



On the (im-)possibility of deriving transport policy implications from hybrid choice models



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ABSTRACT

This paper focuses on hybrid choice models of the type increasingly being used by travel demand modelers, which include latent perception and attitude related variables. We argue that, contrary to current practice, these models do not support the derivation of policies that aim to change travel behavior by means of changing the value of a latent variable. An example of such a policy is a marketing campaign which aims to influence the latent variable 'perceived quality of public transport', and as a consequence mode choice behavior. We argue that this lack of support is due to the combination of two factors: (i) the latent variable is usually to a non-trivial extent endogenous to the travel choice, precluding inference of causality; and (ii) the data are almost without exception cross-sectional as far as the latent variable is concerned, and as such do not allow for claims concerning changes in the variable at the individual level. When data for the latent variables are cross-sectional, and to the extent that endogeneity of the latent variables cannot be ruled out, these variables should best not be used as targets for travel demand management policies—although they may still be used as input for scenario studies that involve changes in the population over time.

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1. Introduction

Although the notion that attitudes and perceptions play an important role in explaining travel choice behavior has been around for decades (e.g., Koppelman and Pas, 1980), the incorporation of these latent factors in discrete choice models is fairly recent. Starting with seminal work by Walker and Ben-Akiva (2002) and colleagues, hybrid choice models (or: integrated discrete choice latent variable models) have indeed become a trend lately. Especially during the last few years, an increasing number of researchers have begun to develop and test such hybrid choice models (e.g. Abou-Zeid and Ben-Akiva, 2011; Prato et al., 2012; Kamargianni and Polydoropoulou, 2014; Glerum et al., 2014; Paulssen et al., 2014), motivated by the idea that the integration of latent attitude- and perception-related variables in choice models enhances their behavioral realism and may ultimately lead to more tailored and better informed travel demand policies.

However, in this paper we argue that when it comes to deriving policy implications from these hybrid choice models (from here on: HCMs), their added value compared to that of conventional choice models is rather limited, and that many recent papers in fact have presented policy-implications that are not adequately supported by

the data used for HCM estimation. More specifically, after finding that latent variables such as attitudes and perceptions are significantly related to choice behavior, authors routinely propose the development of policies that aim to influence these latent variables and as a consequence choice behavior. Prime examples of such proposed policy options refer to information campaigns to increase the environmental consciousness of travelers (and presumably as a consequence change their mobility behavior towards choosing more sustainable travel options), or to improve travelers' perceived image of a particular travel mode like transit (and presumably as a consequence change modal choice behavior). In the next section, we will argue that such policy implications are not supported by the cross-sectional nature of the data in combination with the endogenous nature of the latent variables.¹

¹ There is another class of Hybrid Choice Models (HCMs) which has been receiving much attention lately, being the integration of latent class structures and choice models. These models aim to capture unobserved taste- or decision rule-heterogeneity by means of specifying different classes, each characterized by its own behavior. When it comes to the derivation of policies, these latent class models from a quite distinct category of HCMs, compared to HCMs of the latent variable-type. In this paper, we focus on this latter type of HCMs. Note that latent variables related to perceptions and attitudes may be used as input for membership functions of latent classes, as is done in, for example, Hess and Stathopoulos (2013); for the latent variable-portion of those HCMs, the observations made in this paper – as far as they relate to problems associated with making within-person inferences based on between-person data – do apply.

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The remainder of this paper is structured as follows: [Section 2](#) very briefly discusses the structure of HCMs (more in-depth introductions to the model type can be found in each of the papers cited above). [Section 3](#) argues which types of policy implications can, and which cannot, be drawn from these models, depending on the nature of the data used for estimation. [Section 4](#) concludes with a discussion about the added value of HCMs for travel demand modeling and policy making.

2. Hybrid choice models

We focus on the arguably most popular type of HCM: the integrated latent variable discrete choice model which includes latent perceptions and/or attitudes. [Fig. 1](#), adapted from [Walker and Ben-Akiva \(2002\)](#), presents the overall structure underlying latent-variable models.

A range of explanatory variables (possibly including characteristics of the decision-maker, the choice situation and choice-alternatives) are modeled as influencing the latent constructs (which may be perception- and/or attitude-related variables). These variables in turn enter the utility-function of one or more travel alternatives. The model is estimated based on observed choices (which serve as indicators for the alternatives' utility) and observed indicators for the latent variables (generally Likert-scale based survey questions). Although conceptually, a distinction can be made between a measurement model and a choice model, the two are (or: should be) estimated simultaneously as a hybrid choice model with a joint likelihood function, in order to obtain efficient and consistent parameter estimates. It should be noted at this point, that the indicators provide additional information content (i.e., in addition to observed choices), and as such add efficiency to the estimation of (choice) model parameters (e.g., [Bolduc and Daziano, 2010](#)). Importantly, this paper is not concerned with the estimation of HCMs and the potential econometric endogeneity issues – i.e., correlation between one or more covariates and the error term of the utility of one or more choice alternatives – that may arise and lead to biased estimates. Rather, our focus is on the derivation of policy implications from estimated models—most specifically those policies that aim to change the latent variable, and by doing so aim to change choice behavior.

It is important to note here, that although usually multiple Likert-scale questions are used to identify a latent construct, these measurements are almost without exception made at one particular moment in time. In other words, for each individual, there is a single moment during which her latent perception(s) and/or attitude(s) are measured. In still other words, the latent variable-related data are cross-sectional. Choice data employed in hybrid choice models are obtained either through Revealed Preference data collection (resulting in cross-sectional data when one choice is observed per person), or by Stated Choice experiments (resulting in a panel data structure), or a combination thereof.

Some recent examples of latent variables employed in hybrid choice models referring to traveler behavior include:

- Latent variable 'commute satisfaction' and many other latent variables, in the context of a mode choice study ([Abou-Zeid and Ben-Akiva, 2011](#)).
- Latent variable 'attitude towards the importance of public transportation' and many other latent variables, in the context of a public transport choice study ([Popuri et al., 2011](#)).
- Latent variable 'familiarity with the choice environment' and many other latent variables, in the context of a route choice study ([Prato et al., 2012](#)).
- Latent variable 'willingness to walk or cycle' in the context of a mode choice study ([Kamargianni and Polydoropoulou, 2014](#)).

- Latent variable 'perceived fairness' in the context of a road pricing acceptability study ([Di Ciommo et al., 2013](#)).
- Latent variable 'environmental consciousness' in the context of an alternative fuel vehicle type choice study ([Daziano and Bolduc, 2013](#)).
- Latent variable 'difference between the actual and acceptable attributes of the commute trip' in the context of a public transport choice study ([Hess and Stathopoulos, 2013](#)).
- Latent variable 'perceived comfort of public transport' in the context of a travel mode choice study ([Glerum et al., 2014](#)).
- Latent variables 'Comfort and convenience' and 'Flexibility' in the context of a mode choice study ([Paulssen et al., 2014](#)).

The main argument we want to put forward in the remainder of this paper is that there is insufficient evidence for the using latent perceptions or attitudes that enter HCMs as a basis for supporting travel demand policies that aim to change travel behavior (i.e., travel choices) by means of changing the value or level of the latent variable. Importantly, we focus on the situation where a policy directly aims at a latent variable (such as a marketing campaign directly aiming at a perception-variable). There are other, less problematic, ways to use HCMs for the derivation of transport policies; for example, when a latent variable is modeled as a function of covariates such as socio-economic variables or attributes of alternatives, the HCM can be used to forecast the effects of policies that target these covariates and as such indirectly impact the latent variable. This is done in, for example, [Glerum et al. \(2014\)](#) who model the impact of increased levels of vehicle ownership on Public Transport market share, through the latent variable 'perceived comfort of Public Transport' (the latter being specified as a function of car-ownership). In the remainder of this paper, we focus on the situation where the latent variable is directly targeted by a policy intervention.

3. The derivation of policy implications based on latent variables in hybrid choice models

3.1. The problems

There are two reasons why there is a lack of evidence supporting the use of latent variables in HCMs as targets for transport policies: (i) latent attitudes and perceptions are partly endogenous with respect to travel behavior, precluding strong inference of causality; and (ii) they are measured at a single moment in time, precluding inference of within-person variation. To start with the first of these notions: there are at least three compelling reasons why latent variables and perceptions of the type used in HCMs are in most cases to be treated as being partly endogenous with respect to the travel choice itself.

- First, both the latent variable and the choice variable are likely to be jointly influenced by the same (unmeasured) underlying factors, which causes endogeneity. Take for example a hybrid travel mode choice model which incorporates a latent variable 'perceived quality of public transport'. Clearly, this variable as well as the mode choice (car versus public transport) itself may be co-determined by an underlying personality trait of the type 'preference for not meeting other people when commuting', as well as other personality traits that are not part of the estimated model.
- Second, the travel choice may influence the latent variable (as opposed to the other way around), due to learning effects: in the above example, one's 'perceived quality of public transport' is very likely to change to some extent upon actually using

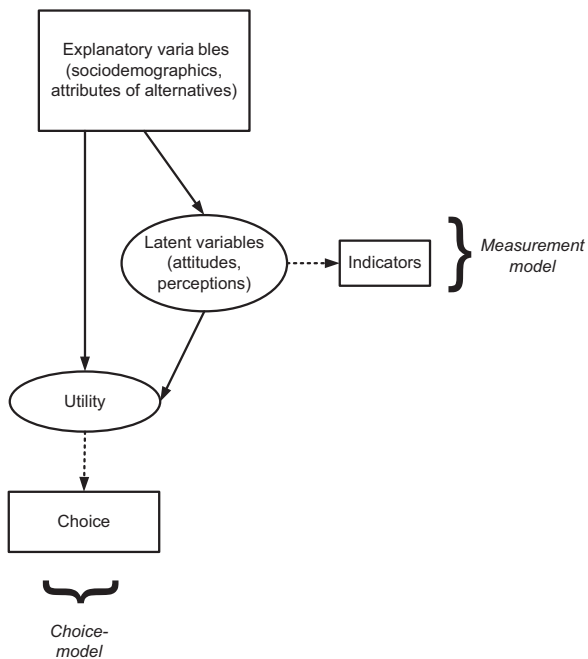


Fig. 1. Structure of a hybrid choice model. (adapted from Walker and Ben-Akiva, 2002).

public transport. This too, is a clear sign of endogeneity of the latent variable, as causality goes from the choice to the latent variable rather than vice versa.

- Third, the empirically well-established theory of cognitive dissonance (Festinger, 1962) shows that people attempt to align their attitudes and perceptions with their actual choice behavior. For example, a person who has chosen a particular mode is likely to increase her satisfaction with the attributes of the chosen alternative (or the importance she attaches to these attributes) and decrease her satisfaction with (or the importance she attaches to) the attributes of the rejected alternative. Again, such after-the-fact justifications imply that the causal relation might run from the choice to the latent variable, implying endogeneity of the latter.

Related to the last two points, empirical studies focused on the bidirectional relationship between attitudes/perceptions and (choice) behavior have consistently revealed concurrent relationships, i.e. attitudes/perception influence travel behavior and travel behavior influences attitudes/perceptions (Dobson et al., 1978; Golob et al., 1977; Reibstein et al., 1980; Tischer and Phillips, 1979; Thøgersen, 2006), in some cases even revealing larger effects from behavior to attitudes than vice-versa (Tardiff, 1977). Moreover, the notion that post-hoc justifications play an important role is also supported by several recent studies which indicate that users of a particular travel mode generally have – negatively – biased views towards non-used options. For example, it has been shown that car users generally overestimate public transport travel times (Van Exel and Rietveld, 2009) and underestimate the amount of satisfaction they would experience if they would actually use public transport (Pedersen et al., 2011). Another recent study has reported similar results in the context of car drivers' perceptions of travel times of chosen versus non-chosen routes (Vreeswijk et al., in press). Such biased views fit with the idea that people adjust their perceptions and attitudes according to and favouring their current behaviour.

Note that at first sight, one may be tempted to think that the issue of endogeneity (of the latent variable) does not arise in Stated Choice (SC) data, as long as attitude and perception related

questions are posed, before the choice tasks are presented; in that case, some may argue, any attitude formation takes place before a choice is made, and hence the direction of causality is clear. However, this argumentation is based on the assumption that the choices made by people in Stated Choice experiments have little or no connection to the real world. Since the goal of any SC-experiment is rather to mimic real world behavior and to stick as closely as possible to actually observable (travel) choice situations, it is unlikely that people arrive at their choices in SC-experiments completely on the spot, without reference to their personal experiences in real life. Take for example someone who has an intrinsic dislike for Public Transit in real life (leading to negative perceptions and attitudes for that mode in real life, as well as a very low level of usage of that mode in real life). We would not expect this individual to respond to attitudinal and perceptual survey questions and hypothetical travel mode-choice tasks, as if she would consider her travel mode choice for the first time. Rather, we would hope and expect her to carry her attitudes, perceptions, together with her choice behavior from the real world into the experiment. In fact, this expectation is a core pillar on which the SC-paradigm rests. As such, the endogeneity issues highlighted above are expected to play a similar role in SC-data as in revealed data settings.²

Inspection of the latent variables and travel choices modeled in recent HCM-studies (see the end of the previous section) clearly suggests that in most if not all cases, endogeneity issues arise. As is well known, endogeneity on its own already causes significant problems when policy-implications are to be derived, due to a lack of causality supporting such implications.

A second issue which further complicates the derivation of policy implications targeting a latent variable, is that latent attitudes and perceptions are almost without exception measured (by means of indicators) at one point in time, as opposed to at several points in time. The reason why this cross-sectional nature of latent variable measurements causes problems for the derivation of transport policy implications, is fairly straightforward—although note that similar arguments have been presented in a very detailed and rigorous manner in the field of social psychology (e.g., Borsboom et al., 2003): when variables are observed in the form of cross-sectional data, only between-person comparisons based on *differences* in latent variables are allowed for, as opposed to within-person comparisons that are based on *changes* in the latent variable. Take for example, once again, the latent variable 'perceived quality of public transport'. If this variable (more specifically, its indicator) is measured at only one point in time, then any covariation between the latent variable and the dependent variable (choice for a public transport option) that is captured in the estimated hybrid choice model may only be interpreted in terms of a between-person comparison: "if person A scores higher on the latent variable 'perceived quality of public transport' than does person B, then A is more likely to choose public transport than B". No within-person comparisons are allowed for (such as "if person A would score higher on the latent variable 'perceived quality of public transport' than she would become more likely to choose public transport"). The underlying reason for this is that there are simply no data points available that show how any person A would in fact react, in terms of changes in choice behavior, to a change in her latent variable 'perceived quality of public transport'. Only differences between individuals are observed, rather than changes for (or: variation within) the same individual. In other words, there is no observed covariation (of the

² A possible exception to this argumentation is the situation where new alternatives (e.g., currently not existing travel modes) are presented in the SC-experiment.

latent variable and the choice-variable) at the individual level, and since covariation is a prerequisite for causation, there can be no causal inference at the individual level.

The combination of the partial endogeneity of the latent variable and the cross-sectional nature of the data implies that any policy derived from an estimated HCM which aims to change the travel behavior of individuals by changing their latent perceptions or attitudes, is built on quicksand.

It is instructive at this point, to discuss the difference between the derivation of transport policies targeting a latent attitude or perception on the one hand, and a more objectively measurable variable like travel time on the other hand. A distinction needs to be made between Revealed Preference (RP) data and Stated Choice (SC) data. We start with a discussion of RP data in the context of a travel time-mode choice example: first it should be noted that, regarding the endo-/exogeneity of objectively measurable variables like travel times in RP-data, it appears that transportation researchers generally assume that these variables are exogenous to the travel choice. While this may be true to some extent (e.g. insofar as these variables such as travel times vary on a day-to-day basis due to random events in the transport network), endogeneity cannot be ruled out completely due to, for example, self-selection effects. Consider the situation where a public transport-lover chooses to live nearby public transport access points such as a metro station, which results in lower travel times for that mode (causing endogeneity for the travel time-variable). Nonetheless, compared to the levels of endogeneity one may theoretically expect in the context of latent perception and attitude variables (see above), the endogeneity of travel times seems much less pervasive and problematic.

Regarding the inference of individual level causality from cross-sectional ('between-person') data, it should be noted that RP data are usually cross-sectional in that a travel time observation (for multiple modes simultaneously) and a choice observation are made at one point in time. Clearly, these data (just like cross-sectional measurements of latent variables in hybrid choice models) strictly speaking do not allow for within-person comparisons of the type "an increase in person A's travel time for a particular mode of x minutes coincides with a decrease in the choice probability for that mode of y percentage points". An obvious solution for this problem would be to collect longitudinal data, where combinations of travel times and mode choices are observed at various points in time. However, it should be noted that also in case no longitudinal data are available, inferring within-person causality from cross-sectional data is much less problematic for the travel time-context, than for the latent variable-context discussed further above. The reason is that interpreting between-person variation in terms of within-person variation is less problematic, to the extent that variation at the within-person level has the same effect as variation at the between-person level (Borsboom et al., 2003). As an illustration, roughly following an example presented in Borsboom et al. (2003), take the relation between the height of a child and her ability to grab a book from the upper shelf of a bookcase. It is perfectly clear that a statement of the type "If Lucy grows ten inches taller, she will become able to grab the book from the upper shelf" is equivalent to a statement of the type "If we replace Lucy by someone who is ten inches taller, that person would be able to grab the book from the upper shelf". In other words, the relation between height and the ability to reach the upper shelf is the same at the within-person and the between-person level, which makes that we can safely interpret cross-sectional data (i.e., observations concerning the height of people as independent variable, and their ability to grab a book at the upper shelf as the dependent variable) at the within-person level. Going back to the travel time-example: also here, as illustrated by numerous studies using panel and

longitudinal datasets, there is a considerable degree of equivalence between the effect of travel time variation at the between- and within-person level. An increase (decrease) in travel time coincides with a decrease (increase) in the probability of choosing a particular travel option. To the extent that one is willing to consider travel time as an exogenous variable, this causality between travel time and the attractiveness of a travel mode is theoretically obvious, has been empirically confirmed, and is also firmly embedded in micro-economic theories of behavior (e.g., Small and Verhoef, 2007). Clearly, this equivalence between within- and between-person variation is not at all obvious in the case of latent perceptions and attitudes. That is, given the often subtle and bi-directional relations between these latent variables and the choice variable (see above), one may certainly not simply assume that the effect on choice behavior of a between-person variation in the latent variable is equivalent to its within-person counterpart. To summarize, while cross-sectional data on latent variables and choices should not be interpreted at the within person level, this is much less of a problem for variables such as travel time.

Stated Choice data form yet a different picture. First, these data involve multiple measurements per individual in that the individual is generally asked to respond to multiple choice tasks. This allows for the observation of within-person changes, paving the way for statements of the type "an increase in person A's travel time for a particular mode of x minutes coincides with a decrease in the choice probability for that mode of y percentage points". Furthermore, the very nature of SC data collection implies that (variations in) attributes of travel alternatives are exogenous to the travel choice. In sum, SC data circumvent both the issue of within/between person comparisons, as well as the issue of endogeneity. In that sense, SC data of objectively measurable characteristics of travel alternatives (such as travel times) form a particularly solid basis of the derivation of transport policies that target these characteristics.³

The above discussion shows that to some extent, the issues associated with (deriving transport policies from) latent variables in HCMs estimated on cross-sectional data, also play a role in the context of cross-sectional RP-data concerning objectively measurable characteristics of travel alternatives—such as travel times. However, problems associated with deriving transport policy implications targeting latent variables should be considered (much) more serious than those that are associated with deriving transport policy implications targeting objectively measurable variables such as travel times, even when the RP data concerning these objectively measurable variables are cross-sectional.

3.2. Partial solutions and a research agenda

To start with the problem of deriving within-subject interpretations from between-subject relationships, one obvious solution for this issue would be to collect latent-variable data across multiple moments in time, for the same individual(s). Such a longitudinal data collection would at least provide support for the notion of how *changes* in the latent variable for a given person correlate with *changes* in travel behavior.⁴ Such longitudinal data would only provide a solution, however, in cases where there is enough over-time variability in the latent variable(s) at the level of the person. This, in turn, depends on the nature of the latent

³ Of course, it is well known that the hypothetical nature of SC-data limits their appeal in terms of forming a foundation for transport policies. This issue has been discussed in depth in numerous publications, and is left aside in this paper.

⁴ Note that when the latent variable itself is specified as a function of covariates such as socio-economic factors (see the discussion at the end of Section 2), the need to collect longitudinal data applies to these factors as well.

variable(s) being considered. Personality factors, for example, are assumed to represent rather stable individual traits and, as such, are assumed to vary little over time. As a result, it is difficult to estimate a within-subject model in which personality is assumed to influence behavior (since a long time span is required to get enough variability at the subject level). That being said, it is likely that the latent variables typically being considered in hybrid choice models (perceptions and attitudes) are more variable at the within-subject level and can therefore more easily be included in a within-subject model. This, however, is an important issue for empirical investigation.

Moving to the issue of endogeneity/causality inference, there is certainly no easy solution to the problem that latent perceptions and attitudes are endogenous to the travel choice. Conceptually speaking, the most easy way forward would be to actually put to the test those policy-implications that are currently being simply assumed. Take for example the canonical case of a ‘marketing campaign’ that should improve perceptions of Public Transport-quality and convenience, and as a consequence Public Transport-market share. Routinely, this (type of) policy is proposed, after having pointed at the statistically significant relation between the latent perception variable and the choice for the travel mode option. Testing it, however, involves a careful experimental set-up. In phase one, a sample is drawn from the population of interest, and besides socio-economic factors, attributes of mode alternatives, and travel mode choices, also perceptions and attitudes regarding Public Transport are administered. In phase two, individuals from the sample are randomly assigned into a control group and a ‘campaign’ group. The latter group is being subjected to the campaign (policy instrument). At a subsequent moment in time, all variables of interest (including, of course, latent perceptions and attitudes) are measured once again, using the exact same format as in the first wave of the survey. Preferably, in this second wave, one would want to measure the latent variables before a travel mode choice has been made, to make sure that any changes in the latent variable are not the result of (accidental) changes in mode choice behavior. This, however, is practically infeasible in most cases involving frequently made choices such as travel mode choices. Nonetheless, when the ‘before’ and ‘after’ data are compared (e.g. through the estimation of a HCM on the pooled data), one can derive conclusions regarding the effectiveness of the campaign that are much more credible than those that are derived based on cross-sectional data. Needless to say, constructing such an experiment is much more costly and time-consuming than ‘simply’ collecting cross-sectional data. Nonetheless, there have been some recent successful efforts (Huijts et al., 2013; Jariyasunant et al., in press) along these lines, which is encouraging.

If one has to rely on cross-sectional data, a somewhat cosmetic way of circumventing both the two issues highlighted above would be to reframe ‘policies’ aimed at changing latent variables (and as a consequence choice behavior) into ‘scenarios’ in which members of a population are replaced by individuals with a different value or level for the latent variable. For example, strictly speaking, a scenario of the following type can be derived from a hybrid choice model estimated on cross-sectional data: “if each individual in the population is replaced by one that scores one point higher on the variable ‘perceived quality of public transport’ and who is otherwise identical to the replaced individual, then this coincides with a market share for public transport that is $x\%$ higher than in the initial situation”. In a sense, a latent variable that is part of a hybrid choice model that is estimated on cross-sectional data, should best be dealt with as a socio-demographic variable like ‘income’, ‘gender’, or ‘age’: rather than being used as a target for policies, it may be used as input for scenario studies, where the population itself (alongside its characteristics) is assumed to

change over time. Obviously, this does limit to a non-trivial extent the scope of policy-implications that may be drawn from HCMs which are estimated on cross-sectional data.

4. Discussion

This paper has argued that hybrid choice models of the type usually employed in the transportation literature do not support the derivation of travel demand policies (e.g., a marketing campaign) that aim to change choice behavior (e.g., travel mode choices) through changes in the value of a latent variable (e.g., ‘perceived quality of public transport’). We have argued that this is due to the combination of two factors: (i) the latent variable is usually to a non-trivial extent endogenous to the travel choice, and (ii) the data, which are almost without exception cross-sectional as far as the latent variable is concerned, do not allow for intra-person comparisons (i.e., changes in the variable for a given person). Following this argument, it appears that many of the policy-implications reported in the recent HCM literature are not supported by the combination of the model and the data. We discuss how these issues are (much) more pervasive for latent variables in HCMs, than for objectively measurable variables – such as travel times – in conventional choice models, although somewhat similar issues may play a role in these conventional choice models as well. We also argued that carefully designed (longitudinal) experiments are needed to provide a more solid foundation for the derivation of policy implications related to latent variables in HCMs. If no longitudinal data are available, and to the extent that endogeneity remains an issue, latent variables should best be interpreted in the same way as socio-demographic data: they may be used as input for scenario studies rather than being used as targets for travel demand management policies.

If one accepts our line of argumentation, a natural question to pose is the following: what does this imply for the added value of HCMs? Clearly, the recent surge of research into and application of HCMs in the transportation domain signals that many researchers are enthusiastic about these models. A review of a sample of these studies (see references in Section 1 and in Section 2) tells us that most authors motivate their use of the HCM paradigm by arguing that these models allow for a deeper and richer understanding of travel behavior, and/or the derivation of more tailored, richer and better informed travel demand management tools or transport policies. As we argued in this paper, the latter claim seems to be to a non-trivial extent unsubstantiated, especially when the model is estimated on cross-sectional measurements of the latent variable – as is usually the case.

Regarding the former claim (‘deeper behavioral insights’), it goes without saying that latent constructs such as perceptions and attitudes are likely to play an important role in many travel choice situations. However, this does not necessarily imply that these constructs should be incorporated in our models. For this incorporation to be warranted, it must be made clear what exactly these new, additional and deeper behavioral insights are, which we can presumably expect to extract from HCMs, but not from conventional choice models. In fact, thinking about and highlighting the added value of using HCMs, in terms of generating new behavioral insights, becomes all the more important in light of the fact that their added value in terms of the derivation of new policy-implications appears to be limited – as argued in this paper. We consider this – the formulation of what is the added value of HCMs in terms of gaining new and deeper behavioral insights – as a particularly important direction for further research. Especially when one considers the often very substantial added costs related to HCM development and estimation (including the substantial

amount of additional data collection), a clear picture of their added value is warranted than is nowadays available.

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