Motility as a tool to uncover mobility practices

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Abstract

This paper investigate the causal relationships that exist between the motility, defined as the personal ability to be mobile (Kaufmann et al., 2015), and mobility behaviors. To do so, we use the first wave (2018) of the "national daily mobility panel" survey (PaNaMO), which is a longitudinal Internet study for the social sciences (ELIPSS). From a methodological point of view, we use latent variables to construct an aggregated motility index based on each of its pillars (accesses, skills and aspirations). This allows us to get a structural vision of the concept. Building a motility typology, we show by a comparative approach how this concept may lead to rediscover inequalities related to mobility. Conceptually, our motility index reveals how a significant part of the population can be mobile without high competencies to do so. Operationally, it shows the importance of the car mode for people with low mobility aptitudes, that is motility.

Keywords

Motility, Mobility habits, Mode choice, Structural Equation Modeling

1. Introduction

The objective of the article is to develop a measure of the motility concept to produce a typology in order to test the robustness and the operational potential of the concept. The typology will help in understanding transport mode choice from the perspective of individual's latent aptitudes of being mobile. Transportation research and planning usually understand mode choice as an attribute of the offer. From this perspective, a given context proposes a more or less wide range of transportation modes, which of individuals can take advantage. These offers define so-called accessibility and thus condition mode choice. This functional and sometimes mechanical approach considers that people account for accessibility to make their decision on how to be mobile on a daily basis. However, some social sciences studies show that the opportunity of choosing one's transportation mode may remain "theoretical" since people highly relate on their personal habits, historical preferences and alternatives knowledge (Fichelet et al. 1969 ; Lash et Urry 1994 ; Tertoolen et Verstraten 1995 ; Kaufmann 2000 ; Munafò et al. 2015). To shed light on some of these considerations, we will refer in this article to the concept of motility.

2. Literature review

The scientific literature usually considers "mobility" as spatial and use functional measures to approach it, for example the number of trips (Gallez & Kaufmann, 2009). In a contemporary world characterized by flexibility injunctions, seeing "mobility" as both spatial and social is empirically useful on the one hand and necessary in understanding how this mobility is shaping social relations and the territory on the other hand.

These challenges have been a leitmotiv in theoretical research on mobility for the last fifteen years, sometimes under the denomination of mobility turn. In this paper, we see "mobility" as "the intention, then the realization of a crossing in the geographical space involving social change", which is a definition based on previous work by Sorokin (Sorokin, 1927), Chicago school (Mc Kenzie, 1927) and Michel Bassand (Bassand & Brulhardt, 1980). The idea behind this is to give as much importance on the intention of being mobile and on the decision to become mobile as on the actual act of being mobile. Here, every individual or group is characterized by its potential on being geographically, economically and socially mobile, or by its "motility".

"Motility" is conceptualized as "all the factors that define an individual's capacity for movement, or being mobile". It encompasses three pillars, or components: social accesses, referring on the conditions to make use of the transportation offer; knowledge and skills, referring on the necessities to use this offer; and desires and aspirations, referring on the actual reasons to use this offer. This notion is helpful when it comes to understanding the relation between what it is possible to do regading mobilit and one's propensity to activate this potential. It is especially appealing since transportation infrastructures has considerably developed in recent years (and still is) and since travel speeds are seen as an important factor of, and debate in, urban development.

Motility was initially developed in 2002 (Kaufmann, 2002) and frequently discussed since then in the field of sociology (Merriman, 2012 ; Sheller, 2011 ; Söderström & Crot, 2010 ; Kesselring, 2006 ; Jensen, 2006 ; Nowicka, 2006 ; Kesselring, 2005) but also anthropology (Glick Schiller & Salazar, 2012), management (Sergot et al., 2012), human geography (Kellerman, 2012 ; Kellerman, 2006 ; Lévy, 2004 ; Albertsen & Diken, 2001), historical research (Flonneau & Guigueno, 2009 ; Guigueno, 2008) and urbanism (Lord, 2011 ; Chalas & Paulhiac, 2008). Since then, further theoretical (Ohnmacht et al., 2009 ; Canzler et al., 2008 ; Kaufmann et al., 2004) and methodological (Kaufmann, 2011 ; Flamm & Kaufmann, 2006) deepening was conducted. Scholars also proposed quantitative operationalization dealing with travel time appropriation (Vincent-Geslin & Kaufmann, 2012), waiting time appropriation (Tillous, 2009) or social inequalities (Maksim, 2011). In quantitative studies, motility was used to explain high mobility (Kaufmann et al., 2010), the link between travels and social network (Viry, 2011) or mode choice (Witter, 2012). Tackling transportation behavior was also done by several scholars building on the concept of motility (De Witte et al., 2013 ; Kellerman, 2012 ; Fouillé, 2011 ; Rivere, 2009 ; Faulconbridge et al., 2009 ; Vincent, 2008 ; Rocci, 2007).

3. Methodology

3.1 Dataset and variables

Our study of the motility concept is based on data from the PaNaMo survey conducted on the ELIPSS panel. This is an internet-recruted panel representative of the French population, based on a random selection. Each month, panelists respond to thematic surveys developed by researchers. Considering their participation and for the purposes of the survey, they receive a tablet and a mobile Internet subscription by ELIPSS. The team carries out a specific survey each year to collect socio-economic and demographic data of the panelists.

Among various surveys of the ELIPSS panel, PaNaMo provides data on the daily mobility practices of the French population between 18 and 79 years old. Authors of the questionnaire investigate factors that influence mobility behaviors: perception of social norms, habits, intentions, spatial and social situations and motility. The project aims to clarify the relationships between personal practices and their variations over time, with these five major inputs measureable at the individual level. PaNaMo has the particularity of being a longitudinal survey renewed over five consecutive years. The administration of the first wave of the survey took place from February to March 2018 to gather 2290 panelists' answers. The survey institute is currently passing the second wave. Within this research, we mainly use PaNaMo data and some socioeconomic and demographic informations coming from the yearly global ELIPSS survey.

3.2 Estimation of latent variables

By definition, motility is a "latent" variable. Unlike other "manifest" variables such as the ownership of a car or a transport subscription, a questionnaire cannot directly estimate it. This latent nature complicates the measurement of motility and its latent pillars through quantitative approaches. Among the two doctoral research projects and the research project (Job Mobilities and Family Lives in Europe) that have proposed quantitative measures of motility with data collected from a large sample of individuals (Viry, 2011 ; Witter, 2012 ; Kaufmann et al., 2010) , the approaches are essentially exploratory. Factor scores quantify latent variables for each individual, obtained thanks to a principal component analysis (PCA) from the manifest variables measured in the surveys. One of the objectives of this research is to use a theory-driven method to compare the theoretical concept of motility with the data from the Panamo survey.

On the basis of several studies conducted in the field of social sciences (Cuignet et al., 2019, Gerber et al., 2018), we use structural equation modeling to test the concept of motility. This process offers a statistical approach to test hypotheses on the relationships between latent and observed variables (Hoyle, 2014), starting from the theoretical construction of latent variables according to the indicators by confirmatory factor analysis (Brown, 2006) to the exploration of the relationships between latent variables. In addition to the evaluation of the model and the estimation of the motility variable, structural equation models can also measure all the latent variables of the model (factor scores) as well as the intensity of the relationships between these variables (loadings), which offers the possibility of a detailed study of the motility structure.

For our study, structural equation modeling has the advantage of being more flexible in terms of data hypothesis than conventional statistical approaches, particularly with respect to the independence of variables and measurement errors and the orthogonality of factors. It also
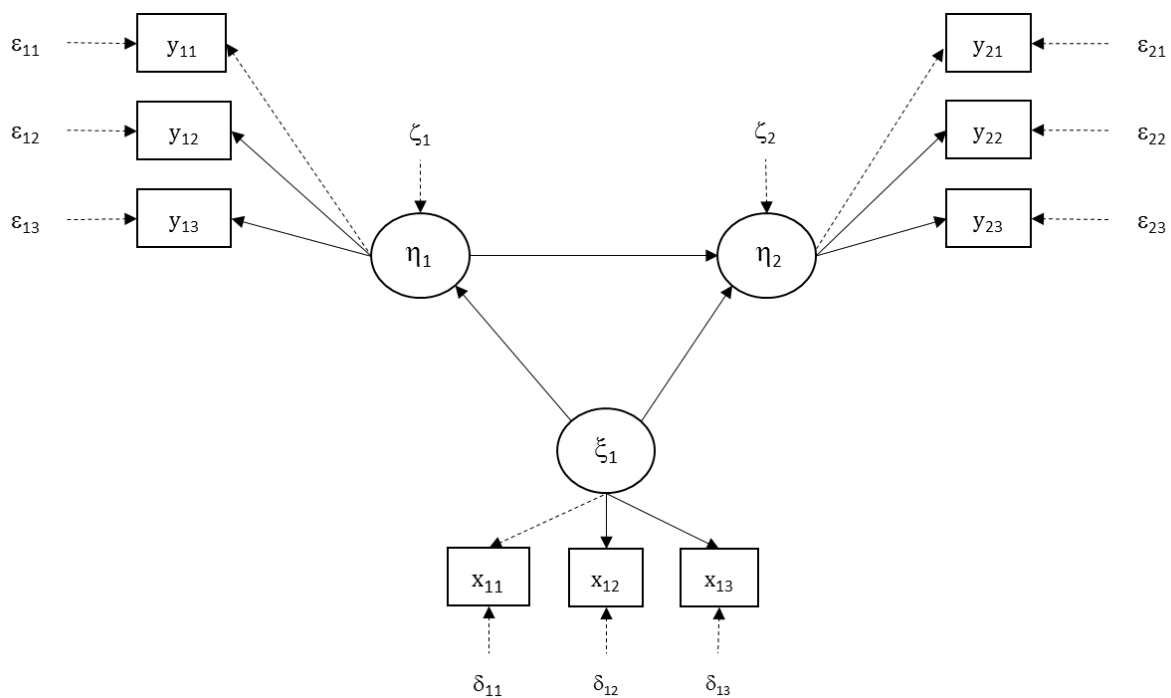
permits to take into account the endogeneity of latent variables (Van Acker and Witlox, 2010). In addition, the models obtained are relevant for subsequent data-mining (Gerber et al., 2018) or comparison studies between various conceptual models (Ma et al., 2014).

Structural equation modeling is a synthetic method that embraces several distinct approaches. The method we use focus on the analysis of covariance matrices, and is useful for the validation of a model based on data collected on a large sample of individuals (Jakobowicz, 2007). It assumes a reflective interpretation of the manifest variables that are supposed to reflect the latent variables in causal relationships.

3.3 Structural equations modeling

A synthetic way to represent a system of structural equations is to use an oriented graph (Fig.1).

Figure 1: Example of structural equations model

In this graph, latent variables are circles while manifest variables are squares. The arrows represent the causal relationships between the variables in the model, in accordance with the theory the researcher wishes to test. The other variables correspond to measurement errors. We follow here the notations by Jakobowicz (Jakobowicz, 2007), which respect the standard

distinction between endogenous latent variables (ie explained by other latent variables) and the remaining latent variables, or exogenous ones:
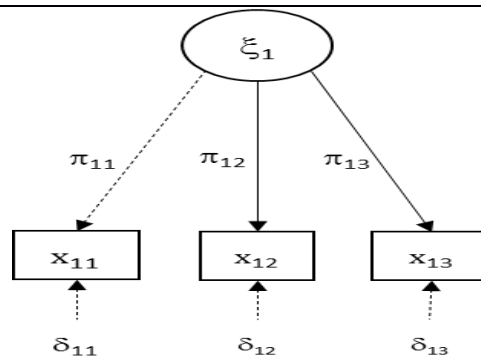
- η : endogenous latent variables

- ξ : exogenous latent variables

- y : manifest variables related to η

- x : manifest variables related to ξ

- ε : measurement errors related to y

- δ : measurement errors related to x

- Λ_y : matrix of coefficients (loadings π) linking y to η

- Λ_x : matrix of coefficients (loadings π) linking x to ξ

- Θ_ε : covariance matrix of ε

- Θ_δ : covariance matrix of δ

- ζ : measurement errors associated with η

- B : matrix of structural coefficients of the relationships between the η

- Γ : matrix of structural coefficients of the relations between the η and the ξ

- Φ : covariance matrix of ξ

- Ψ : covariance matrix of ζ

- P : number of manifest variables

The measurement model produces latent variables from the observed variables. In the case of a reflective model, which we will use here, each observed variable relates to a latent variable by a simple regression. The equations of the measurement model are as follows:

$$y = \Lambda_y\, \eta + \varepsilon \quad (1) \qquad x = \Lambda_x\, \xi + \delta \quad (2)$$

They are represented by the arrows connecting the indicators to the factors in the oriented graph of the structural equation system (Fig.2).

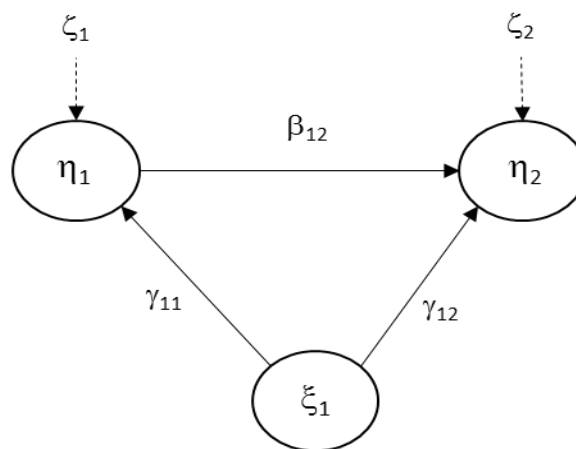Figure 2: Part of the measurement model related to ξ_1

The structural model consists of connections between the latent variables of the system, which result in equations of the following form:

$$\eta = B\eta + \Gamma\xi + \zeta \qquad (3)$$

This allows us to represent the structural model for the structural equation model above (Fig.3).

Figure 3: Structural model

For that model with a reflective modeling, the variables respect several constraints:

- ε and η are uncorrelated;

- ξ and δ are uncorrelated;

- ε, δ and ζ are uncorrelated;

- δ and η are uncorrelated;

- ε and ξ are uncorrelated.

For the estimation of unknowns in the structural equation model, it is common to use the LISREL-ML method with maximum likelihood and assuming multinormality of the variables. In a structural equation model, we assume then:

$$\Sigma = \Sigma(\theta) \qquad (4)$$

Where Σ is the covariance matrix of the X columns, noted $\Sigma(\theta)$ as a function of the vector θ of the parameters to be estimated in the model, and which admits the following decomposition:

$$\Sigma(\theta) = \begin{bmatrix} \Sigma_{yy} & \Sigma_{yx} \\ \Sigma_{xy} & \Sigma_{xx} \end{bmatrix} = \begin{bmatrix} \Lambda_y\,(I-B)^{-1}(\Gamma\Phi\Gamma'+\Psi)[(I-B)^{-1}]'\Lambda_y' + \Theta_\varepsilon & \Lambda_y\,(I-B)^{-1}\Gamma\Phi\Lambda_x' \\ \Lambda_x\,\Phi\Gamma'[(I-B)^{-1}]'\Lambda_y' & \Lambda_x\Phi\Lambda_x' + \Theta_\delta \end{bmatrix} \quad (5)$$

We then look for an estimate of $\Sigma(\theta)$ from the covariance matrix S of the data, by optimizing the following function in the use of the LISREL-ML method:

$$F_{ML}(S, \Sigma(\theta)) = \log|\Sigma(\theta)| + tr(S \cdot \Sigma(\theta)^{-1}) - \log|S| - P \qquad (6)$$

In the LISREL-ML method, we obtain measurement errors and loadings during the optimization calculation. However, factor scores that correspond to the values taken by the latent variables for each individual are not initially calculated but estimated after optimization to match the covariance matrix obtained previously.

During the estimation, some other results assess the statistical validity of the structural equation model and thus confirm or disprove the conceptual construction of the model. The fit indices are abundant in the literature (Yoder, 1998). We retain four traditional indices (Hooper et al., 2008; Hoyle, 2014) automatically generated by the main structural equation modeling softwares.

Table 1: Conditions of fit for the acceptance of the model

Fit statistics	Cut-off criterion	Description
SRMR	< 0.08	Standardized root mean squared residual
RMSEA	< 0.06	Root mean squared errors of approximation
CFI	> 0.90 or 0.95	Comparative fit index
TLI	> 0.90 or 0.95	Tucker-Lewis index
(Hooper et al., 2008; Hoyle, 2014)		

The SRMR rely on the standardized variation between the observed covariances and those derived from the studied model. The RMSEA measures the square root of the average deviation of the χ^2 statistic from its expected value per degree of freedom. This index is convenient for
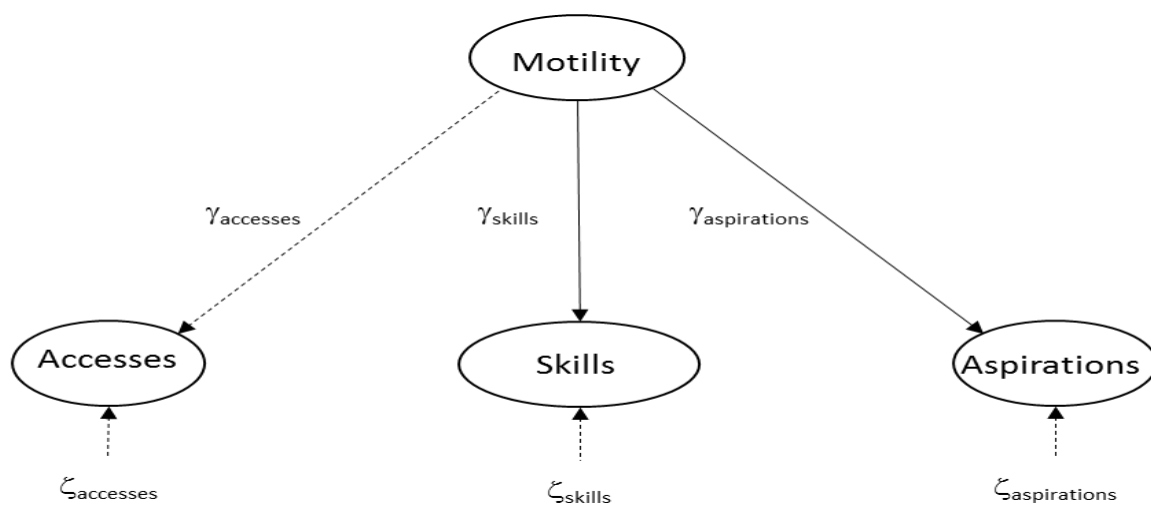
large data samples. The CFI derivates from the comparison between the studied model and the complete independence model, while the TLI quantifies the progression of the adjustment from the null model to the studied model.

The comparison between the χ^2 and the number of degrees of freedom of the model is not convenient for the evaluation of our model because of its sensitivity to the sample size but also because it is highly influenced when the variables do not satisfy the assumption of normality. In that case, it tends to reject too many models (Meijer, 1998, West et al., 1995).

4. Modelisation

The structural model developed for this study rely on the decomposition of motility into pillars, which we use to analyze motility inequalities (Kaufmann, 2008). We solicit this conceptual framework to propose a motility index around three fundamental pillars: accesses, skills and aspirations (Fig.4).
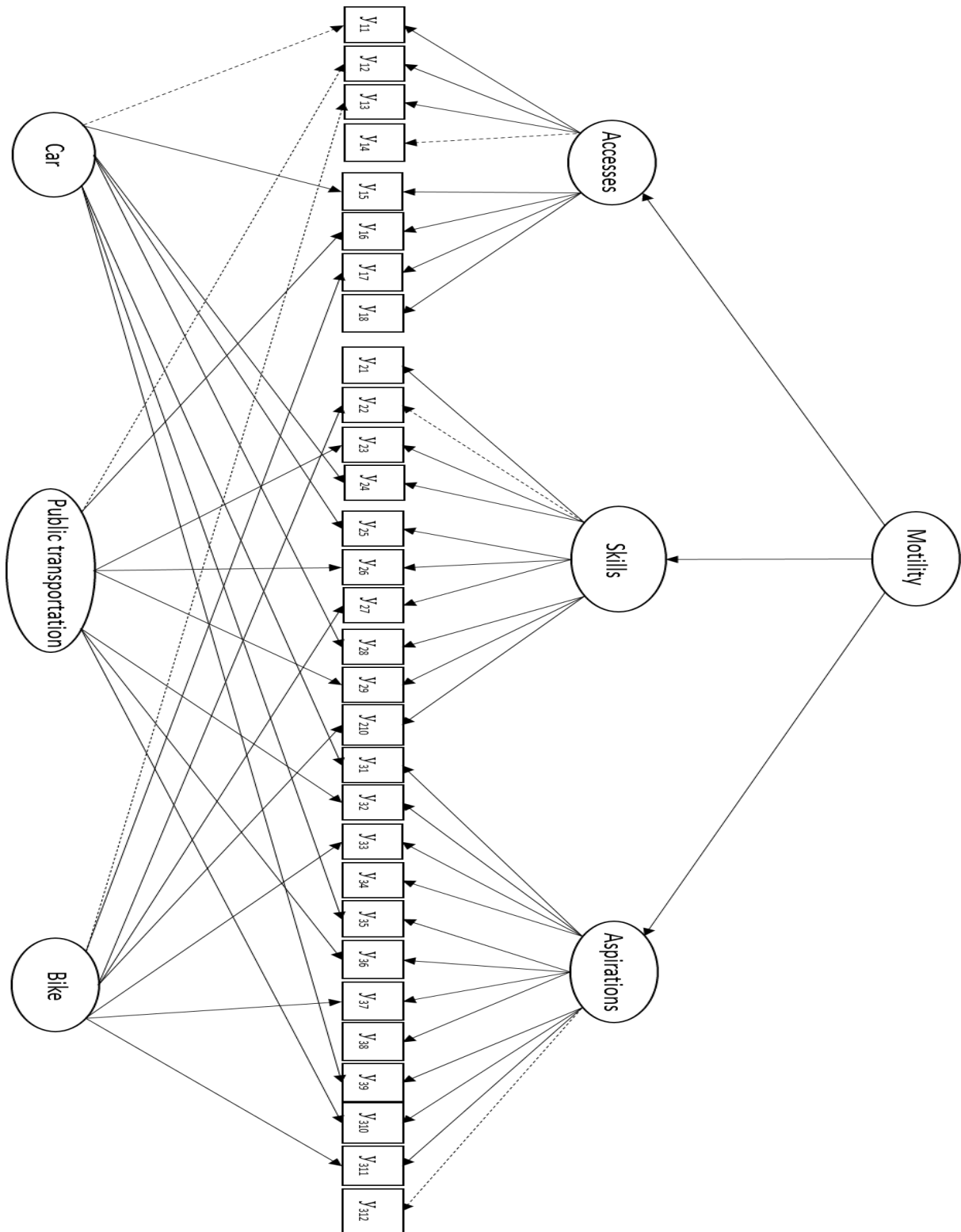
Figure 4: Structural model between motility and its pillars

As motility, we model pillars as latent variables with the indicators coming from the survey. Each pillar relates to motility by a reflective relationship to respect the framework of the LISREL method. From a theorical point of view, the concept of motility does not imply that the pillars are independent, but the relationships they maintain are still unexplored. We therefore do not introduce a causal relationship between accesses, skills and aspirations, but the model estimation calculate correlations at the end of the process.

For the selection of relevant indicators for the identification of latent variables, we exclude the variables in the questionnaire that relates to the social and spatial context. This guarantees the construction of a latent variable where motility corresponds to an individual aptitude, not directly depending on the scope of possibilities (i.e. the individual's environment). We then extract from the questionnaire the variables for which a reflective relationship makes sense with one of the latent variables. The result is the following model (Fig.5), where measures of the indicators consist of a 7-level categorical Likert scale.

Figure 5: Structural equation model concepted for the estimation of motility

Indicators reflecting accesses are the following for car, public transport, cycling and walking:

- y_{11} to y_{14} : possibility to use each mode for travel in the coming year;

- y_{15} to y_{18} : capacity to use each mode for travel in the coming year.

Orientation skills and transportation modes habits create the skills pillar:

- y_{21} to y_{24} : reading a road map, spatial orientation, reading a public transit plan, using a GPS;

- y_{25} to y_{27}: use of each mode (except walking) for a long time;

- y_{28} to y_{210}: use of each mode (except walking) without having to remember how to do it;

Finally, we evaluate aspirations according to three complementary modalities: interest, pleasure and moral value regarding different transportation modes:

- y_{31} to y_{34}: would benefit from using each mode for travel in the coming year;

- y_{35} to y_{38}: would be nice to use each mode for travel in the coming year;

- y_{39} to y_{312}: would be a good thing to use each mode for travel in the coming year.

In the model, some questions specifically relate to a particular transportation mode (e.g. public transports map understanding) while others are declined for each mode of transport (car as driver, public transport, cycling and walking). In order to ensure that the construction of latent variables structuring motility does not include covariance regading the degree of "affection" for different modes, we introduce three new "modal" latent variables. These variables "Car", "Public transport" and "Bike" result from the predisposition to use a particular mode. Walking is the only mode of transport that does not have an associated latent variable because very few individuals report never using it and because not all indicators do exist for this particular mode. It is also a way for us to use it as a refenrece and better identify the model. The latent variable motility does not result from a set of specific indicators, but from the three latent pillars according to the conceptual model.

To ensure model identification and convergence, it is necessary to choose one indicator per latent variable standardized for model estimation. We show these indicators by a dotted arrow on Fig.5. We choose them so that each standardized indicator optimally reflects the latent variable, without associating it with a specific modal behavior. Our choice for the estimator is

the MLR option (Maximum Likelihood Robust) recommended for estimation from data that do not satisfy the normality hypothesis (Arminger et Schoenberg, 1989).

Finally, we introduce some corrective correlations between manifest variables to take into account the succession of questions associated with these variables in the questionnaire. We do not account for the other correlation suggestions appearing in the "modification indices" to preserve a conceptual model faithful to the concept of motility. It is also a way to have no influence from the singularity of the data collected.

We carry out the estimation by modeling structural equations on the complete model using the LAVAAN package on R. The model converges and the fit values obtained for the model satisfy the cut-off criteria for the SRMR, RMSEA, CFI and TLI indices. The parameters' values estimated by the algorithm are significant. Estimation does not reject the theoretical model at the end of the structural equation modeling and we can now use it to study the compiled results. However, it is worth noting that the parameters of course depends on the indicators we use, even if the approach is confirmatory.

5. Application

Following the estimation of the model, we present here some first descriptive results regarding social differenciations and transportation mode choice. These results are insights on how such a measure of motility might help in better understanding research questions related to mobility and its social impact in more general terms.

We first perform a cluster analysis on the full sample in order to obtain a typology showing different levels of motility in the population and to adopt a comparative approach. Input variables are the scaled latent scores of the three motility pillars given by the estimated model: accesses, skills and aspirations. We compute the Euclidean distance matrix between all observations and perform a hierarchical cluster analysis using the Ward method in order to obtain consistent groups of motility. The table 2 presents results of this process.

Table 2: Means of the latent scores after cluster analysis

	im-motiles	*intra*-motiles	*pseudo*-motiles	*hyper*-motiles
% in population	21.3%	26.2%	27%	25.5%
Motility	-2.1	-0.48	0.92	1.25
Accesses	-2.52	-0.49	1.06	1.47
Skills	-0.62	0.48	-0.83	0.73
Aspirations	-1.31	-0.34	0.61	0.8

We identify four groups in the sample, which differ in their levels of accesses, skills, aspirations and, by definition, motility. We label and describe these different categories hereafter:

- The "*im*-motiles" are the less motile individuals of the population. All three of the latent scores averages are below zero. Conceptually, they are people that show low aptitudes of being mobile.
- The "*intra*-motiles" are indiviuals that are more motile than the "*im*-motiles", especially in terms of skills as they also lack of accesses and aspirations. Conceptually, they are people that show abilities of being mobile but that do not have the possibility or the willingness to use these abilities.
- The "*pseudo*-motiles" are individuals that are more motile than the "*intra*-motiles". They are opposite compared to them as they present high accesses and aspirations but low skills. Conceptually, they are people with the possibility and the willingness of being mobile but with limited abilities to do so.

- The "*hyper*-motiles" are the most motile individuals of the population. They are opposite compared to the "*im*-motiles". All three of the latent scores averages are above zero. Conceptually, they are people that show high aptitudes of being mobile.

The comparative approach, based on this typology, presents the advantage of not considering any pre-established social criterion (*ie* age, gender) to reveal some specific behaviors regarding mobility. Nevertheless, it is useful to see how people fit in these four different groups for two reasons. First, it is a way of testing if mobility capital is equally distributed in the population and, if not, which kind of social inequalities may appear. Second, it helps us to interpret and to replace our results in the context of previous research, whether it concerns motility or not.

We use a multinomial logit model to investigate which independent variables play a role on being *im*-motile, *intra*-motile, *pseudo*-motile or *hyper*-motile. To do so, we fix the *im*-motile status as the reference in order to interpret every coefficient as its associated variable's role on a potential motility increase. Table 3 presents results of the regression.

Table 3: Regression coefficients for socio-economic, demographic and equipment variables

	intra-motiles		*pseudo*-motiles		*hyper*-motiles	
Constant	-1.902	**	-.572		-2.667	**
# cars	-.220	**	-.222	*	-.537	**
# bikes	.102	*	.145	**	.248	*
PT card	.579	**	.889	**	.876	**
Driver licence	.140		-.755	*	.064	
Man	.527	**	-.400	**	.409	**
Age (cont.)	.063	*	.143	**	.119	**
Educ (cont.)	.072	**	.016		.154	**
Couple	.317		.093		.323	
Child(ren)	.107		-.101		.023	
Work	-.149		-.355	*	-.535	**
Income (cont.)	.039		-.009		.041	
City size (cont.)	.091	**	.130	**	.167	**

Mobility equipments (number of cars and of bikes, public transport pass, driver's license) play an ambivalent role on the motility typology. On the one hand, possessing a driver's license and a higher number of cars tend to decrease the probability to be in a higher motility group. On the other hand, attributes related to the other transportation modes increase the probability of being in those groups. This might suggest that the use of the car may be a mode that requires a low amount of mobility aptitudes and that can be used for people who do not show high levels of motility. On the contrary, bus and bike, even though they do not require some kind of license, may be less accessible modes for the *im*-motiles or the *intra*-motiles.

Men are significantly overrepresented in both categories where skills are above average (*intra*-motiles and *hyper*-motiles). This result goes in the sense of a double gender inequality. Men are privileged since they show higher aptitudes of being mobile, but also since their potential lack of motility do less often depends on compentencies than on accesses and aspirations, the latters being more unconstrained choices. Coefficients associated with the linear age variable are all positive. It is important here to remind that the physical condition does not enter our motility model, even though in reality this might decrease it when people grow older. We still highlight here that the highest coefficient is the one of the *pseudo*-motile alternative, where mean competencies regarding motility are the lowest in the population. Thus, our motility index is not only to be seen as the actual aptidudes of being mobile, but also as a capital highly based on past experiences. Unsurprisingly, the highest education coefficient concerns the *hyper*-motiles. Important is to note that educational level and gender impact motility groups in a similar way, raising the same inequalities implications.

Interestingly, neither being in couple or having children plays a significant impact on the probability for someone to be in either of the motility categories. It emphasizes the conceptual role of motility as the "indivudal" aptitude of being mobile in this research. This definition is reinforced as Table 3 also shows that income, treated as a continuous variable, is not significantly affecting motility. Financial ressources are of course an important factor of mobility practices and behaviors, but their role might more be in how one's is activating its mobility potential rather than in its subconscious manifestation.

The size of the city in which each individual is living, expressed in number of inhabitants, plays a significant role regarding the motility typology. This suggests the existence of a relation between the agent and the context in which he is shaping his aptitudes of being mobile. Values of the coefficients indicate that the bigger the city, the higher the probability for an individual to be in the most motile groups. On the one hand, it can be expected that mobility infrastructures are more developed in core urban centers than in smaller peripheries or rural villages, attracting people with a certain amount of mobility perspectives. On the other hand, this also raises questions about potential sociospatial inequalities in the sense that some territories may be more or less adapted to particular profiles.

Finally, the last coefficient we interpret here relates to the working status of the individuals. Counterintuitively, it shows that non-active people present a higher probability of being *hyper*-motile, for example. We understand this result as a manifestation of a routinization process. The sample shows that the respondents in a working situation are the one who make the highest use of the car, which we argue to be a mode that does not require high mobility aptitudes. In particular, they also show a lower tendancy to use different modes of transportation, or to be "multimodal", which may configurate daily habits requiring lower levels of motility.

After describing our motility typology in terms of individual caracteristics, we now use it in order to see its implication on effective mobility practices. Since no question measures directly and objectively how much each individual is being mobile on a regular basis in the sample, we create a mobility index based on a set of answers regarding daily activities. Each respondant was asked the frequency at which they work, shop, go out at night, etc., per week and which mode they used to do so. Answers range from *"all days of the week"* to *"never during the week"* on a five levels scale. This paper will use this index as a first approximation to study mobility practices and mode choice.

Figure 6 shows the relation between motility and the total amount of mobility while Figure 7 show the relation between motility and the relative part of each mode of transportation. We first show that, in average, a higher motility leads to more intensive mobility. As discussed in the literature on the subjet, highly motile individuals can chose not to activate it and stay immobile. Still, our result suggest that for a significant part of the sample, having higher aptitudes to be mobile leads to more mobility.

Figure 6: Degree of mobility by mode for each class of motility
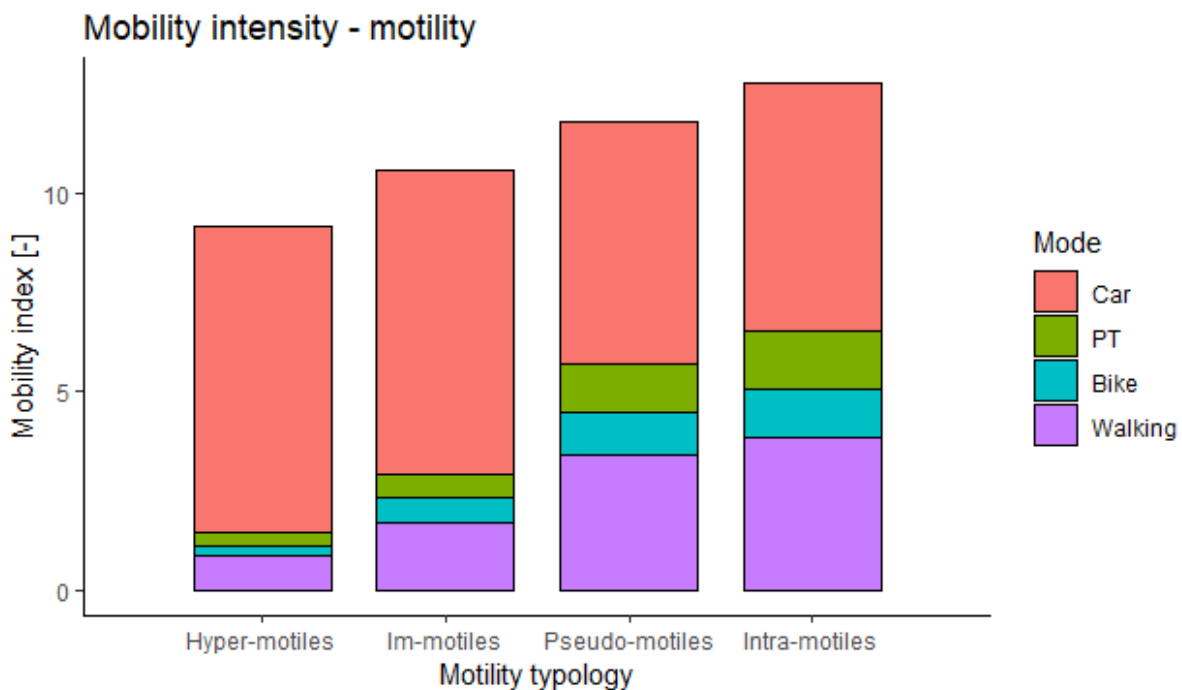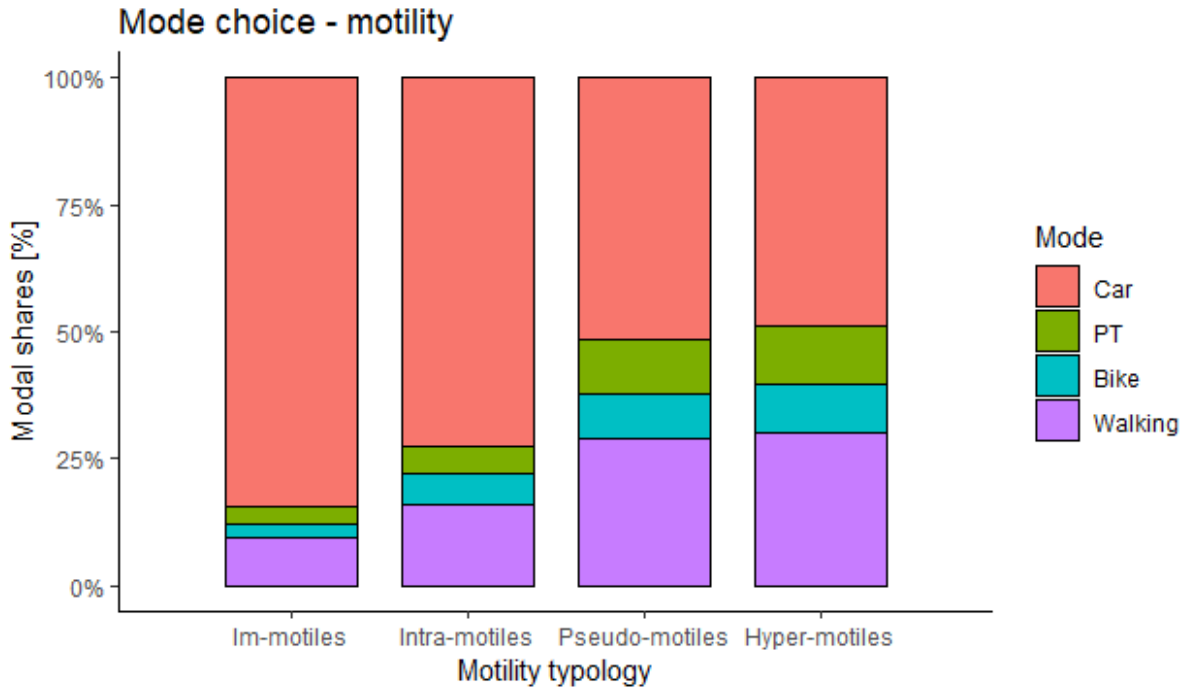
Figure 7: Modal shares for each class of motility

Interpreting the *im*-motile and the *hyper*-motile groups is straightforward. The former are people with low aptitudes in being mobile and consequently slighty mobile. The latter are people with high aptitudes in being mobile and consequently strongly mobile. *Pseudo*-motiles are also quite mobile but with much less competencies than *hyper*-motiles. This may be an indicator of a mobility seen as a constraint and, as such, a form of dependence. On the opposite, *intra*-motiles are close to the *im*-motiles but they score high in the competence pillar. This may enhance people that choose to keep motility as a potential, and have the choice to stay non-mobile.

More interesting is the participation of each mode of transportation we consider in the total mobility amount as significant differences appear. The *hyper*-motile and the *pseudo*-motile present very similar shares.

They realize only half of their declared activities by using the car. Walking account for about a quarter of these activities, public transport and bike share the remaining part. The next group, *intra*-motile, present a huge shift in the use of the car: they take it for about 75% of the activities they declare. Walking and public transport shares decrease sharply. The *im*-motiles are by far

the ones who make the most important use of the car, accounting for almost nine activities out of ten. Both bike and public transport shares are smaller than 5% of the total mobility index. These results have two implications. First, they suggest that driving a car does not require high mobility aptitudes, and that "altermobility" modes are less accessible. Second, they tend to associate a high motility with a higher propension of being multimodal; that is being able to make use of the full transportation system offer we consider in this paper.

Reading the intensity at which people are mobile and their mode choice routines using the motility concept raises important questions. In particular, the role of the car in its ability to accommodate one's daily program seems crucial to us. An important body of research qualify the car as a flexible alternative to combine multiple activites in a day, and that public transports or other altenatives struggle to be concurential in this regard. We argue that the "power" of the car does not only reside in its capacity to combine many activities, but also in the way it makes easy to accomplish any activity independently. Our motility index being both a manifestation of aptitudes and ease of being mobile, it reveals the car as an accessible, highly experience-based and routinized mode of transportation. It suggests that people with low levels of motility depend on it and that it is an efficient way to compensate a potential discomfort in being mobile.

Our findings also point at the conceal difficulty of using bike and, more importantely, public transportation. Even if one does not need any licence to ride a bus, feeling comfortable and at ease in it may be challenging for a significant part of the population and for different reasons. It is then important to think of mechanisms to facilitate the use of alternative modes of transportation when aiming at modal shift. Building new public transportation infrastructures might not be enough for people to change their habitual behaviors if they have no socialization to their regard.

6. Conclusion

This paper presents a proposition for measuring individuals' aptitudes of being mobile using Kaufmann's motility definition conceptually and structural equation modeling techniques methodologically. To our knowledge, this combination is still very unpopular and we think mobility to be a great topic to propose such interdisciplinary work since its understanding depends on both observable practices and unobservable mental constructions and decisions. Building on a particular survey measuring mobility habits and psychosocial behaviors, we develop a statistically valid model to measure motility. In order to operationalize this concept, we use it to identify different groups in the population that present unequal capabilities to respond to today's society mobility injunction. If some people are effectively both highly mobile and highly motile, others realize far less activities because of their ease in the

transportation system. We also highlight the existence of hybrid motility – mobility relations: on the one hand, motility may stay at the stage of a potential when accesses and aspirations do not match competencies. On the other, mobility may be a hard-time experience when competencies are not sufficient to make use of the transportation offer and to realize mobility aspirations. Finally, we show how the use of the car as the main transportation mode is predominant for people with low levels of mobility aptitudes. We argue that the car is not only "flexible" in the sense of enabling the combination of different activities on a daily basis, but also more generally "flexible" in the sense that it may be a mode of transportation that is the most convenient and easy to use. It suggests that we need to think other modes of transportation, especially public transports and bike, as alternatives that are not "natural" and for which individuals need important aptitudes. We think that it is only under such considerations that modal shift policy will be able to generate significant modal shift.

More specifically, this is an encouraging first approach, which seems to justify the continuation of research combining motility and structural equation modeling. The model used for our analysis correspond to one interpretation of motility, but some others are also realistic. A way to improve future models would be the integration of manifest formative variables, particularly for accesses. This will open the way for model comparisons where the latent variable motility would be associated, like its pillars, with manifest variables. From the initial concept, we could test different variants of the structural model, for example by considering motility as an exogenous variable. To this end, it would be crucial to optimize the choice of indicators and the design of the surveys, for instance by gathering questions by modules in the questionnaire, related to accesses, skills and aspirations.

7. References

Albertsen N. et Diken B. (2001). Mobility, Justification and the City. *Nordic Journal of Architectural Research. vol 14, no 1*, pp.13-24.

Bassand M. et Brulhardt M.-C. (1980). *Mobilité Spatiale*. Georgi.

Brown T.A. (2006). *Confirmatory Factor Analysis for Applied Research*. Guilford Press.

Canzler W., Kaufmann V. et Kesselring S. (2008, eds.). *Tracing mobilities*. Ashgate.

Chalas Y. et Paulhiac F. (2008). *La mobilité qui fait la ville*. Editions du CERTU.

Cuignet T., Perchoux C., Caruso G., Klein O., Klein S., Chaix B., Kestens Y. et Gerber P. (2019). Mobility among older adults: Deconstructing the effects of motility and movement on wellbeing. *Urban Studies*. [à paraître]

De Witte A. et al. (2013). Linking modal choice to motility: A comprehensive review. *Transportation Research Part A. vol 49*, pp. 329–341.

Faulconbridge J. et al. (2009). Corporate ecologies of business travel in professional service firms: working towards a research agenda. *European Urban and Regional Studies. vol 16, no 3*, pp.295-308.

Fichelet M., Fichelet R. et May N. (1969). *Pour une approche écologique de l'utilisation des moyens de transport*. SERES.

Flamm M. et Kaufmann V. (2006). Operationalising the Concept of Motility: A Qualitative Study. *Mobilities. vol 1, no 2*, pp.167-189.

Flonneau M. et Guigueno V. (2009, eds.). *De l'histoire des transports à l'histoire de la mobilité?* PUR.

Fouillé L. (2010). *L'attachement automobile mis à l'épreuve. Etude des dispositifs de détachement et de recomposition des mobilités*. Thèse de doctorat. Université de Rennes 2.

Gallez C. et Kaufmann V. (2009). « Histoire et sociologie face à la mobilité », in : M. Flonneau M. et Guigueno V. (eds.) *Histoire de la mobilité*. PUR.

Gerber P., Thériault M., Enaux C. et Carpentier-Postel S. (2018). Modeling impacts of beliefs and attitudes on mode choices. Lessons from a survey of Luxembourg cross-border commuters. *Transportation Research Procedia. vol 32*, pp.513–523.

Glick Schiller N. et Salazar N. (2012). Regimes of Mobility accross the Globe. *Journal of Ethics and Migration Studies. vol 39, no 2*, pp. 183-200.

Guigueno V. (2008). Building a High-Speed Society: France and the Aérotrain, 1962–1974. *Technology and Culture. vol 49, no 1*, pp. 21-40.

Hooper D., Coughlan J. et Mullen M. (2008). Structural equation modeling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods. vol 6, no 1*, pp.53-60.

Hoyle R.H. (2014, eds.). *Handbook of Structural Equation Modeling*. Guilford Press.

Jakobowicz E. (2007). *Contributions aux modèles d'équations structurelles à variables latentes*. Thèse de doctorat. Conservatoire national des arts et metiers.

Jensen O. B. (2006). Facework, Flow and the City: Simmel, Goffman, and Mobility in the Contemporary City. *Mobilities. vol 1, no 2*, pp. 143-165.

Kaufmann V. (2000) *Mobilité quotidienne et dynamiques urbaines*. PPUR.

Kaufmann, V. (2002). *Re-thinking Mobility*. Ashgate.

Kaufmann V. (2008). *Les paradoxes de la mobilité, bouger, s'enraciner*. Presses polytechniques et universitaires romandes.

Kaufmann V. (2011). *Rethinking the City*. Routledge and EPFL Press.

Kaufmann V., Bergman M. et Joye D. (2004) « Mobility: mobility as capital ». *International Journal of Urban and Regional Research. vol 28, no 4*, pp.745-756.

Kaufmann V., Ravalet E. et Dupuit E. (2015). *Motilité et mobilité : mode d'emploi*. Éditions Alphil-Presses universitaires suisses.

Kaufmann V., Viry G. et Widmer E. (2010). Motility, in Schneider N. et al. (eds.). *Mobile Living across Europe II – Causes and determinants of Job mobility and their individual and societal consequences*. Barbara Budrich Publishers. pp. 95-112.

Kellerman A. (2006). *Personal Mobilities*. Taylor & Francis.

Kellerman A. (2012). *Daily Spatial Mobilities – Physical and Virtual*. Ashgate.

Kesselring S. (2005). New mobilities management. Mobility pioneers between first and second modernity. *Zeitschrift für Familienforschung. vol 17, no 2*, pp. 129-143.

Kesselring S. (2006). Pioneering mobilities: new patterns of movement and motility in a mobile world. *Environment and Planning A. vol 38, no 2*, pp. 269-279.

Lash S. et Urry J. (1994). *Economies of Signs and Space*. Sage.

Lévy J. (2004). Les essences du mouvement, in Allemand S., Ascher F. et Lévy J. (eds). *Les sens du mouvement, Modernité et mobilités dans les sociétés urbaines contemporaines*. Belin.

Lord S. (2011). Le choix de vieillir à domicile : l'inévitable adaptation des modes de vie - Évolution de la mobilité quotidienne d'un groupe d'aînés de banlieue pavillonnaire. *Retraite et Société. vol 60, no 1*, pp. 197-213.

Ma T., Gerber P., Carpentier S. et Klein S. (2014). Geographic, social-cultural and modal usage determinants of activity space: A case study of EU institutions in Luxembourg and Strasbourg. *Transportation Research Procedia. vol 3*, pp. 109–118.

Maksim H. (2011). *Potentiels de mobilité et inégalités sociales : La matérialisation des politiques publiques dans quatre agglomérations en Suisse et en France*. Thèse de doctorat. EPFL.

McKenzie R. D. (1927). Spatial distance and community organization pattern. *Social forces. vol 5, no 4*, pp. 623-627.

Meijer E.(1998). Structural Equation Models for Nonnormal Data. DSWO Press.

Merriman P. (2012). *Mobility, Space and Culture*. Routledge.

Munafo S., Kaufmann V., Christie D., Vincent-Geslin S. et Ravalet E. (2015). Dispositions et usages de l'automobile et des transports publics en 1994 et 2011. *Revue d'Economie Régionale et Urbaine. vol 2015, no 5*, pp.753-782.

Nowicka M. (2006). *Transnational Professionals and their Cosmopolitan Universes*. Campus.

Ohnmacht T., Maksim H. et Bergman M. (2009, eds). *Mobilities and Inequality*. Farnham: Ashgate.

Rivere M. (2009). *Socio-histoire du vélo dans l'espace urbain – d'une écologie politique à une économie médiatique… Toulouse, Genève, Saragosse*. Thèse de doctorat. Université de Toulouse - Le Mirail.

Rocci A. (2007). *De l'automobilité à la multimodalité ? Analyse sociologique des freins et leviers au changement de comportements vers une réduction de l'usage de la voiture. Le*

cas de la région parisienne et perspective internationale. Thèse de doctorat. Université de Paris 5.

Schoenberg R. et Arminger G. (1989). Pseudo maximum likelihood estimation and a test for misspecification in mean and covariance structure models. *Psychometrika. vol 54, no 3*, pp.409-425.

Sergot B. et al. (2012). Mobilités spatiales et dynamiques organisationnelles. *Revue française de gestion. vol 7, no 226*, pp. 77-90.

Sheller M. (2011) *Mobility*. Sociopedia.isa.

Söderström O., et Crot L. (2010). *The mobile constitution of the society: Rethinking the mobility society nexus*. Université de Neuchâtel: Working Paper.

Sorokin P. (1927) *Social Mobility*. Harper & Brothers.

Tertoolen G. et Verstraten E. (1995). Changing Attitudes and Behaviour by Means of Providing Infromation. A Study on Private Car use ", in : Zwerrer et al. (eds) *Climate Change Research - Evaluation and Policy Implications*, Elsevier. pp.1189-1192.

Tillous M. (2009). *Le voyageur au sein des espaces de mobilité*. Thèse de doctorat. Université de Paris 1.

Van Acker V. et Witlox, F. (2010). Car ownership as a mediating variable in car travel behaviour research using a structural equation modeling approach to identify its dual relationship. *Journal of Transport Geography. vol 18, no 1*, pp. 65–74.

Vincent S. (2008). *Les « altermobilités » : analyse sociologique d'usages de déplacements alternatifs à la voiture individuelle. Des pratiques en émergence ?* Thèse de doctorat. Université de Paris 5.

Vincent-Geslin S. et Kaufmann V. (2012, eds.). *Mobilités sans racines - Plus loin, plus vite… Plus mobiles ?* Editions Descartes & Cie.

Viry G. (2011). *Mobilités spatiales, réseaux sociaux et familiaux : Quels mécanismes d'intégration à l'épreuve de la mobilité ?* Thèse de doctorat. Université de Genève.

West S.G., Finch, J.F. et Curran P.J. (1995). Structural equation models with nonnormal variables : Problems and remedies. In : Hoyle, R.H. (Ed.), *Structural Equation Modeling : Concepts, Issues and Applications*. Sage. pp. 56–75.

Witter R. (2012). *Public urban transport, mobility competences and social exclusion. The case of Santiago de Chile*. Thèse de doctorat. EPFL.

Yoder K.A., (1998). *Alternatives indices for testing goodness-of-fit in structural equation modeling*. Mémoire de Master, Iowa State University.