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Abstract:
In mobility research scientists from different disciplines agree widely that a current challenge is to consider macro-structural influence factors and individual motives simultaneously. In explanations of mobility behavior the connections between sociological approaches, individual behavior concepts coming from psychology and spatial planning approaches are still poorly developed. In different disciplines an interdisciplinary approach is emphasized as a need but the development in methodological and empirical terms is lagging behind. This article combines different disciplinary perspectives to develop a conceptual and empirical approach to pursue the question whether and in which way the consideration of the physical geographical structure of a specific local environment contributes to the explanation of individual mobility behavior. In doing so, the generic Theory of Planned Behavior is enhanced by *Geographic Structural Data* to develop the Geographic Theory of Planned Behavior (GeoTPB). A standardized questionnaire combined with a GIS-Model enabled the empirical implementation of the theoretical frame. The statistical results, in particular the goodness of fit indexes and the statistical comparison of the TPB structural equation model (SEM) versus the GeoTPB SEM support the utility of the GeoTPB in predicting mobility behavior. Since in fragmented mobility regimes political influence and responsibility is particularly high for physical infrastructure and city planning it is crucial to identify the most influential starting points to develop sustainable and comprehensive mobility concepts. The here developed GeoTPB provides a theoretically founded, empirically feasible and statistically supported approach to identify these.

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Geographic Theory of Planned Behavior (GeoTPB) – an Interdisciplinary Approach for the Explanation of Mobility Behavior

Simone STRAMBACH & Lisa DÖRING

1. Introduction[1]

Mobility is a prerequisite for a self-determined life and participation in social interaction (Bamberg, 2001, p.7). Moving in a flexible, efficient and comfortable way is a gain of life quality for most individuals and important for a country's economic success (Adler, 2005, p.5; Rammler, 2011). At the same time, the increased environmental awareness about negative traffic-related effects particularly caused by private motorized transport are substantially proven in numerous environmental reports. One of these studies about environmental indicators, published by the European Commission, makes clear that 75.8% of the greenhouse gas ozone is emitted by energy consumption. Traffic (as a measure for mobility) is the main consumer of energy (Eurostat and European Commission, 2007, p.128; Adler, 2005, p.5). In Germany for example, conventional motorized traffic uses six times more energy than air traffic and 27 times more energy than rail traffic (measured in ktoe - kilo tons of oil equivalent) (Eurostat and European Commission, 2007, p.128). Additionally fossil fuels are limited and thus the dependency of conventional motorized engines poses ample risks. To address these risks sustainability and sustainable mobility are promoted by politics (Rammler, 2011, p.40, Bundesregierung, 2010).

In contrast, globalization and the profound structural transformation of highly developed countries towards knowledge economies and knowledge societies (Strambach, 2011, p.25, Kujath, 2010, p.19; Foray, 2004) is connected with an increase of mobility demand. The dynamic growth of economic transactions related to knowledge itself and the more systematic generation, commodification and trading of knowledge are the main underlying characteristics of knowledge-based economies. This ongoing development is connected with a growing percentage of knowledge-based working positions (Strambach, 2004, p.1ff). Even though new information and communication technologies facilitate virtual communication and information exchange, there is no disagreement that face to face relations remain very important in knowledge production. Compared to information, knowledge does not easily flow due to its inherent intangible and tacit dimension, its process character and its context dependence (Foray, 2004; Nooteboom, 2009; Strambach, 2011). These features generate the need for co-presence as knowledge is a socially constructed outcome of interactive learning processes, based on personal experience and linked to individuals as well as embodied in specific contexts. Short or medium-term visits and temporary proximity are considered a forceful mechanism enabling coordination and learning over spatial distance (Torre, 2008). Moreover knowledge work is often organized in project-based forms that reinforce the need for temporal spatial proximity and enhance mobility (Torre, 2008; Crevoisier and Jeannerat, 2009). In addition, the interconnection of leisure and work time and flexible working hours make mobility behavior even more complex (Hinz,

[1] We appreciated very much the useful discussions with our colleagues Aribert Heyder, Udo Kelle, Hendrik Kohl, Kristin Momberg, Alexander Nolte and Christoph Reudenbach.

2008). At the same time a societal change towards individualization and pluralization of lifestyles as well as changes in norms and values are reshaping the context for individual mobility behavior.

Accordingly there is a hidden tension between the requirement of sustainability and the growing demand for mobility in knowledge-based economies and societies. In order to take into account sustainability and the enhanced mobility demand simultaneously, complex and interdisciplinary comprehensive mobility concepts instead of isolated product innovations like e-bikes and cars are needed. Confronted with more complex and fragmented mobility processes, we argue there is no single best practice concept for sustainability in the mobility realm. Hence strategies intending to foster sustainable mobility have to be embedded and adjusted to local environments and respective target groups for being efficient. It is widely acknowledged that subjective perception and individual beliefs affect mobility behavior (Ajzen, 2002b; Bamberg, 2001). However, somewhat underexplored is the influence of the macro context of the specific local environment and its subjective perception on the individual mobility behavior. Knowing more about this relationship may provide a starting point for political actors to develop locally adapted concepts to support sustainable mobility.

The article aims to develop a conceptual and empirical approach by combining different disciplinary perspectives to pursue the question: whether and in which way does the consideration of the physical geographical structure of the specific local environment contribute to the explanation of individual mobility behavior.

2. Methodological and Theoretical Frame

In mobility research scientists from different disciplines agree widely that a current challenge is to consider macro structural influence factors and individual motives simultaneously (Rammler, 2011; Götz, 2007; Scheiner and Holz-Rau, 2007; Monheim, 2001). Indeed the understanding of the complexity and interdisciplinarity of mobility behavior is growing but to our knowledge there are no methodic approaches that meet these requirements to date (Scheiner and Holz-Rau, 2007, p.488; Golob, 2001). In the following a brief outline of the development of mobility research will be presented and the current mobility approaches will be introduced to provide the theoretical background for this study.

Since the beginning of the 20th century psychology (e.g. social, cognitive, ecological and traffic psychology) analyses the relationship between the individual and traffic. Thanks to this discipline decision-making theories, like transportation mode choice or route choice theories were developed. These approaches are primarily focussing on the individual behavior without taking the macro structure into account. In contrast social science approaches (e.g. in traffic sociology) investigate in the societal mobility on the macro level, but neglect the individual behavior and spatial influence factors. Spatial sciences (e.g. geography, traffic, regional and city planning and engineering) in turn concentrate on spatial determinants that influence mobility. The transportation geography has its roots in the economic geography so that traditional models are mainly objective and deterministic. While in the 1950/60s the traditional traffic research distinguished between aggregated studies on the macro level and individual studies on the micro level (Nuhn and Hesse, 2006; Gather et al., 2008), nowadays there are additionally attitude-orientated theories which include subjective indicators (Scheiner, 2009; Scheiner and Holz-Rau, 2007).

Since 1990 the overlaps of the disciplines are noticed and interdisciplinary mobility research has been established. Yet the representatives of the mentioned perspectives still mainly oppose each other (Götz, 2011; Monheim, 2001). In recent mobility research a lot of different disciplines are active and the research focus develops internationally very differently, but there are mainly three literature threads that come along with the mentioned disciplinary perspectives.

However in a few actual studies psychological, sociological and spatial science perspectives are partly combined. Götz (2007) combined the micro psychological perspective with the sociological macro view and defined mobility styles (Mobilitätsstile). According to him there is still the need to connect these perspectives with the space (Götz, 2007). A similar approach was made by Schneider and Limmer (2008) who identified mobility types referring the family status and business mobility as well as Cohen (2010) who defined mobility types regarding temporal and occupational restrictions (Schneider and Limmer, 2008; Cohen, 2010).

First approaches to build a bridge between the spatial and sociological perspective were made by Urry, Axhausen and Larson (2009; 2006). As a sociologist Urry connected social networks with mobility and together with the spatial scientists Axhausen and Larson their spatial extension was surveyed (Urry, 2002; Larsen et al., 2006). Thus this approach connects the social and spatial perspective but neglects the individual freedom of action. The leeway for agency in the individual mobility behavior to take decisions and choices are not taken into account. With the Theory of Planned Behavior (TPB) Bamberg et al. (2000) linked the individual behavior with space. However space as a macro structural influence factor is only introduced in a dichotomous form as rural or urban space. Even though the approach does not reflect the structural diversity of local macro contexts, it offers a promising approach.

In sum it can be concluded that the mentioned studies provide interesting insights and identified relevant determining factors as well as they enriched substantially methodic approaches with new perspectives. Nevertheless in the explanations of mobility behavior the connections between sociological approaches, individual behavior concepts coming from psychology and spatial planning approaches are still poorly developed.

The literature review shows that in different disciplines an interdisciplinary approach is emphasized as a need but the development in methodological and empirical terms is lagging behind. In spatial science actual behavior control given by the spatial context is of major interest. While the latter is of minor importance as research object for other disciplines such as sociology and psychology, this article aims to contribute to a deeper understanding of how the physical geographical structure and its subjective perception as well as the individual beliefs affect the mobility behavior. Hence the key question we follow in the paper is: "*Does the further consideration of the geographical context contribute to explain the mobility behavior?*" In other words the central argument of the paper is that models should be able to explain mobility behavior in its specific local structural embeddedness in a more differentiated way.

The Theory of Planned Behavior is a commonly applied generic behavioral theory often also used in the field of mobility research. Substantial insights are already available in determinants and in the specification of interactive effects. Therefore the TPB provides the base for our further research. While the TPB has the micro view and focusses on the individual level, the spatial context, placed on the macro level, is mainly taken into account by aggregated data. In the following the objective is to combine the micro and macro level by individualizing the spatial context and integrating the latter into the TPB. Thereby we intend to establish the Geographic Theory of Planned Behavior (GeoTPB). However for doing so two further guiding questions need to be addressed:

- Where is the spatial context causally located within the TPB?
- How can the macro context and individual micro behavior be investigated empirically so that the data refer to the same scale and entity?

In this article the GeoTPB will be developed and applied to the mode choice of pedestrians to exemplify the methodological frame and theoretical concept. To do so, the methodic realization will be worked out with GIS analysis, while for the statistical evaluation structural equation models will be used.

3. Geographic Theory of Planned Behavior

In the following the GeoTPB will be placed in a methodological frame, afterwards the theoretical concept of the theory will be presented and finally the implementation and statistical evaluation will be demonstrated. The socio-scientific Macro-Micro-Macro Model (MMM Model) (Coleman, 1986) provides the methodological frame for this research. The transportation mode choice (1) as the object of investigation is placed on the macro level (see Figure 1). Explaining this macro phenomenon it is indispensable to explore the individual behavior on the micro level based on the MMM Model.

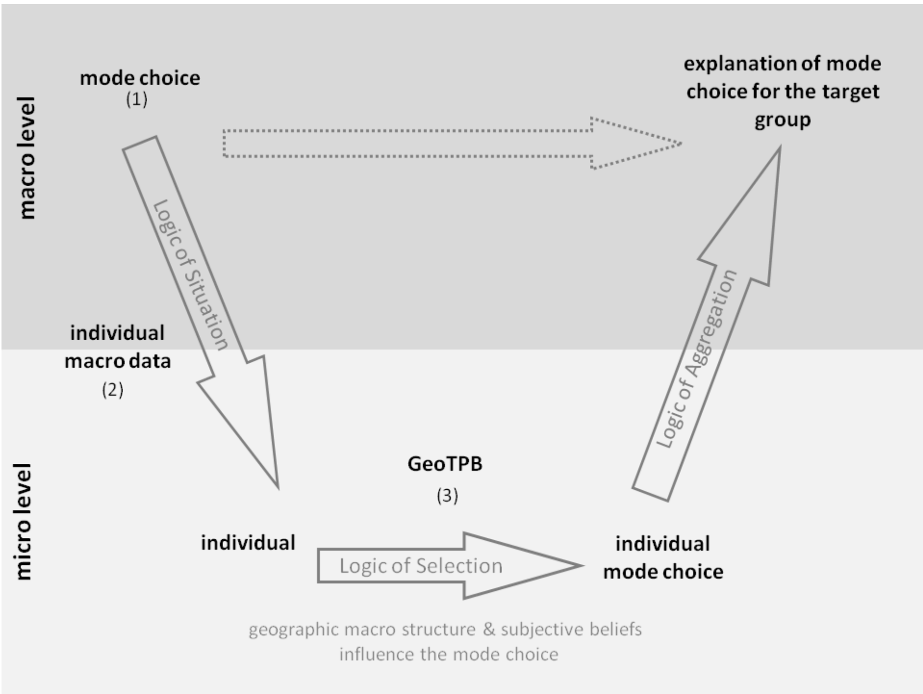

Figure 1: MMM Model applied to transportation mode choice

To do so, in the Logic of Situation (2) the context in which the individual behaves is analyzed. The situation for mode choice is assumed to be defined by living and working location and further the route between these locations with its characteristics like *time*, *distance*, *difference in height* and *slope* that are considered. In addition the access to transportation modes is taken into account. Since these characteristics vary strongly between individuals, it is necessary to take them into consideration on an individual level.

On the micro level the personal attitude and beliefs are considered. These data build the input for the GeoTPB which is the hereby developed theory of behavior, integrated in the Logic of Selection (Figure 1(3)). Finally it can be assumed that the analysis of the individual mode choice contributes to a better understanding of the same on the macro level.

Within the MMM Model the theory of behavior is the crucial point for the analysis. The TPB (Ajzen 1991) is a generic rational choice theory that has been applied to plenty different behaviors. In summary according to the TPB "human behavior is guided by three kinds of considerations: beliefs about the likely consequences or other attributes of the behavior (*behavioral beliefs* [BB]), beliefs about the normative expectations of other people (*normative beliefs* [NB]), and beliefs about the presence of factors that may further or hinder performance of the behavior (control beliefs [CB])."(Ajzen, 2002b, p.665). Further there is *Actual Behavioral Control* (ABC) that "refers to the extent to which a person has the skills, resources, and other prerequisites needed to perform a given behavior" (Ajzen, 2006). For few existing mobility studies the TPB is the theoretical foundation (Bamberg et al., 2000; Hunecke et al., 2007). In these studies the ABC is not considered in the empirical models. Since most of the studies are based on psychological approaches the external factors are evaluated by questionnaires and interviews. In consequence the data is subjective and does not reflect ABC. Thus ABC is only included by the proxy *Perceived Behavior Control* (PBC) as also suggested by Ajzen (Bamberg et al., 2000; Hunecke et al., 2007).

For sociologists and psychologists the role of ABC is no particular object of investigation but in spatial science the ABC given by the context is of major interest (Blöbaum et al., 1998, Ajzen, 1991; Bamberg et al., 2000). The development of a GeoTPB requires an extension of the commonly used TPB with geographic structural data. The so far theoretical construct ABC will be measured by geographical indicators in the GeoTPB.

From a geographical point of view the influence of the macro context is essential for the mobility behavior in space. In the following it will be shown that it is possible to consider it and refer to the individual socio-psychological influence factors simultaneously. According to the TPB and taking classical attitude-orientated traffic theories into account it is argued that the macro structure provides individually different objective factors that are perceived subjectively different by each individual.Therefore we develop the construct Geographic Structural Data (GSD) and extend the TPB to increase the degree of explanation. GSD concretizes part of ABC and replaces it. Based on theoretical considerations and explorative empirical studies the indicators *difference in height* (height), *slope* (in %), *distance* and *time* for the individual route measure the latent variable GSD.

Our main hypothesis is that the construct GSDi (individualized GSD) is causally placed before the subjective perception (see Figure 2). These impact effects are not just derived from methodological considerations but also with regard to the content. We argue that personal Beliefs and thus *Attitude towards Behavior* (AB), *Subjective Norm* (SN) and *Perceived Behavior Control* (PBC) are depending on the individual situational macro-context; e.g. person A, living on a mountain, commutes to work in the close-by valley by car because of the steep slope and height the person has to overcome on the way. As the same person A moves into the Valley; now the individual-situational macro-context changes and person A perceives a higher behavioral control to go by bike and a positive attitude towards cycling to work because the slope is not steep and no height has to be overcome anymore. Accordingly marked topographies or inadequate bicycle infrastructures may contribute to a negative attitude towards cycling. In this case cycling is expected to be exhausting and as a consequence the actual opportunity for cycling is perceived very low. To meet these thoughts in the GeoTPB it is assumed that the beliefs are affected by the structural context and therefore the GSD is placed causally in front of the TPB.

Due to this model structure the beliefs become internal constructs, in consequence there are just unambiguous relationships between them allowed (Weiber and Mühlhaus, 2010, p. 40). Based on significant regressions between the beliefs and A, SN and PBC found by Bamberg et al. (2000) the here presented model structure is grounded on existing results (Figure 2; Bamberg et al., 2000, p. 190). Grounded on theses theoretical and empirical considerations the causal system of the GeoTPB has been established (Figure 2).

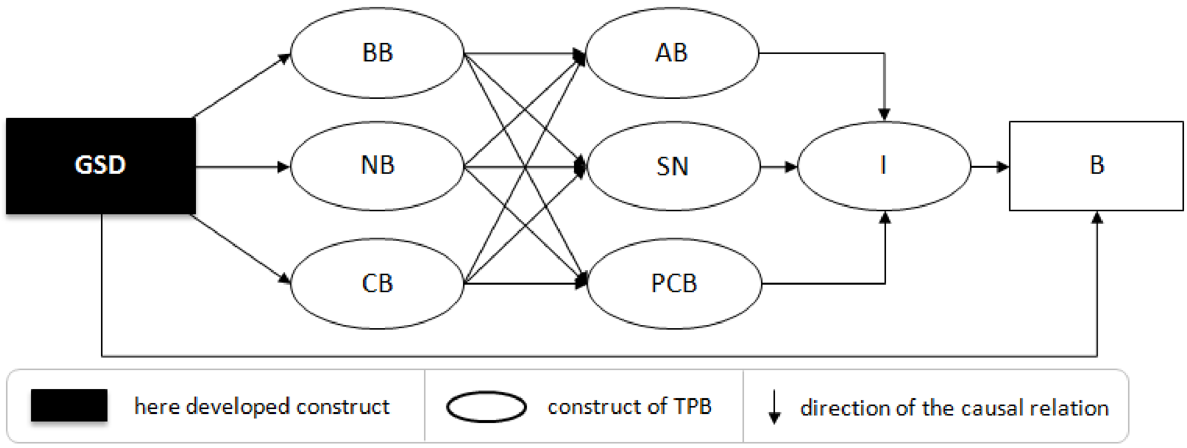

Figure 2: Geographic Theory of Planned Behavior

(GSD= Geographic Structure Data, BB= Behavioral Beliefs, NB= Normative Beliefs, CB= Control Beliefs, AB= Attitude towards Behavior, SN= Subjective Norm, PBC= Perceived Behavior Control, I= Intention, B= Behavior, ellipses= latent variable, rectangle= measured variable)

As already mentioned, in most existing mobility studies the macro structure is measured in an aggregated way, for instance connectivity or services in traffic zones or postcodes. The central argument for the development of the GeoTPB is that the GSD and the intended ways to overcome space are very different for each individual. Accordingly there is the challenge on the basis of theoretical structure of the GeoTPB to measure the new construct GSD individually. An appropriate approach is still lacking. However, with a combination of already existing methods in geography and social sciences in addition with the necessary empirical data to verify the model, such an approach can be developed as explained in the following.

4. Empirical approach

The approach is built on the complementary instruments qualitative interviewing, a standardized survey and Geographical Information System (GIS). The data were collected in a project of the Philipps-University of Marburg on the students´ mobility behavior (Strambach et al., 2011). Figure 3 provides an overview of the theoretical framework and the methodical implementation of the research approach. It shows where the GeoTPB is placed in the methodological framework and demonstrates that the theoretical constructs of the GeoTPB are measured by both individual questionnaires and GIS network analysis based on structural data and individual data.

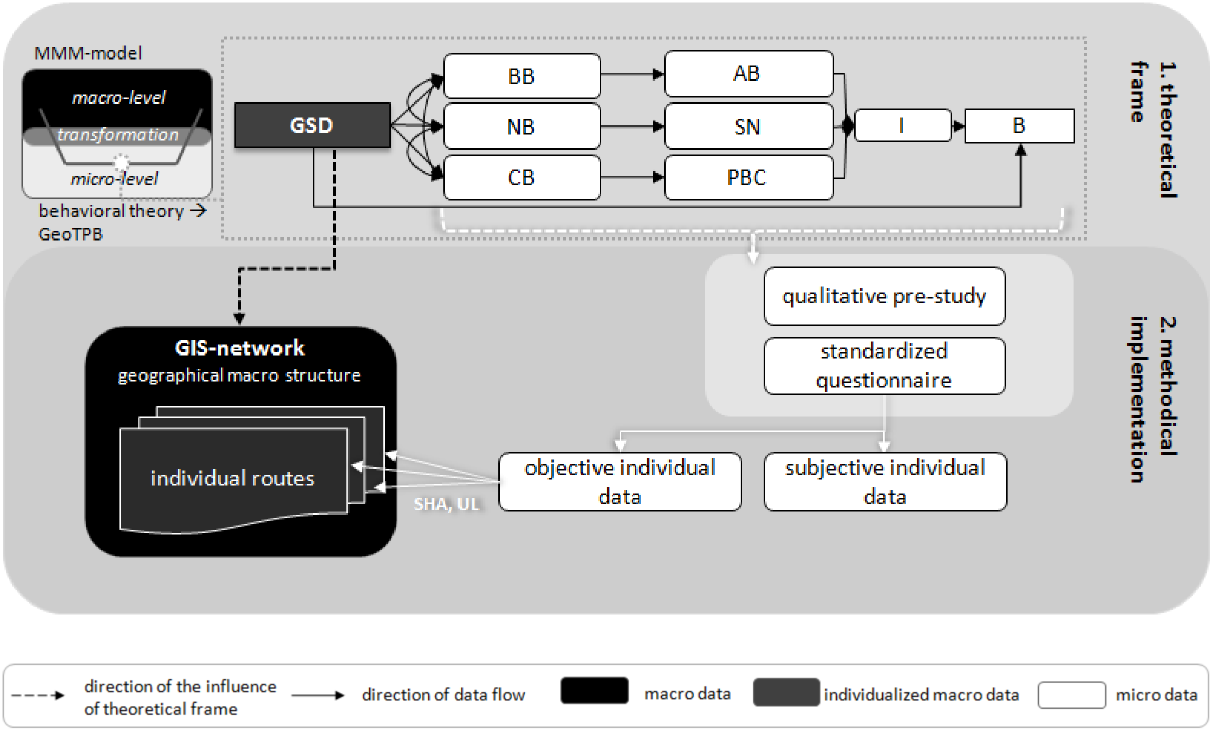

Figure 3: Study design, theoretical framework and implementation of the GeoTPB

(GSD= Geographic Structure Data, BB= Behavioral Beliefs, NB= Normative Beliefs, CB= Control Beliefs, AB= Attitude towards Behavior, SN= Subjective Norm, PBC= Perceived Behavior Control, I= Intention, B= Behavior)

For the survey, a representative stratified sample referring to the number of enrolled students in each faculty was made. The standardized questionnaire was based on categories (e.g. fast, ecological) and relevant variables were identified by an explorative pilot study using interviews, focus groups and other qualitative methods. With the standardized questionnaire individual objective data about the semester home address (SHA), the most visited university location (UL) as well as the subjective beliefs and attitudes towards the different modes (bicycles, bus, car and walking) were collected for 3741 students. Ajzen´s instructions to build a questionnaire for the TPB were taken into account to ensure validity of the data (Ajzen, 2002a). The data were measured in batteries on a five-point scale for each item similar to the Likert scale. For instance >Walking/cycling/driving/taking the bus to the university is for me… 'fast, comfortable, cheap, flexible, stress-free, save, ecological, supporting my fitness'< was asked with answer possibilities on a scale from likely to unlikely. In addition commuting behavior was surveyed. It was asked which means of transport are actually used on the usual way to the university. Multiple answers were possible, so the actual behavior was assessed on a scale from 1; signifying one mode is used on the university way, to 4; which means all considered means of transport are used.

GIS was applied to model traffic lines and the topography. It provides sophisticated tools for quantitative spatial analysis. Based on OpenStreetMap (OSM) and ATKIS data the street network and topography was modeled (ATKIS, 2005; OpenStreetMap Wiki Contributors, 2011). First the OSM-data was cleaned, completed and relevant information was added. According to the means of transport the speed was defined; pedestrians 4km/h, cyclists 15km/h and cars corresponding to the speed limit (four street classes are differentiated; see Figure 4). Second, based on that data and the geocoded SHA and UL the distance and the time for the university way were calculated for each student and each mode of transport for the fastest route. In a third step height and slope for each route were calculated based on the topography and unified with the vector data of each route.

The described data provides a reliable dataset and representative sample, but however there are certain weaknesses that should be acknowledged. In the realization of the project some compromises in terms of data detail had to be accepted to ensure the feasibility. For example the SHA of the students were evaluated by the street name and not the house number to guarantee anonymity and avoid a high quote of abortion of the survey. In consequence the SHA was located for all students living on the same street in the middle of the vector. The maximal bias caused by that was 1.86 km (two students), but all in all Marburg has a narrow street network and 50% of the streets are 0.15-0.47 km long, hence the bias in these cases is maximal 240 meters.

Figure 4 summarizes the empirical results of the survey. It shows the inner city of Marburg with the geocoded SHA and UL; the bigger the point the more often the location was mentioned. It illustrates the four traffic line types which were differentiated. In the analysis restrictions for each mode of transport were included, for example a pedestrian could walk over all traffic lines in arbitrary direction apart from the highway, the cyclists could use all network lines apart from pedestrian ways because these include steps and forest tracks et cetera. For the analysis of car routes only streets were considered and one-way restrictions were added moreover.

In summary individual subjective and objective as well as individual macro structural data were computed from a questionnaire and a GIS application. These data were used as input for the estimation and comparison of the structural equation models of the traditional TPB and the GeoTPB.

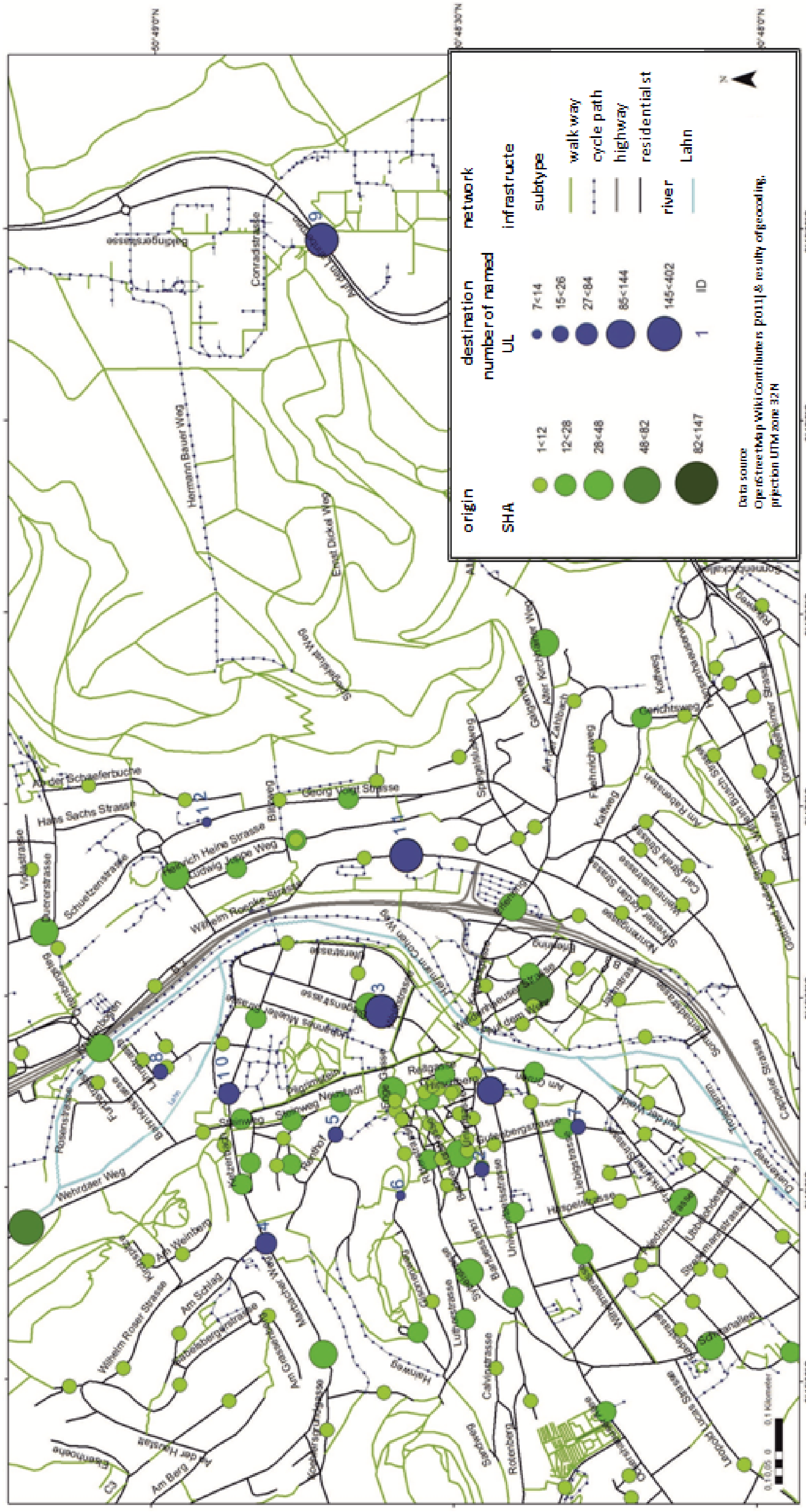

Figure 4: Geocoded semester home addresses (SHA) and university locations (UL) in the inner city of Marburg

5. Statistical Analysis

Structural equation models (SEM) offer an opportunity to verify statistically the hypothetical causal relationship between the constructs simultaneously and thus provide an adequate method to analyze the complex model structure and interactive effects between the constructs.

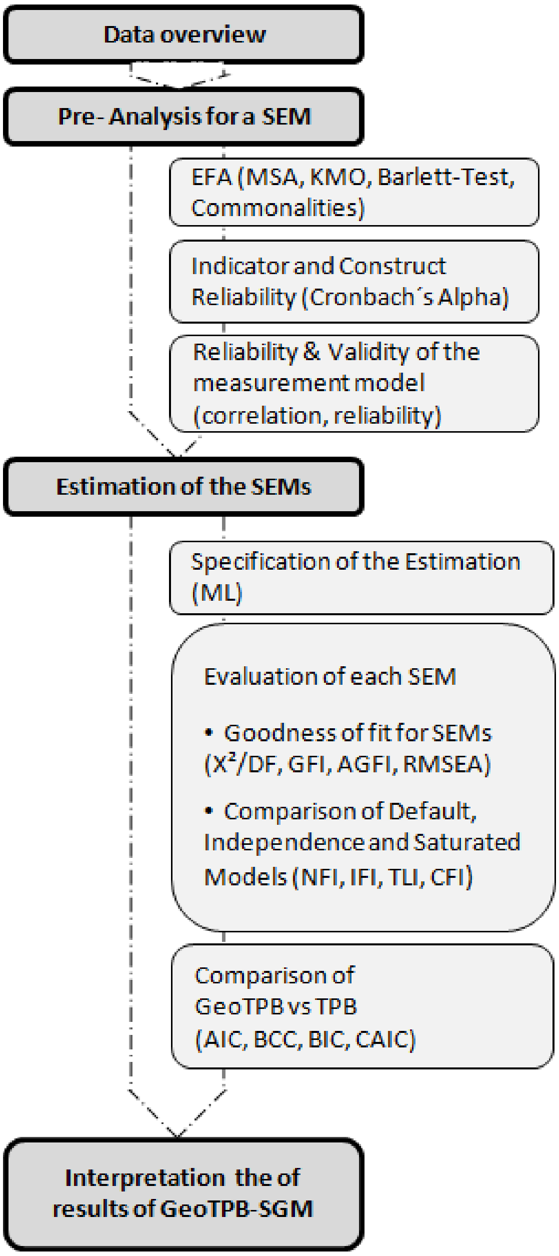

Figure 5: Empirical evaluation of TPB and GeoTPB, work steps to estimate the SEM

Figure 5 illustrates the analytical steps which were made within the empirical evaluation. In a first step a descriptive overview of the data was taken. In a second step pre-analysis identified the relevant indicators. Thus in a third step the SEMs of the TPB and the GeoTPB were estimated, evaluated and compared. Finally the results could be interpreted.

For the following analysis the data of pedestrians was used to exemplify the procedure. Pedestrians are chosen because they are especially environmental-friendly and a high percentage of them is desirable. Given time is based on a constant speed for pedestrians the scores are perfectly correlated with the distance and thus excluded in the exemplified pedestrian model.

After a first data overview, it becomes clear, that the data are normal distributed. The explorative factor analysis (EFA) as the first step of the pre-analysis, includes communality, KMO-Criterion, Kaiser-Criterion, Cronbach´s Alpha and confirmatory factor analysis. Due to unacceptable values in the EFA various items were dismissed. In the last step of the pre-analysis of the SEM the remaining fifteen items were included in the reliability and validity tests.

Table 1 summarizes the reliability of the constructs. The indicator reliability over 0.4 for all indicators suggests that they are suitable for the model (Weiber and Mühlhaus, 2010, p.122). Most of the values are even above 0.6 and signify desirable values (Bagozzi and Yougjae, 1988, p.80). The average variance extracted (AVE) for each factor exceeds the threshold value 0.5. The factor loadings are additionally significant on a confidence level of 99% and exceed the threshold value 0.5 with values over 0.7.

In consequence the measurement models are classified as significant for the further estimation and comparison of the TPB and GeoTPB SEM (Weiber and Mühlhaus, 2010, p.180f).

Table 1: Goodness of fit test through reliability criterions (calculated in AMOS and EXCEL)

(BB= Behavioral Beliefs, GSD= Geographic Structure Data, SN= Subjective Norm, CB= Control Beliefs, PBC= Perceived Behavior Control, I= Intention, AB= Attitude towards Behavior,)

Constructs	Items	Item reliability	Factor loading	Error variance	Factor reliability	AEV
threshold value		>=0.4	>=0.5		>0.6	>0.5
BB	comfortable	0.59	0.77	0.027	0.99	0.96
	flexible	0.603	0.78	0.026		
	stress-free	0.733	0.86	0.026		
GDS	height	0.599	0.77	1.055	0.72	0.56
	km	0.794	0.89	0.027		
SN	opinion of third	0.85	0.95	0.025	0.99	0.97
	support of third	0.847	0.92	0.025		
CB	distance too long	0.861	0.93	0.026	0.98	0.96
	too steep	0.572	0.76	0.028		
PBC	decision freedom	0.495	0.70	0.028	0.98	0.96
	difficult/easy	0.898	0.95	0.026		
I	try	0.912	0.96	0.025	0.99	0.97
	purpose	0.876	0.94	0.025		
AB	pleasant/ unpleasant	0.813	0.90	0.024	0.99	0.97
	good/bad	0.841	0.92	0.025		

6. Results

Out of the empirical raw data a correlation matrix was calculated and submitted to structural equation analysis applying the Maximum Likelihood method in AMOS. The TPB and GeoTPB SEMs were estimated and the goodness of fit of the estimation and the empirical data was assessed by standard indexes first for each model independently and later for both models in comparison.

Goodness of Fit Indexes

Chi-Square (χ^2) depends strongly on the sample size and evaluates for large samples in most cases a bad model fit (Hooper et al., 2008, p.53f) but the proportion of Chi-Square to degrees of freedom (χ^2 /DF) is helpful and can be interpreted as the lower the value the better the model fits (Weiber and Mühlhaus, 2010, p.162). The Root-Mean-Squared-Error of Approximation (RMSEA) evaluates the difference between the empirical data and the correlation matrix and is independent of the sample size. Values less than 0.05 indicate an acceptable model fit (Reinecke and Pöge, 2010). The index PCLOSE declares the probability of error that the RMSEA is less than 0.05. A value between 1-0.5 indicates a good fit. The Goodness-of-Fit (GFI) and the Adjusted Goodness-of-Fit (AGFI) indexes are indicators between 0 to 1 and indicate a good model fit with values above 0.9 (Hooper et al., 2008, p.54).

Apart from these indexes, the Normed (NFI), Incremental (IFI) and Comparative Fit Index (CFI) as well as the Tucker-Lewis-Index (TLI) summarized under *Baseline Comparisons* indicate if the tested model is similar to the saturated model, which holds the statistical best values. The threshold values are: CFI 0.97-1 = good fit; 0.95-0.969 = acceptable, NFI 0.95-1 = good fit; 0.9-0.949 = acceptable (Moosburger and Schermelleh-Engel, 2008, p.319), for IFI and TLI >= 0.9 = good model fit (Weiber and Mühlhaus, 2010, p.171).

Table 2 displays the indexes for each model. For the TPB model χ^2 indicates that the empirical data is not similar to the correlation matrix. In addition GFI is marginal over 0.9 and AGFI is actually under the threshold value. Even though the Baseline Comparisons point to an acceptable model fit, due to the first mentioned χ^2, GFI and AGFI as well as moreover the unacceptable RMSEA and PCLOSE, the model fit indexes of the TPB model indicate a bad model fit (Browne and Cudeck, 1993, p.136ff quoted in Backhaus et al., 2011, p.144). Besides that the ratio of χ^2 and degrees of freedom (CMIN/DF) confirms these results.

Table 2: Goodness of fit indexes for TPB and GeoTPB

Model	CMIN/DF	GFI	AGFI	RMSEA	PCLOSE	χ^2	NFI	IFI	TLI	CFI
TPB	29.354	0.91	0.86	0.105	0.000	2583.19	0.936	0.938	0.915	0.938
GeoTPB	6.981	0.97	0.954	0.048	0.781	593.378	0.985	0.987	0.982	0.987

In contrast the GeoTPB model achieves a much lower CMIN/DF value and can be interpreted as a better model fit (Heyder and Decker, 2011, p.247). However the high χ^2 -value indicates that the empirical data is not similar to the correlation matrix. A possible reason for that is the large sample size because the RMSEA, which is tolerant towards the sample size, points to a good model fit. PCLOSE, GFI and AGFI confirm a good model fit. Additionally the Baseline Comparisons approve this interpretation with values about 0.98 for the GeoTPB model (Moosburger and Schermelleh-Engel, 2008, p.319).

Results of the Structural Equation Models

Since the model fit and the reliability are clarified, the estimations within the causal SEM can be analyzed. In the following the focus lies on the relationship between the constructs. Figure 6 summarizes the results of the tested SEMs.

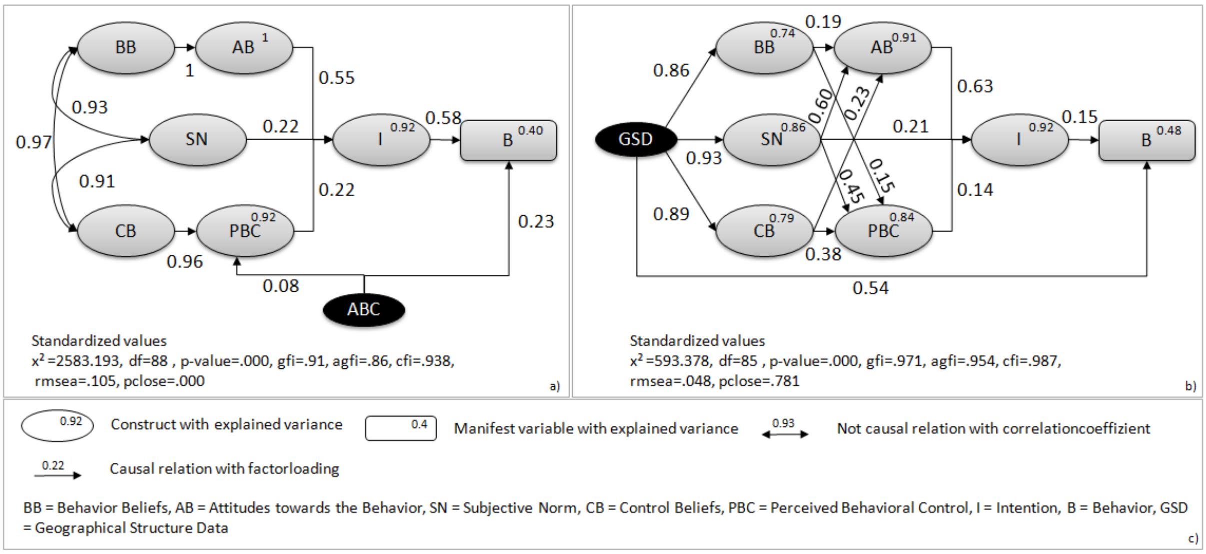

Figure 6: Estimated structural equation models, a) TPB, b) GeoTPB & c) legend

In both models all relations are significant apart from the relation PBC to Intention (I). Even though some factor loadings are less than 0.2 they are included because the theoretical concept should be tested. Apart from that the critical ration (C.R.) indicates with values above 1.96 that all parameters conduct a significant part to the models (Weiber and Mühlhaus, 2010, p.180; Arbuckle, undated, p.30).

The factor loadings from one construct to another give the opportunity to draw conclusions on the importance and influence of each construct. In the TPB model (see Figure 6a) the factor loading from *Intention* to *Behavior* (walking to university) is the strongest, it is stronger than the loading for ABC on *Behavior*. Though the construct ABC itself has an influence on the *Behavior* almost half as strong as *Intention*, which is influenced by all other constructs. *Intention* has the strongest influence on *Behavior*. *Intention* itself is mainly influenced by *Attitude* and *Behavioral Beliefs*. However *Actual Behavior Control* affects the *Behavior* after *Intention* (0.584), *Attitude* (0.319) and *Behavioral Beliefs* (0.319) remarkably with a total effect of 0.238. In contrast *Actual Behavior Control* has an unexpected low factor loading on *Perceived Behavioral Control* (d.e. 0.08).

In the GeoTPB model the direct effects are different. As can be seen in Figure 6b *Subjective Norm* has a direct effect on *Perceived Behavioral Control*, *Attitude* and *Intention*. Thereby the construct has in particular a strong effect on *Attitude* and *Perceived Behavioral Control* whereas considerable less on *Intention*. *Subjective Norm* in turn is mainly affected by *Geographical Structure Data*. This might be explained by low perceived social pressure when *Geographical Structure Data* values are high. In other words social pressure to walk to university is mostly perceived as low when the distance is far and the topography strong. Apart from that the construct *Geographical Structure Data* has an almost four time higher factor loading on *Behavior* than *Intention*. In addition

Geographical Structure Data explain a large part of the variance of *Control Beliefs*, *Behavioral Beliefs* and *Subjective Norms*. Referring the total effects GSD respectively ABC play a dominant role in the GeoTPB but is an important factor in the TPB model as well. In the GeoTPB model GSD construct is the only one that influences all other constructs remarkably with total effects between 0.62 and 0.927. It strongly affects *Attitude* (0.915), PBC (0.88) and *Intention* (0.893). According to the total effects the pedestrians´ behavior is more than four times stronger influenced by the *Geographic Structural Data* (0.674) than by *Intention* (0.149). In the GeoTPB all other constructs have a total effect smaller than 0.1 on the behavior.

Summarizing the total effects show that the construct *Behavioral Beliefs* plays a dominant role in the TPB while it has a marginal effect in the GeoTPB to explain the pedestrian behavior. *GSD* respectively *ABC* in comparison have a strong influence on *Behavior* in both models even though the influence is stronger in the GeoTPB model. Remarkably the explained variance of the behavior is 8% higher in the GeoTPB than in the traditional TPB. Overall the results indicate that *Geographic Structural Data* influence significantly beliefs and the GeoTPB has a higher degree of explanation than the traditional TPB.

Comparison of the TPB and GeoTPB

For the comparison of two models the information criterions Akaike Information (AIC), Consistent Akaike Information (CAIC), Bays Information (BIC) and Browne-Cudeck Criterion (BCC) are usually used. They inform about the complexity, goodness and simplicity of SEMs. The lower the information criterions the better the model fit (Arbuckle, undated, p.591; Reinecke and Pöge, 2010, p.785). Thus in a comparison of two models the model with lower information criterions can be interpreted as the better one and should be used (Weiber and Mühlhaus, 2010, p.198). Table 3 shows the information criterions for each model. It indicates that the values of the GeoTPB model are lower than the values of the TPB. In consequence they point to a less complex model and stand for a better model fit than the values of the TPB. Additionally the GeoTPB values are closer to the saturated model and thus enforce this interpretation.

Table 3: Information criterions of the structural equation models, comparison between TPB and GeoTPB (AMOS Output)

Model	AIC	BCC	BIC	CAIC
TPB	2679,193	2679,832	2960,11	3008,11
GeoTPB	695,378	696,057	993,852	1044,852
Saturated	272	273,81	1067,932	1203,932
Independence	40342,622	40342,835	40436,261	40452,261

To sum up the results of the pre-analysis, the estimation and evaluation of the SEM as well as the comparison of these models the RMSEA, GFI and AGFI illustrate that the values of GeoTPB indicate a good model fit. In contrast the goodness of fit indexes of the TPB suggest a minor model fit. In both models χ^2 is unacceptable but as generally acknowledged this index depends strongly on the sample size and therefore the other goodness of fit indexes are more meaningful. Under additional consideration of the Baseline Comparisons the TPB shows acceptable values whereas those of the GeoTPB underline a good model fit. Finally the information criterions prove that the empirical data fits better to the SEM of the GeoTPB than to SEM of the conventional TPB. Furthermore the explained variance in the GeoTPB is 8% higher than in the TPB. Consequently the conclusion can be drawn that the GeoTPB model explains the pedestrians´ behavior better than the TPB.

7. Discussion and Conclusion

The GeoTPB aims to meet the discussed challenge in mobility research how to consider the macro structural influence factors and individual motives simultaneously by combining different data, methods and disciplinary perspectives. This paper aimed to answer the key question whether the geographical context can contribute to explain mobility behavior. Analyzing the latter, the results confirm that the GeoTPB enriches the explanatory power compared to the conventional TPB.

The MMM-Model provides a reasonable methodological framework within which the here developed GeoTPB was integrated. The guiding question *“Where is the spatial context causally located within the TPB?”* was answered in this study. The finally causal structure is based on the spatial context that is the foundation for beliefs and affects the behavior directly as well. The claimed causal structure was found to be reasonable to predict mobility behavior. The GeoTPB structure is grounded on logical considerations of geographical and social-psychological theories and supported by the presented statistical results.

A standardized questionnaire combined with a GIS-Model enabled the empirical implementation of the theoretical framework. The questionnaire provides the individual subjective data and moreover the objective individual data, like the Semester home address and university location that enable the GIS analysis. The GIS analysis in turn made it possible to individualize the spatial macro context, so that the data were generated and referred to the same scale and entity. With the questionnaire we took advantage of the characteristic that the survey data is subjective and individual. However the disadvantage of it was avoided by calculating the *time*, *distance, height* and *slope* in a GIS rather than generating these data by subjective estimations. Due to the technical strength of GIS it was possible to create individual macro data and include them combined with the subjective data from the questionnaire in further statistical analysis.

Generally it can be stated, to implement the GeoTPB the data have to fulfill the following preconditions:

i) being disaggregated on the individual level (here it was calculated by GIS analysis)
ii) referring to the same entity and situation
iii) referring to a certain spatial, temporal and socio-demographical as well as socio-institutional frame

The statistical results in particular the goodness of fit indexes and the statistical comparison of the two models support the utility of the GeoTPB as a behavioral theory to predict mobility behavior. An additional advantage of the GeoTPB is that it provides the explanations for the activators of beliefs which are neglected in the TPB. In the GeoTPB the Geographic Structural Data explain 73.7 to 85.9% of the variance of the beliefs. The results of this study underline that the geographical context enhances the explanation power of the TPB.

Figure 7 summarizes the whole study design with all connections from the theoretical framework over the methodical implementation to the empirical evaluation.

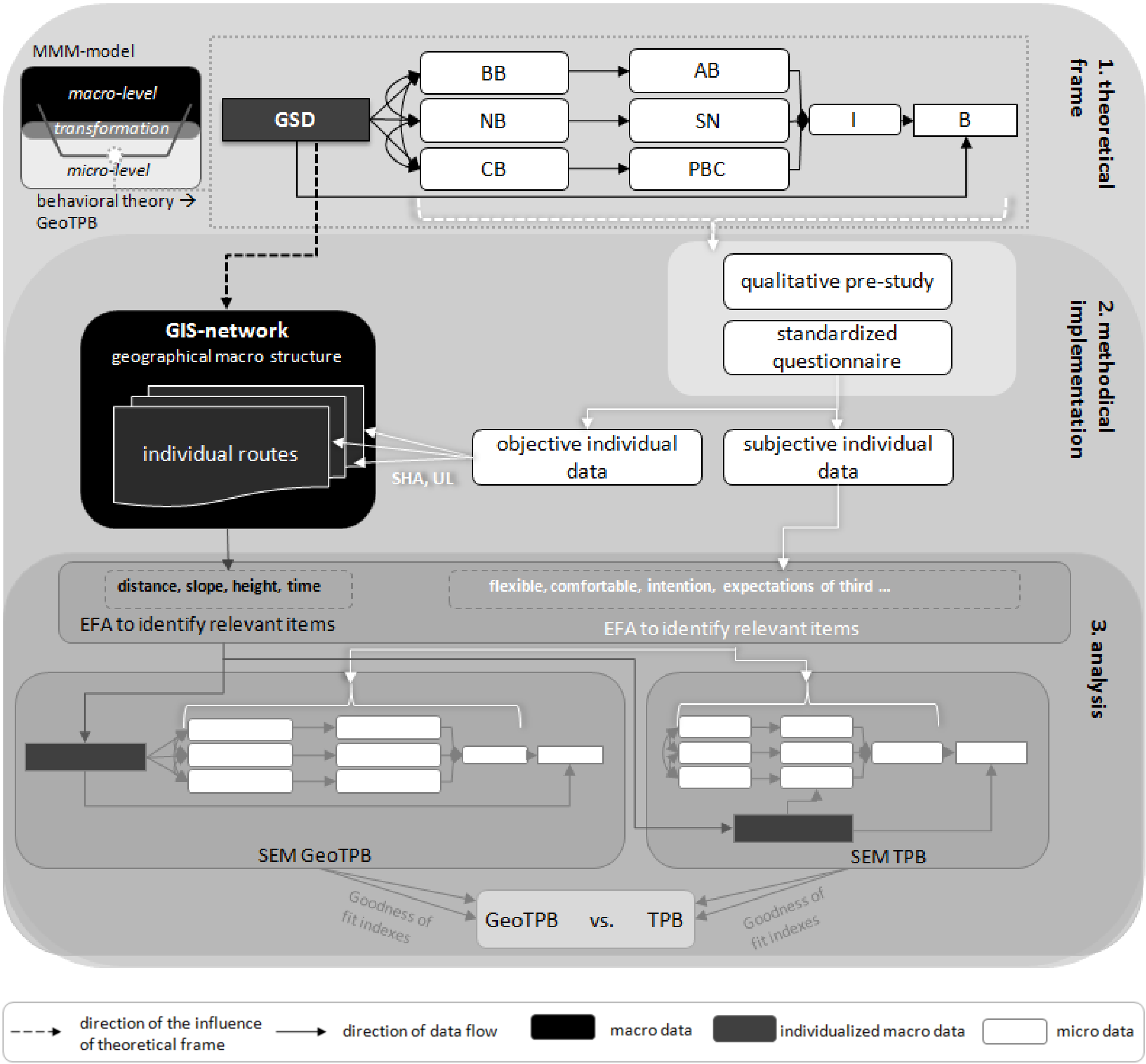

Figure 7: Study design, theoretical frame, implementation and empirical evaluation

To put the gained results from the GeoTPB into a broader perspective in the following we will discuss the mobility behavior and the role of normative beliefs as well as the implications for the development of sustainable mobility concepts.

It is argued that social pressure influences behavior especially when the behavior touches third parties groups (Ajzen, 1991). Transferring these results to mobility behavior, it can be derived that for regularly travelled ways normative beliefs have no great influence. *Normative Beliefs* have already been dismissed by pre-analysis. These findings underline that the mode choice is made without significant social pressure. Especially in such behavioral situations it appears that taking the spatial context into account is an useful enhancement. Nevertheless the application of the GeoTPB to more socially affected behavioral situations is open for further exploration.

Confronted with the need for developing sustainable mobility concepts these findings can be helpful for political actors to find required approaches to achieve this goal. We argue that sustainable concepts have to be embedded and adjusted to local environments and respective target groups for being efficient. The growing socio-economic disjuncture and the increasing transnational mobilities in the emerging knowledge based economies have enabled the flow of people, objects, information and knowledge at an unprecedented scale. In this process considerable social, economic, political and environmental processes, connecting specific social groups, places and regions and disconnecting others, are set off. The capacity to be mobile in social and geographic spaces is becoming increasingly important but the forms and versatility of these new, emerging 'mobility regimes' still need to be thoroughly analyzed and understood.

Since in these fragmented mobility regimes the political influence and responsibility is particularly high for physical infrastructure and city planning it is crucial to identify the most influential starting points in this field to foster sustainable behavior. This study refers only to university students in Marburg, therefore the generalization is questionable and should be investigated further. But students are in the same life situation which, as Scheiner and Holz-Rau, 2007 (p. 491-509) underline, refers to socio-structural conditions that cannot easily be altered by individuals and seem to be as objective conditions more important than life style as determinants of travel mode use. For Marburg, a science city with around 85.000 inhabitants including more than 22.000 students dispersed over 150 locations within the town, these are a main target group in the mobility regime. One important result of our study is that today´s students prefer sustainable means of transport. However geographical structures and existing transport infrastructures may push them to use motorized means of transport. Accordingly we make the case that sustainable mobility concepts need to be tailored to specific target groups to unfold the intended aims. For the development of systemic mobility solutions the GeoTPB provides an approach to identify starting points not just for city marketing, information and education concepts but also for infrastructural planning referring to the respective target groups.

For instance in some communities it might be more successful for target groups to shorten distances while for others avoiding slopes and rather enlarge distances or making routes safer has more potential. In the here provided example, *Intention* is significantly affected by the indicators *stress-free*, *flexible* and *comfortable* which differ individually and locally. That means the political concepts might focus on these indicators, particularly as these results are consistent with the change in mobility demand towards moving in more flexible, efficient and comfortable way mentioned at the beginning.

The question how socio-institutional environments influence mobility behavior remains open. For future research special challenges are associated with the identification of measurement and individualization methods of additional localized contexts and their impacts on mobility behavior. The integration of further contexts that define the individual situation, seems to be a promising approach to enrich the explanatory power of behavior and provides a further detailed decision-making tool. The modern technical devices within GIS make it feasible to calculate numerous individual spatial data and analyze them. The geodatabases are growing fast and there is a great opportunity to use the technological possibilities to analyze mobility and general behavior in space embedded and adjusted to local environments. This study gives an example how the disciplinary theories and methodological approaches can be combined, however further research in the field is needed to gather experiences and deeper insights.

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