

Our study adds the perspective of long distance movers and the idea of urban mobility cultures to research of residential relocation and daily travel behavior. Consequently, the analysis has been linked to the concepts of built environment and residential self-selection

and their impacts on daily mobility patterns. In this context, urban mobility cultures themselves are understood as rather solid mobility orientations of both transport policy and a city's inhabitants, encompassing long-lasting elements such as urban form and lifestyle patterns at city level. The analysis is based on a standardized questionnaire asking people who have recently moved between the German cities Bremen, Hamburg and the Ruhr area for their travel behavior before and after the relocation as well as their perception of the contrasting mobility cultures represented by these cities. In our analysis we concentrated on the change in car, rail transit and bicycle use as dependent variables. Our findings can be arranged into three sections. First, variables derived from the mobility culture approach have identified socio-cultural settings as factors influencing mode choice of new residents. Second, our analysis shows that the spatial impact is shifting from neighborhood-scale to metropolitan-scale level when focusing on long-distance movers. In our study the metropolitan level is represented by the relevant dimensions of urban mobility culture. As an exception, car use is still partly dependent on local level. Third, mode-specific differences in regard of the factors influencing travel behavior have been revealed. Most obviously among the three modes, car use is the one most dependent on objective characteristics like socio-economic attributes or spatial characteristics of the neighborhood the person moved to. Interestingly, preferences of residential choice and underlying self-selection processes heavily influence modifications in car use and rail transit use, but have considerably less impact on cycling. In sum, we found that city-wide characteristics such as aggregate travel behavior or perceived transport policy representing urban mobility cultures have a strong influence on frequency of cycling of new residents and to a lesser extent also driving and rail transit use.

The study has several limitations, though. First of all, the applied OLS regression models suggest a linear relationship between residential relocation and travel mode change, whereas these components are actually interwoven by a complex set of mutual direct and indirect influences. Linear regression models are appropriate to generate a clearly structured overview of the complex interdependencies of travel, built environment and attitudes. However, future research of long distance moving and travel behavior change would clearly benefit from more complex multivariate statistics such as longitudinal structural equation models. Correspondingly, our study is based on the assumption that residential choice is influencing mode orientation at one particular point of time. In reality though, the adaption of travel behavior to the new context is better understood as a process and additionally influenced by the travel-related socialization before the move. Therefore, future research would benefit from integrating the periods of living at the new and the old location into statistical models. Lastly, panel analysis would presumably lead to more valid results, since quasi-longitudinal surveys like ours have regularly been criticized because the quality of retrospective responses is potentially negatively affected by missing recall capacity of the respondents (Beige and Axhausen 2012; Hollingworth and Miller 1996). Altogether, our study can be understood as a first step towards analyzing the complex interdependencies between residential relocation, urban mobility cultures and travel behavior change.

Acknowledgments This research has been made possible by a grant of the Rhein-Main-Verkehrsverbund (RMV) and the Integriertes Verkehrs- und Mobilitätsmanagement Rhein-Main (ivm), the founders of the professorship for mobility research at Goethe University Frankfurt. The authors are grateful to Gabrielle Hermann, Veit Bachmann as well as the editor and three anonymous reviewers for their helpful comments on a previous version of the paper. They also thank Elke Alban for the figures in this article. Earlier versions of this paper have been presented at IATBR 2012 in Toronto (Klinger and Lanzendorf 2012), the

Forschungskolloquium at Technische Universität Dortmund 2012 and the German Geographers Meeting 2013 in Passau. The authors thank the participants of the sessions for their constructive feedback.

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