The interaction between motility, accessibility and modal choice

Clément Rames

Eloi Bernier

Jules Grandvillemin

Florian Masse

Guillaume Drevon

Philippe Gerber

Vincent Kaufmann

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Clément Rames
LaSUR, EPFL
Clement.rames@epfl.ch

Eloi Bernier
LaSUR, EPFL
Eloi.bernier@epfl.ch

Jules Grandvillemin
LaSUR, EPFL
Jules.grandvillemin@epfl.ch

Florian Masse
LaSUR, EPFL
Florian.masse@epfl.ch

Guillaume Drevon
LaSUR, EPFL
Guillaume.drevon@epfl.ch

Philippe Gerber
Luxembourg Institute of Socio-Economic Research
Philippe.gerber@liser.lu

Vincent Kaufmann
LaSUR, EPFL
Vincent.kaufmann@epfl.ch

Abstract

While built environment characteristics, in particular transport infrastructure, play a pivotal role in modal practices (Ewing & Cervero, 2010, Van Acker et al., 2007), individual attributes, for instance travel dispositions and aptitudes, are equally decisive in the choice of modes of transport (Kaufmann, 2011). In this paper, we leverage a large panel survey dataset (n=10,202) covering the Greater Geneva region (straddling Switzerland and France) conducted in 2022. We pose three hypotheses. The first is that motility and accessibility both influence modal practices in specific ways. The second is that motility, defined as the potential to be mobile, varies as a function of the accessibility of one's environment. Finally, we hypothesize that motility has a compensatory dimension for deficiencies in accessibility. In order to test these, we adopt a Structural Equation Modeling (SEM) approach (Hoyle, 2014). We construct three latent variables – Motility, Accessibility and Mode Choice – which are first tested individually with Confirmatory Factor Analysis. The complex relationship between these three aspects is then evaluated with a SEM model. The model converges, with appropriate indicators of fit, and shows that motility is strongly connected with alternative mode choice, to a greater extent than accessibility. Results also show that individuals living in more accessible environments tend to possess higher motility, countering our third hypothesis.

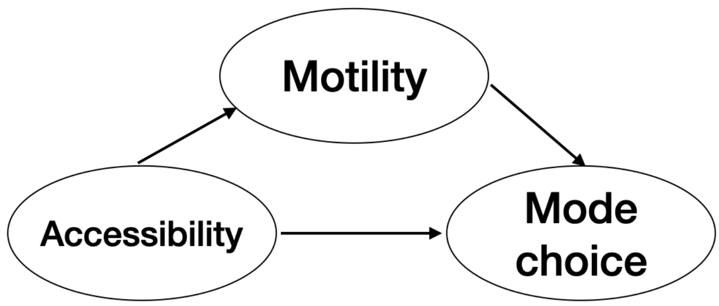
1 Introduction

Planners (urban planners, architects, engineers) assume that planning action on space will influence individual and collective practices (Banister, 2008). Mobility is no exception to this doxa, which finds a particularly strong echo in the socioeconomics of transport with respect to the use of different modes of transport. Although the configuration of living areas and the available transport supply play a role in modal practices (Van Acker, Witlox, and Van Wee, 2007), other approaches, notably from sociology, have shown that individual attributes, including travel dispositions and aptitudes, are decisive in the choice of means of transport (Kaufmann 2011). All these individual attributes have been conceptualized using the concept of motility. In the literature on motility, the field of possibilities defines the territorial framework within which mobility practices manifest themselves, depending on the characteristics of the territory and the opportunities offered by it. However, the relationship between motility, territorial characteristics and modal practices remains largely unexplored.

We propose to analyze the interdependencies between spatial accessibility, people's motility and travel behavior using an original approach based on unpublished data and latent variable modeling tools (Hoyle 2014). We leverage the concept of motility as proposed by Kaufmann (2011). This conception defines motility as the set of characteristics that enable people to move around, i.e. physical means, income, the pursuit of sedentariness or mobility, the social conditions necessary to be able to access the technical transport and telecommunication systems available, as well as acquired knowledge such as education, driving license and knowledge of international English for traveling, etc. Motility thus refers to the social conditions of access (conditions under which transport infrastructure is used in the broadest sense of the term), skills (which are required to take advantage of this infrastructure) and aspirations to be mobile (which can be realized thanks to the effective use of transport infrastructure). In this short paper, we leverage the concept of motility to measure the ability and willingness to use different modes of transport for everyday mobility.

To analyze the interdependencies between spatial accessibility, people's motility and modal practices, we start with the conceptual model shown in Fig. 1. Based on the state of the art, we can consider that motility influences modal practices, and that the accessibility influences motility and modal practices.

Figure 1: Conceptual model



More specifically, we pose three hypotheses. The first is that motility and the accessibility both influence modal practices in specific ways (H1). The second hypothesis is that motility, which has a latent character, varies as a function of the living environment, and more specifically of its accessibility (H2). Finally, we hypothesize that motility constitutes a compensatory dimension for deficiencies in the field of travel possibilities. In other words, an environment with limited accessibility could tend to favor the activation and development of motility. Conversely, a high spatial accessibility could reduce the need for motility (H3).

In favor of this hypothesis, it is conceivable that a less accessible environment could stimulate the development of motility, as individuals are encouraged to compensate for constraints with adaptive and ingenious strategies. Faced with limited resources, they would deploy increased skills, developing creative solutions to circumvent mobility obstacles, thus reinforcing their autonomy and resilience. On the other hand, limited accessibility could also have the opposite effect, reducing the impetus for mobility. Lack of infrastructure or adequate means (typically in underserved rural areas) could discourage individual initiative, encouraging the adoption of more sedentary behaviors and increased dependence on external aid schemes. This context could then restrict individuals' ability to develop their motility, curbing their aspirations to travel and limiting their mobility potential. This hypothesis is open to debate: in an environment saturated with travel amenities, individuals may also give up on travel in the longer term, because of fatigue.

2 Data and methods

2.1 Dataset

The research infrastructure of the "Lemanic Panel for analysis of sustainable behaviors" is a five-year project initiated by the EPFL and starting in autumn 2022, involving a sample of over 10,000 people living in the Greater Geneva region. The target population defined for this project corresponds to all people aged 18 or over living in private households within the perimeter of the Lake Geneva urban region, i.e. 2,011,006 people (1,485,941 people living in Switzerland and 525,065 people living in France). After contacting 46,850 households by post, we obtained 11,234 usable responses in autumn 2022. Of these, 2,802 also agreed to take part in a GPS survey in spring 2023. Responses are weighed according to reference socio-demographic data in each region, so as to ensure representativeness.

The panel covers the whole of the Greater Geneva regions, i.e. the cantons of Geneva (GE) and Vaud (VD), part of the cantons of Fribourg (FR) and Valais (VA), Pays de Gex (AI), Chablais and the French Genevan area (HS). The area has been drawn up taking into account the structure of mobility between the source municipalities (of residence) and those that are attractive for employment or other daily activities. It spans two countries and has a population of two million. The municipalities included in the Lemanic Panel are divided according to a territorial typology into five categories: major metropolitan centers, central urban areas, urban suburbs, secondary centers and rural areas. Of the 11,234 usable responses collected in the first wave of the Lemanic Panel, we finally drew on 10,202 individuals who answered all the questions required to weigh the sample, in order to guarantee its representativeness.

2.2 Measured and latent variables construction

In line with the state of the art, we leverage the 5D (Cervero and Kockelman, 1997, Ewing and Cervero, 2010) to assemble the key aspects of the built environment that are widely recognized to influence travel behavior. Density refers to the concentration of population in an area, encouraging the use of public transport by making services and shops more accessible. Diversity refers to the mix of land uses, such as residential, commercial or leisure functions, which facilitates access to nearby activities and encourages travel on foot or by bicycle. The Design of urban space, including street connectivity and the presence of pedestrian and cycling infrastructure, enhances the safety and enjoyment of active travel. Distance to transit measures the proximity of public transport infrastructures, whereas transit Level of Service (LOS) refers to the frequency of public transit service at each transit stop. Finally, Destination accessibility indicates ease of access to “essential” places, such as work, schools and shops. These indicators are all log-transformed to harmonize their distribution.

We build the latent variables of our model as follows:

- Access: this variable covers the resources that enable or facilitate mobility, such as the possession of public transport or train passes and the availability of a vehicle
- Skills: this encompasses the knowledge and aptitudes required for mobility, including the ability to plan routes using maps, to ask for directions or orient oneself in the street
- Aspirations: this variable reflects the attitudes of individuals towards different transport modes, as measured by three adjectives used to qualify these modes
- Motility: a central variable in our model, motility represents an individual's overall ability to move efficiently, resulting from the interaction between access, skills and aspirations. It is therefore a second-order latent variable
- Accessibility (5Ds): this variable describes the characteristics of the urban environment influencing motility, including density, diversity of urban functions, distance to public transport, design of urban space, and access to destinations
- Mode choice: the dependent variable of this model is made up of the frequency of use of train, urban public transit and cars respectively, as stated by the respondents.

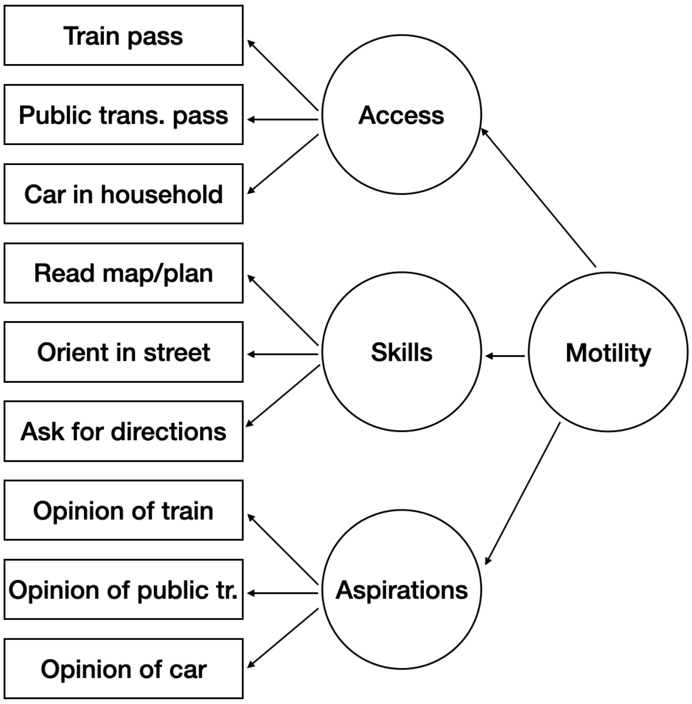
2.3 Methodology

In order to test the conceptual framework and measure the relationships prefigured in the hypotheses, we opted for a confirmatory factor analysis (CFA) followed by a structural equation model (SEM). The SEM comprises two parts: a measurement model and a structural model. The principle of the measurement model is to link a set of measured, observable variables to unobservable (latent) variables. Latent variables are set up using a CFA and Cronbach's alpha coefficient for indicator congruence (Hoyle, 2014).

The structural model then establishes explicit links between the different latent variables, thus testing our hypotheses. This combination of methods is frequently used to test whether a set of indicators reflects a theoretical construct. In our case, it applies to measuring the relationship between motility, accessibility and mode choice. We used the robust weighted least-squares estimator of the R lavaan library (Rosseel, 2012) with robust standard errors and the scaled test statistic of Satorra and Bentler (1994) to account for the non-normality of our observed variables (Hoyle, 2014).

Our approach is consistent with Gumy et al. (2025), who used a second-order structural model (SEM) to perform mediation analysis to better understand the relationship between environmental concerns and daily mobility habits. This mediation variable combines transport access, individual skills, and personal willingness to move. They show that environmental concern increases public transport habits and reduces car habits, with a total mediation effect of motility on car habits, and a partial mediation effect on public transport. These results are based on data from the second wave (2019) of the 'national daily mobility panel' survey in France.

Figure 2: Motility modeled as a second-order latent variable



3 Results

3.1 Confirmatory Factor Analysis

We use confirmatory factor analysis (CFA) to evaluate the fit of our measurement model, so as to ensure that the latent variables constructed are valid. Each component is tested separately. First, the second order latent variable of Motility (Figure 2), composed of Access, Skills and Aspirations blocks is tested. The car availability variable was removed as its highly skewed distribution was hampering model convergence (indeed, 88% of our sample has access to a car).

We then test the validity of our our other, first-order latent variable constructs. "Accessibility" is defined as the combination of density, diversity, design and public transit level of service (following Cervero and Kockelman, 1997 and Ewing and Cervero, 2010) – although destination accessibility was removed due to low explanatory power. Mode choice is simply modeled as the combination of frequencies of use of different modes: train, public transport and car, as declared by respondents. The measurement models for these latent variables all converge (Table 1), with satisfactory fit indicators (SRMR<0.08, RMSEA<0.06, CFI>0.95, TLI>0.95).

Table 1: Fit indicators for the three measurement models

Latent variable	Measurement model	SRMR	RMSEA	CFI	TLI
Motility	Access=~TRAIN_PASS+PT_PASS Skills=~MAP+STREET+DIRECTIONS Aspiration=~A_TRAIN+A_PT+A_CAR Motility=~ Access+Skills+Aspirations	0.036	0.051	0.960	0.934
Accessibility	Accessibility=~ DENSITY+ DESIGN+DIVERSITY+PT_LOS	0.031	0.071	0.996	0.989
Mode choice	Mode_choice=~FREQ_TRAIN+ FREQ_PT+FREQ_CAR	0.026	0.058	0.988	0.963

3.2 Structural Equation Model

The three measurement models are then combined to evaluate the respective influence of motility and accessibility on mode choice. Table 2 indicates the factor loadings of each measured variable (in capital letters) composing each latent variable (in bold). It is interesting to note that the latent variables of access and aspirations have a greater influence than skills, within the second-order latent variable of motility. Likewise, density and public transit level of service weigh more than diversity and design, in shaping the latent variable of accessibility. Finally, it is evident that the sign of the frequency of car use is reversed as compared with frequency of train and public transit use, with respect to the mode choice latent variable.

Table 2: Variable loadings of the SEM model

Latent Variables	Estimate	p-value
Access =~		
TRAIN_PASS	1.000	(ref)
PT_PASS	0.607	0.000
Skills =~		
MAP	1.000	(ref)
STREET	1.018	0.000
DIRECTIONS	0.720	0.000
Aspirations =~		
ADJ_TRAIN	1.000	(ref)
ADJ_PT	1.059	0.000
ADJ_CAR	0.807	0.000
Motility =~		
Access	1.000	(ref)
Skills	0.184	0.000
Aspirations	1.046	0.000

Accessibility =~		
DENSITY	1.000	(ref)
DESIGN	0.405	0.000
DIVERSITY	0.580	0.000
PT_LOS	0.786	0.000
Mode choice=~		
FREQ_TRAIN	1.000	(ref)
FREQ_PT	1.657	0.000
FREQ_CAR	-0.758	0.000

Figure 3 illustrates the full model, which brings together the three measurement models (blue dotted lines) and links them through the structural model (red dotted lines). As indicated in Table 2, all measured variables are statistically significant (p=0.000). The coefficients associated with each measured variable is displayed on its respective arrow. For the sake of readability, residual covariance self-loops were omitted from this plot.

Figure 3: Structural equation model

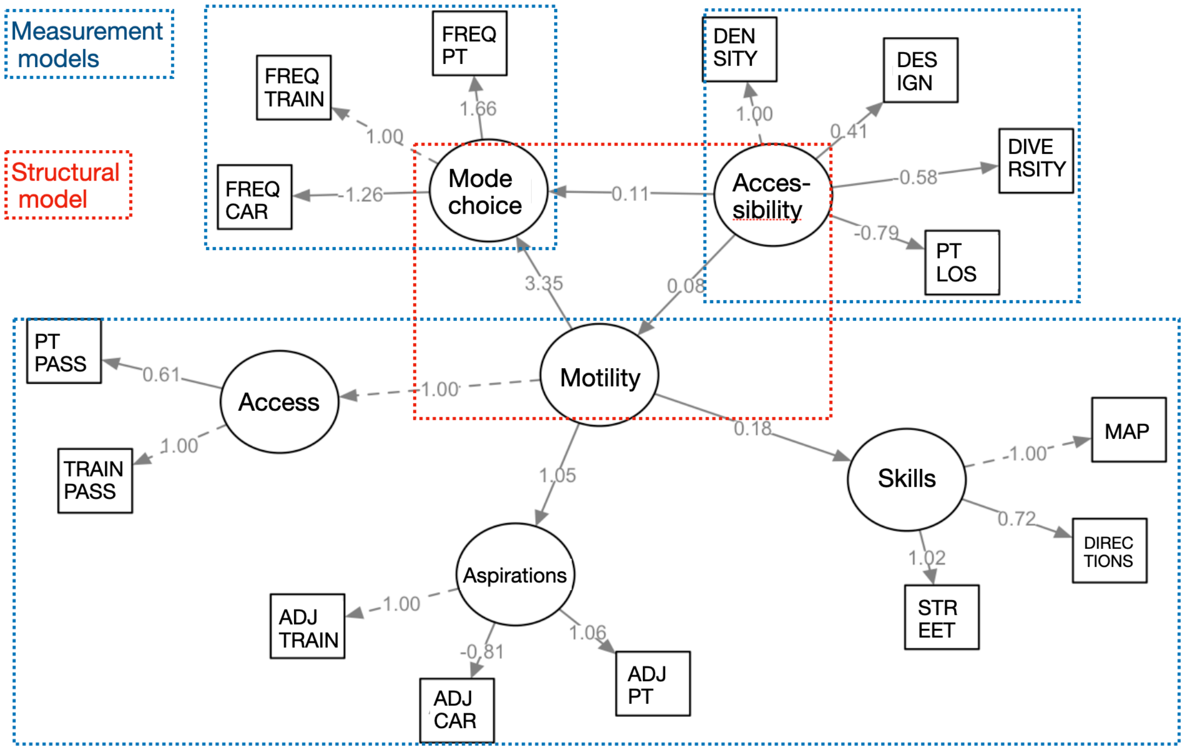


Table 3 sheds light on the relationships between our three main latent variables. Motility appears to be positively associated with spatial accessibility, although the magnitude of the coefficient is very low. In other words, individuals with higher motility tend to reside in more accessible urban areas. Both motility and accessibility are positively associated with a higher frequency of train and public transport trips, and a lower frequency of car trips. Interestingly, individuals' motility appears to have a much stronger effect than the accessibility of their residential environment, suggesting that motility is a decisive factor driving mode choice.

Table 3: Interaction model results

Regressions	Estimate	Std.Err	z-value	P(>|z|)
Motility ~				
Accessibility	0.075	0.002	30.509	0.000
Mode choice~				
Motility	3.354	0.117	28.710	0.000
Accessibility	0.110	0.011	10.108	0.000
Fit indicators: SRMR=0.060, RMSEA=0.071, CFI=0.944, TLI=0.930				

4 Discussion and conclusions

The analyses presented in this article lead to a series of important observations. Motility and accessibility influence the choice of transport mode in a statistically significant way, although motility has a much stronger influence. This illustrates the fact that people's ability to move around has a direct impact on their modal practices (De Witte et al., 2013).

Individuals' travel behavior is weakly associated with their residential environment: people living in more accessible environments unsurprisingly tend to use more sustainable modes. The weak associations found suggest that mode choice is not mechanically linked to transport provision in a given area, but rather to other factors specific to individuals, such as their mobility culture (resulting from a socialization process, see Maksim, 2011).

The pillars of motility, namely access and aspirations, appear to have a much stronger influence than skills on the choice of transport mode. However, it should be noted that with regard to the skills pillar, our survey did not include any questions relating to organizational aspects, which several studies have shown to play a central role in mobility (Jurczyk, 1998).

Socio-demographic variables such as age, gender, income and level of education were not statistically significant in our model. Hamidi and Zhao (2020) obtained similar findings in Beijing, Goteborg and Malmö. Given the explanatory power of motility on mode choice, this finding highlights the importance of motility as a differentiating factor in its own right, a specific resource that cannot simply be reduced to a proxy for socio-demographic variables (Kaufmann and Audikana, 2020).

Active mobility (cycling and walking) is an important aspect of sustainable mobility that is not captured in our model. For instance, the variables of bicycle availability, attitude towards cycling and frequency of cycling trips were remarkably uncorrelated, and were therefore excluded from our model. Indeed, many households have access to bicycles, which are mainly used for recreative purposes, and not for daily mobility. Mode-specific motility latent variables (Gumy et al., 2025) have proven to be an effective way to characterize the ability or propensity to use specific modes.

The concept of motility, which has received considerable attention over the past two decades in the field of social sciences and mobility studies, remains complex to operationalize for quantitative analysis and modelling (as noted by Guitton et al., 2025). We believe that this is an important goal and requires further work.

Following these observations, we believe that the development of a people-centric approach to transport research cannot ignore the integration of people's motility, which is emerging as an important dimension of lifestyles and is widely recognized in the social sciences as a measure of people's ability to move. It would be valuable to compare our findings with studies performed in different geographical contexts, to understand how social, cultural, economic and infrastructural factors affect the dynamics of mode choice differentially.

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