ANALYZING THE RELATION BETWEEN COMMUTING SATISFACTION AND RESIDENTIAL CHOICES USING DISCRETE CHOICE THEORY AND STRUCTURAL EQUATION MODELING

Francois Sprumont, Corresponding Author
University of Luxembourg
6, rue R. Coudenhove-Kalergi, L-1359 Luxembourg
Tel: +352 46 66 44 5501 Fax: +352 46 66 44 35501; Email: francois.sprumont@uni.lu

Paola Astegiano
KU Leuven
L-Mob Leuven Mobility Research Center,
Celestijnenlaan 300A,3001 Heverlee, Belgium
Tel: +32 16 32 27 80 Fax: -2200 Email: paola.astegiano@kuleuven.be

Francesco Viti
University of Luxembourg
6, rue R. Coudenhove-Kalergi, L-1359 Luxembourg
Tel. +352 46 66 445 352; Fax: +352 46 66 44 35501; Email: francesco.viti@uni.lu

Word count: 5937 words text + 5 tables/figures x 250 words (each) = 7187 words

Submission Date
1st of August 2016

ABSTRACT

Commuting is a derived activity performed by hundreds of millions of workers every day. The spatial and temporal concentration of this specific trip is responsible of many negative externalities for both travellers and the environment. Hence, a deep understanding of the elements having an impact on any of the facets related to the home-to-work trip is of tremendous importance. Among other aspects, the concept of positive feelings for travelling is rather recent in the transportation field. Subjective feelings and other personal factors such as mode attitude affect travel decisions (travel path, mode, departure time) as much as other well studied elements (land use characteristics, for instance). Determining how travelling satisfaction affects commuting mode choices is a pivotal issue for practitioners and policy makers aiming to develop any kind of transport measures, e.g. travel demand management strategies. The aim of this paper is twofold: (i) to further analyze the relation between commuting satisfaction and the utility Logsum following some previous studies from the authors; (ii) studying the influence of residential choices on the commuting satisfaction. The case study is based on a staff travel survey that has been implemented at the University of Luxembourg. Our two steps approach using Discrete Choice Theory and a Structural Equation Modelling (SEM) shows that the direct effect of residential preferences on commuting satisfaction is negligible compared to individual's external factors such as trip characteristics. But indirect effects of residential choices on commuting satisfaction have been observed.

Keywords: Commuting satisfaction, Travel Behavior, Utility Logsum, Residential self-selection

INTRODUCTION AND STATE OF THE ART

Since the development of transport economics theory (1) travelling is described as a derived demand permitting individuals to reach activity places. As underlined by (2), when travelling, only the benefit of performing the activity at destination is assumed to matter, and individuals are assumed to minimize the total cost (time, monetary resource, stress level, etc.) when choosing how to perform the trip. However, these intuitive and well-established principles have been challenged by (3). They concluded that for some individuals the trip in itself could be a source of positive utility. The concept of travel liking claims that some travelers are not acting as *homo economics* trying to reduce the travelling cost but are enjoying their trips. Of course this behavior challenges the development of (heavy) transport infrastructures because travel likers might not be receptive to measures aiming at, among other things, reducing travelling time. While (4) found that feelings during the home-to-work trip were mostly positive or neutral, (5) indicate that the work commute was frequently associated with negative feelings. Rating (positively or not) a commuting pattern necessarily implies, from the individuals, an aggregation of the feelings experienced while going to work. Differences in expressed satisfaction levels between commuting, a repetitive trip by definition, and a single trip such as the last leisure trip (6) may be important.

The various elements having an impact on the travelling satisfaction are more and more investigated. As pointed out by (7), travel utility has three main components: the enjoyment of the trip itself, the utility of the activity at destination and the utility of the activities performed while travelling. Controlling the activity at destination is a must and often transport studies dealing with satisfaction analyze single purpose trips (leisure trip for (6)). Indeed, an identical train trip might be perceived differently for an individual going to his workplace than for a tourist on vacation. In this paper, the activity at destination is the same for everyone, i.e. working at the University of Luxembourg. This suggests a certain control on the activity at destination even if the University staff members can have both positive and negative feelings regarding their professional activity.

In their paper, (8) provided an interesting classification of travelling satisfaction determinants. Internal and external factors (to the decision makers) are distinguished. The first category refers to non-mode specific attributes and the latter is related to mode specific attributes such as travelling time and cost or comfort. Since 2001, and the publication of (3), external factors have been the most studied (e.g. (9), (10), (11)). The travelling mode, for instance, is probably one of the most important determinants for the satisfaction rating. Different studies (e.g. (9), (10)) indicate that soft mode users have the highest satisfaction level while car users have an intermediate satisfaction level and public transport users were the least satisfied. Additionally, other mode specific characteristics such as travelling time, comfort, cost are directly impacting the way travelers are satisfied (or not) with a trip. Interestingly, as recently showed by (12), the travelling time is not always seen as a cost to be minimized or suppressed. (3) have shown that workers, on average, would prefer to have a shorter commuting time but very few would like to have a commuting time of zero minutes. On the other hand, extreme commuters (13), sometimes because of the (very) high salary obtained, might indicate that they are happy of their travelling conditions despite the very long distances or times travelled.

On the other side, although less studied, but probably as important, the effect of internal factors related to the decision makers start gaining interest in travel behavior analysis. While the effect of general socio-demographic status on travelling satisfaction is well reported (see e.g. (10)), authors are now focusing on subtle behavioral elements such as specific mode attitudes or effect of residential choices. (6) have insisted on the pivotal role of individual's resident neighborhoods type when rating travelling feelings. Individuals with a negative stance towards travelling (related to leisure trips in this case) were mainly living in urban neighborhoods. Such finding is in line with the concept of residential self-selection (see (14) for a review on the self-selection aspects related to travel behavior) claiming that people select their residential location partly because of the possibility to perform most of their trips using the preferred mode. This is partly why "travel haters" and soft modes fans locate themselves in urban neighborhoods where travelling distances are on average shorter and also why people liking to travel using public transport locate themselves close to subway or train stations. However, empirical evidences on the importance of residential preferences upon travelling satisfaction remain scarce.

To the author's knowledge only three scientific contributions (i.e. (6), (15) and (16)) have studied the relation between travel satisfaction and residential choices. Among other findings, these three scientific contributions confirmed the effect of specific land-use variables or residential attributes on travel satisfaction feelings. (6) concludes that people who do not like to travel prefer to live in the urban center, making possible to minimize traveling costs. Complementary to (6), (16) as well as (15) indicate that suburban dwellers have a more positive perception of their trips compared to urban dwellers. Interestingly, (15) indicate that, to some extent, people move into residential areas allowing them to have "happy traveling". Of course, residential choices or land use variables are only partly explaining differences in travel satisfaction ratings. As already mentioned, external factors such as travel time, comfort but also travel liking attitudes and mode specific attitudes play an important role.

(6) mention the possibility that residential variables (neighborhood type in their case) might have a bigger indirect than direct effect on travel satisfaction. Quantify both direct and indirect effect of residential preferences on travelling satisfaction (commuting trip in this case) is one of the main research questions of this paper. Indeed, the hypotheses in this paper are twofold: first there is a correlation between the stated commuting satisfaction and the Logsum utility related to the Home-to-work trips; second, residential choices have an impact on this correlation because of residential self-selection process.

DATA & METHODOLOGY

Data

The University of Luxembourg (the only one in the country) has been created in 2003 and welcome now 6500 students and 1500 staff members (including PhD students). The first travel survey which has been implemented between May and June 2012 was seen as a way to establish a benchmark regarding the mobility of the University staff members and to acquire insight into their traveling preferences. At that date, 1095 employees were working for the University and 397 replies were collected. After data cleaning, 328 valid surveys were considered for this analysis. The survey sample is representative of the entire staff member population. Males represent 46% of the respondents while professors & researchers were 39%, PhD students 22% and administrative or technical staff 39%.

However, a specificity is related to the living place of the respondents. Indeed, only 63.9% of the respondents live within the country of Luxembourg while the remaining share live in France (10%), Germany (21.2%) and Belgium (4.8%). This situation is due to the high salary offered in the

Grand-Duchy compared to neighbor's countries combined with very high residential cost in the country. Thus, cross-border commuters prefer benefiting of a high salary and live in their "home" county but having the drawback of longer commuting distances and traveling times. While the respondents living in Luxembourg have an average home-to-work distance of 17.7km the cross border workers have to commute, on average, 45.5 km. In addition, for cross border workers, the probability to beneficiate of a good public transport connection to work drastically decrease with distance. Indeed, cross-border would need, on average, 84 minutes to commute using the public transport system compared to 38 minutes for the people living in Luxembourg. Of course, as indicated by (10) and more recently by (8) such important difference in the trip characteristics is assumed to impact the commuting satisfaction.

In the travel survey, the question regarding the commuting satisfaction was formulated as follows:

"Are you globally satisfied by your daily work commute? (If you take into account elements such as the cost, the distance and the stress caused by your home-to-work trips)"

Respondent could choose between very dissatisfied, dissatisfied, satisfied and very satisfied. The questions regarding the residential choices were phrased as presented below:

"*Which elements influenced your accommodation choice?*
- *Desire / need to live closer to the university*
- *The easy access to public transport network*
- *The large number of shops / services around your accommodation"*

And for each of these elements, respondents had to select between 1) very low influence, 2) low influence, 3) strong influence, 4) very strong influence. While some authors have developed and/ or used specific and targeted methodologies such as the Scale for Travel Satisfaction (STS) (for instance, see (16) or (17)) to assess specifically all the elements influencing traveling satisfaction, such tools remain rather experimental, research oriented and it is difficult to implement for an entire company's workforce.

Methodology
The aim of this paper is first to quantify the correlation between the commuting satisfaction and the travelling utility *via* the Logsum function and second to understand how residential choices affect the commuting satisfaction. In order to verify these hypotheses, we employ both a discrete choice theory approach and a SEM approach. We will therefore first calibrate a Multinomial Logit (MNL) model with four different specifications, giving for each of them the degree of correlation between the stated satisfaction and the resulted logsum, and then we will perform a confirmatory analysis through SEM (see figure 1 for the conceptual framework).

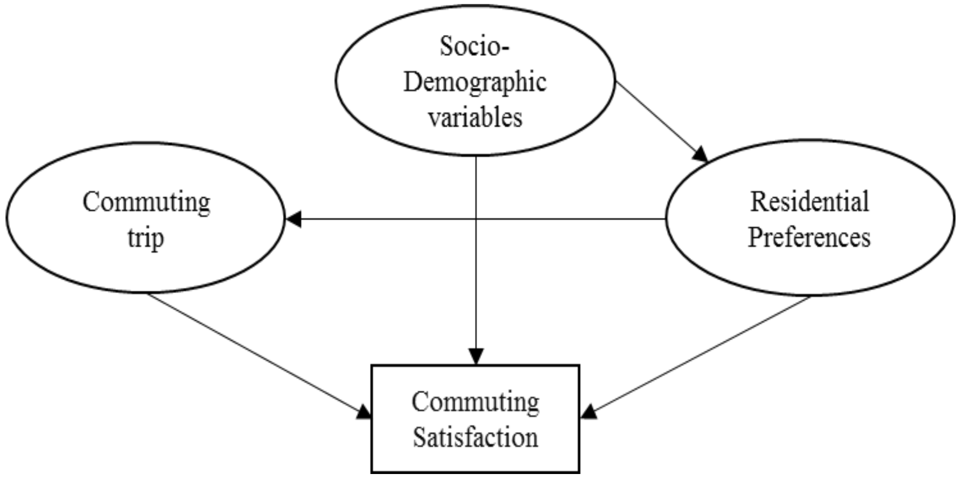

FIGURE 1 Conceptual model to be tested

Random Utility Theory: theoretical framework

Discrete choice analysis is often employed for modelling user's choice within a particular context, and is based on the assumption that each person aims at maximizing his/her utility (18). Specifically, it is assumed that each individual, in making a choice, considers all the alternatives that constitutes his/her choice set and assigns to them a perceived utility. The decision maker will then choose the alternative with the highest utility. The utility function is commonly made by two terms: a systematic part, which depends on a number of attributes, and a residual term, which captures the uncertainty in the model.

Being U_j^i, V_j^i, ε_j^j the general utility, the systematic part and the residual term respectively for individual i and alternative j we can express the utility function as

$$U_j^i = V_j^i + \varepsilon_j^j \qquad (1)$$

where

$$V_j^i = \sum_k \beta_k \, X_{kj}^i \qquad (2)$$

In Eq (2) β_k are the weights assigned to the attributes X_{kj}^i. In literature, different random utility models were proposed. Among them, the most commonly used is the Multinomial Logit which is grounded on the hypothesis that the random residuals are independently and identically Gumbel distributed. Given this assumption, the probability of choosing the alternative j in the choice set m is:

$$p[j] = \frac{\exp(V_j)}{\sum_{i=1}^{m} \exp(V_i)} \qquad (3)$$

The logarithm of the denominator in Eq (3) identifies the Logsum (LS_{RUM}) which is the aggregated utility given by the different alternatives available to the traveler. It can be expressed as:

$$LS_{RUM} = E\left[max_{j=1,\ldots J}\left\{U_j\right\}\right] = \int_{\varepsilon}\left[max_{j=1,\ldots J}\left\{U_j\right\} \cdot f\left(\varepsilon\right)\right]d\varepsilon = \ln[\sum_{j=1,\ldots J}\exp\left(V_j\right)] \quad (4)$$

In transportation, the Logsum function of utility as shown in Eq (4) is often employed as an evaluation measure of the consumer surplus under different transportation planning scenarios.

Structural Equation Modelling approach

While discrete choice theory presents many advantages (relative theoretical simplicity, forecasting power, etc) this methodology also presents drawbacks. The fact that decision makers are supposed to be fully aware of all the travelling alternatives and their characteristics is a major concern. Such issues have led researchers to try new methodologies such as Structural Equation Modelling (SEM). SEM approach, which is now becoming popular in travel behaviour analysis (19) is dating from the 1970's and was initially developed by marketing analysts.

As indicated by (20), mathematically, a SEM takes the following form:

$$Y = BY + \Gamma X + \varepsilon \quad (5)$$

Where: Y is a column vector of endogenous variables
B is the matrix of parameters between the endogenous variables
Γ is the matrix of parameters associated with exogenous variables
ε is a column vector of error terms associated with the endogenous variables

Interested readers might also consult (21) for an extensive description of the mathematical properties of SEM, the hypothesis related to the estimation procedure and so on.

Compared to regression analysis, the main advantage of SEM is the quantification of direct / indirect effect of one factor on another (22). The possibility to develop models allowing the quantification of both direct and indirect effects was crucial feature for selecting SEM methodology. In addition, as mentioned by (15) and (6), SEM methodology might be suited to study both the direct and indirect effect of residential choices on commuting satisfaction.

SEM methodology being more a confirmative rather than explorative modelling technique, the model structure is guided by the existing literature and the research hypotheses to confirm. When developing a SEM the estimation technique should be selected carefully. In this study, the ADF (Asymptotically Distribution Free) also called WLS (Weighted Least Square) has been selected because of the non-normality and the categorical nature (sometimes binary) of the data set ((19), (22)). However, compared to Maximum Likelihood (ML) estimator ADF estimator requires a larger sample (23), at least 10 times bigger the number of parameters to be estimated.

SEM's goodness of fit is not always easy to assess because the myriad of existing indicators, which all measure different aspects of the model (24). In this paper, four common goodness of fit indicators will be used. The SRMR (The Standardized Root Mean Square Residual) evaluates the overall discrepancy between observed and implied covariance matrices and can thus be considered as an absolute index. (25) mention that the SRMR value should always be lower than 0.1 but other publications (e.g. (24)) call for a more constraining threshold such as 0.05. The RMSEA (Root Mean Square Approximation) is a parsimonious indicator that should be lower than 0.1 (23). TLI

(Tucker-Lewis Index) and CFI (Comparative Fit Index) are both called incremental fit measures and should attain 0.9 (26).

Results

Descriptive analysis

As suggested by figure 2 and figure 3 the commuting distance and the commuting mode choice do seem to play an important role in how people rate their trip satisfaction. This supports the conclusion of (27) on the positive feelings related to soft mode used, the intermediate satisfaction for public transport users and the lower satisfaction for car commuters.

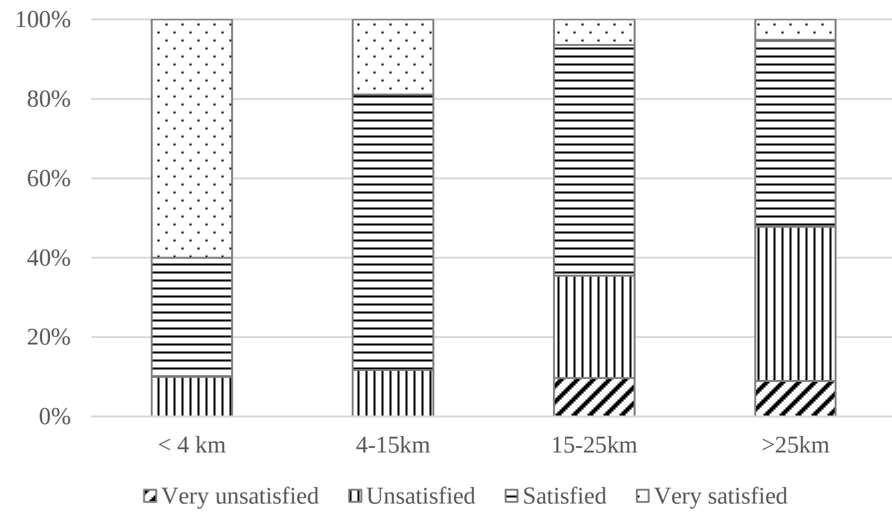

FIGURE 2 Commuting satisfaction and travelling distances

However, by observing these two figures it’s not clear how the commuting distance and the selected commuting mode interact. Indeed, perhaps commuting distance is only indirectly influencing commuting satisfaction by preventing soft and public modes usage.

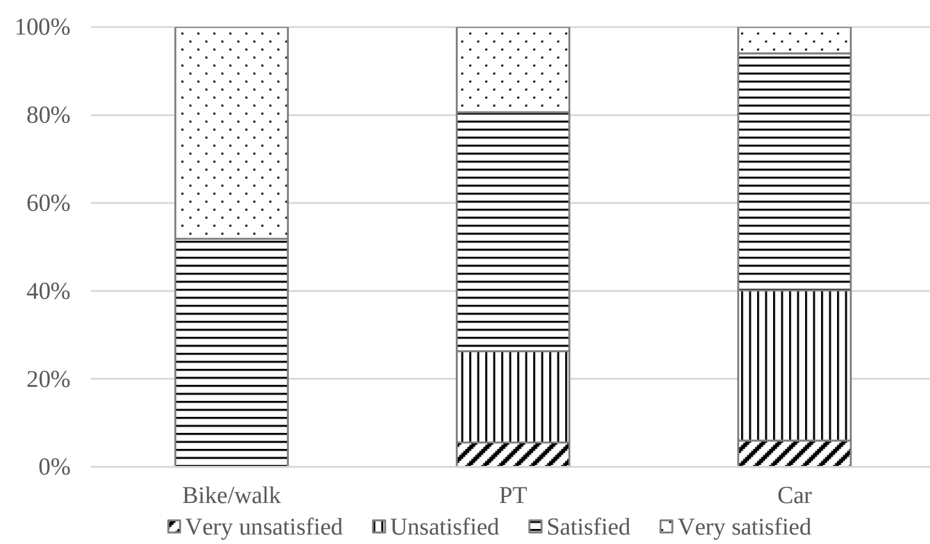

FIGURE 3 Commuting satisfaction and mode choice

Concerning the effect of residential choices, one would expect, for instance, that respondents who claim “the proximity of the university had a very high influence” live closer to the university than those who don’t. As expected, the average home-to-work distance for the two categories reaches respectively 32.9 and 17.5km. Respondents that favored home-workplace proximity have a modal split of 39% for Car, 42% for PT and 19% for soft modes while the modal split is 57% for car 40% for PT and 3% for soft modes for university staff members that didn’t choose their residence based on the home-to-work distance. Thus, intuitively, because short commuting distance can be performed with soft modes which are associated with more travelling satisfaction, the stated travelling satisfaction is more important (3.1 versus 2.6 on a 4 scale point) for respondents who selected their home place location partly based on their home-to-work distance.

Following the same line of reasoning, those that favored the proximity to public transport infrastructure when selecting their residential place tend to use more the public transport system than those who don’t (64.5% vs. 28%). Such simple but striking modal shift variation is in line with the conclusions of (6) concerning the self-selection hypothesis. Obviously, people have selected a residential area that would allow them to commute using the travel alternative that they prefer. Since in our sample PT use is associated with a higher satisfaction compared to car use, the respondents that have selected their home location close to public transport infrastructure are, on average 9% more satisfied of their commuting trip. Among respondents who indicated being very satisfied of their commuting trip, 74% mention that access to public infrastructure was important or very important.

Even though time consuming, the construction of the database prior to the model estimation might provide insightful information. For all travel alternatives, thus including the selected one, travel time, travel cost as well as mode availabilities were computed for all respondents. It has been previously indicated that, on average, commuting satisfaction was higher for soft modes then public transport and car. But this holds true mainly for individuals that have access to three travelling modes, which is not always the case. As discussed by (8) walkers or cyclists may be “happy commuters” as long as their mode was actually chosen and not constrained. Mode-captivity, whatever the mode considered, may reduce the positive attitude towards this alternative. While 60% of the car drivers are satisfied or very satisfied, the percentage decreases to 45% for those having only access to car. Following the same reasoning for public transport, while 74% of PT users declare to have positive stance regarding their commuting trip the share falls to 61% for university staff members having only access to public transport. It’s clear now that whatever mode travelers use if it’s the only accessible mode the stated travelling satisfaction will be probably lower.

Random Utility Theory: MNL calibration

Clearly, the previous section, devoted to the descriptive analysis, provides insightful information on the relation between travel mode characteristics, residential choices and commuting satisfaction. However, so far, no direct or indirect effects of both external (trip characteristics) and internal (residential preferences) on commuting satisfaction have been presented neither the relation between trip characteristics, residential variables and socio-demographic variables.

The very first step is to develop several MNL models and verify the estimated parameters for some variables. Then, for each model specification the utility Logsum is computed and a simple correlation analysis is performed to assess the correlation values. (29) has already used similar methodology with data from a route choice stated experiment, but hasn’t find important correlation between utility Logsum and stated satisfaction. As indicated earlier, the hypothesis is that a certain correlation will be present for all the Logsum values computed as a result of the different MNL model specifications and that the correlation will vary with the inclusion of residential choices variables.

In our model calibration, we considered three modes of transport: Car, Public Transport (PT) and Soft modes (walking and cycling). We then considered the employment status (either "PhD student" or "Other") and two residential attributes: the proximity to work and the proximity to public transport. We tested also other information such as gender, income, residential environment, etc. but they turned to be not significant in the model estimation.

Summarizing the systematic part of the utility function (Eq.2) has different specifications: the "Base model" contains trip characteristics such as travel time and travel cost; the "Socio-demographic model" contains, together with the trip characteristics, the employment status; the "Residential model" includes attributes such as proximity to work and accessibility to public transport.

The models were calibrated through the travel behavior analysis software Biogeme (30) and the results are summarized in Table 1. The Alternative Specific Constant (ASC) reflects the mean of the difference between the residual terms, that is the difference in the utility of an alternative *i* from *j* when all else is equal; PhD is instead a dummy variable that takes value 1 if the user is a PhD student and zero otherwise. The proximity to public transport and to work are two dummy variables that take value 1 if the users declare to be influenced by these two attributes in his commuting choice and zero otherwise.

TABLE 1 Estimation results

	Model1 (Base)	Model2 (Base+PhD Dummy)	Model3 (Base+ Residential)	Model4 (Full model)
ASC_CAR	0.00 Fixed	0.00 Fixed	0.00 Fixed	0.00 Fixed
ASC_PT	-0.567 (0.270)	-0.746 (0.289)	-1.19 (0.406)	-1.31 (0.418)
ASC_SOFT	-1.12 (0.341)	-1.31 (0.358)	-0.772 (0.398	-0.934 (0.416)
B_COST	-0.106 (0.0446)	-0.104 (0.0444)	-0.114 (0.0470)	-0.114 (0.0470)
B_TIME	-0.0509 (0.0116)	-0.0488 (0.0116)	-0.0485 (0.0120)	-0.0471 (0.0120)
B_PHD_CAR		-0.749 (0.392)		-0.586 (0.405)
B_PTprox_PT			1.21 (0.328)	1.16 (0.331)
B_Work_CAR			0.563 (0.390)	0.536 (0.394)
Rho-square	0.199	0.202	0.226	0.226
Final loglikelihood	-167.527	-165.733	-159.667	-158.637

Given this insight we performed a correlation analysis between the stated satisfaction and the utility Logsum for each of these four models in order to understand whether residential attributes could increase the correlation magnitude as we have suggested in (32). In the survey, we asked to each participant to express, with a Likert scale, the degree of satisfaction with their daily commuting trips. They had four options: very unsatisfied, unsatisfied, satisfied and very satisfied.

Pearson's coefficient (33) is employed to compute the above cited correlation. The Pearson's coefficient for each model is:

- Model 1 (Base): 0.3441
- Model 2 (Base+PhD dummy variable): 0.3326
- Model 3 (Base+ Residential): 0.3719
- Model 4 (Full model): 0.3643

It can be observed that the models in which both trip characteristics and residential attributes are included has the higher degree of correlation. However, this value is only marginally higher than the "Base" model. Therefore, we can again confirm that a correlation between the stated satisfaction for the commuting trip and the Logsum function of utility exists but this correlation is mostly influenced by travel time and travel cost. As a consequence, our initial intuition in which we assumed a potential influence of the residential attributes in the commuting choice is confirmed but it is lower than expected.

SEM outputs

Figure 4 shows the results of the SEM tested using SPSS Amos' extension (34). Concerning the latent variables, the related factor loadings are relatively high suggesting that the observed variables represent well the related factor.

The modification indices procedure available in Amos and in most commonly used SEM software indicates a non-negligible correlation between the commuting time and commuting speed. Thus, a covariance link has been added in the model specification. Goodness of fit indicators (see the appendix for a complete overview of the SEM results) indicate that the model fits reasonably well to the data. While some indicator values are aligned with common thresholds (RMSEA and SRMR), other indicators do not show expected values (TLI and CFI). Adding a covariance link, for instance, between "Age" and "PhD", would lead to an increase of the model goodness of fit but the objective was to stay as close as possible to the original conceptual model (as depicted in Figure 1).

Concerning the impact of the three latent variables namely socio-demographic variables, commuting trip and residential preferences on the stated overall commuting satisfaction, important differences are observed. As expected and in line with the literature ((8), (10)) the commuting trip variables are playing an important role in the commuting satisfaction rating. Indeed, by looking at the direct effect of the latent variables on commuting satisfaction only commuting trip characteristics have an important and significant direct effect (see again appendixes for full results). However, the indirect standardized effect for residential preferences reaches 0.302 (-0.57 * 0.53) and the indirect effect of the socio-demographic latent variable reaches -0.078. This result, answering to one of our hypotheses, suggests that the impact of residential choices is more an indirect than a direct effect to commuting satisfaction. This result also confirms the original intuition of (6) on the impact of residential self-selection process on travelling satisfaction.

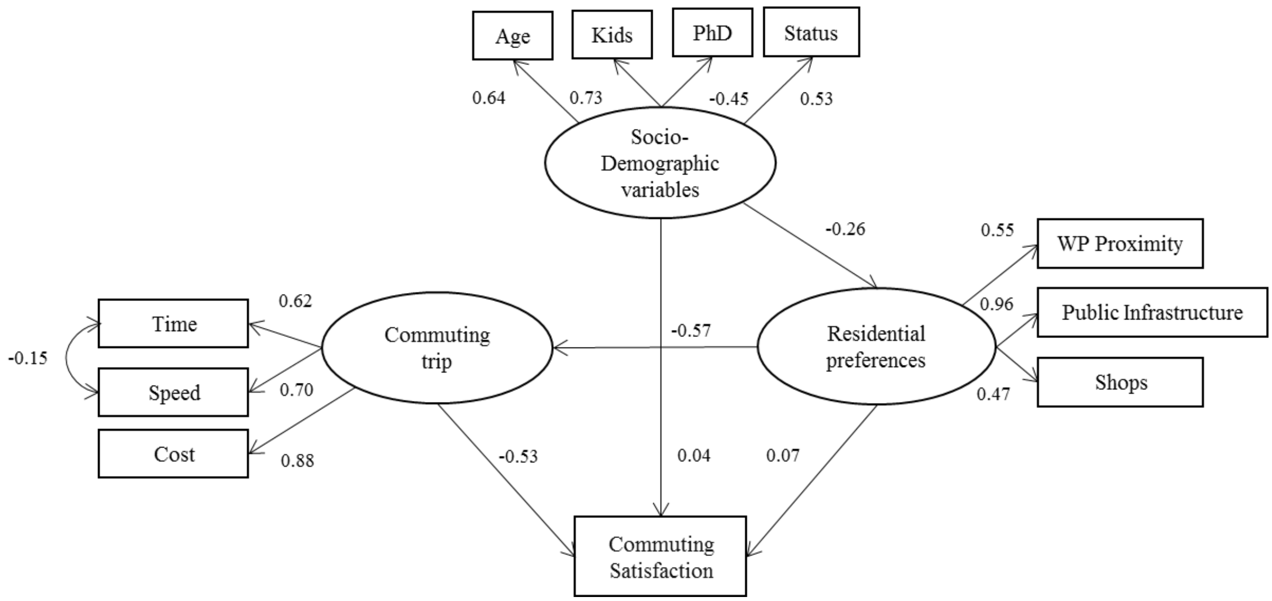

FIGURE 4 Model results (standardized estimates)

Methodological considerations

While the development of a discrete choice model provides interesting information such as the value of time (VoT) or the relative importance of a variable compared to another via the estimated parameters, this approach may not be the most suitable approach to analyze both direct and indirect effect of (latent) vairables on a dependant variable (i.e. the commuting satisfaction). While discrete choice models allow the estimation of modal share and permit to forecast modal shift based on developed scenario their relative important data needs (related to the non-chosen alternatives) may be a deterrent for travel behaviour analysts for using them.

On the other side, Structural Equation Modelling approach do not require additional data than the one provided by staff travel survey respondents and Modification Indices (MI) information significantly reduces the time needed to reach an acceptable model specification. Off-the-shelf software such as Amos Spss extension is drastically reducing the technical / coding skills needed to run simple and more complex models.

Regarding the specific research question related to the possible impact of residential preferences on the way commuters rate their travel satisfaction, both methodologies provided useful information but SEM methodology provided a more straightforward response in fewer steps.

The question regarding the usefullness of using of both methodologies for adressing a specific question remains complex. In this case, SEM has been used as a second approach to corroborate unexpected results of the first methodology. Being totally different, the quality of DCT and SEM outputs can’t be subject to any kind of ranking. However, in this case study, using only SEM would have permit to save time in term of data collection and model development.

CONCLUSION

In this study we investigate the influence of the residential attributes on the correlation between the utility logsum related with the commuting mode of transport and the stated satisfaction in using that particular mode.

One important finding is that, rather intuitively, the commuting satisfaction and the utility logsum are positively and importantly correlated. This shows that despite a growing interest for travel likers, utility theory will remain useful to approximate commuters satisfaction. More precisely, the utility Logsum is an interesting metric allowing travel behavior analysts to approximate the positive or negative feeling associated with a specific trip. In addition to provide a measure of the transport accessibility at one place, it has been showed that its (co)relation with satisfcation is truly valuable.

On the other hand both methodologies (DCA and SEM) used indicated that the direct effect of residential preferences on commuting satisfaction was weak if not inexistant. As discussed previousl, adding of residential attributes increase only marginally the correlation between the logsum and the stated satisfaction. However, SEM (Figure 4) approach shows an indirect effect of these residential attributes on the stated satisfaction. They influence the commuting trip directly and it is then somehow reflected in the coefficient that express the degree of influence of the trip characteristics on the stated satisfaction.

The debate on the commuting satisfaction determinants remains complex and unexplored. This scientific contribution calls for additional research to be done in the field. The limitation of standard employer-based travel survey is certainly reaching its limits in terms of usage. To better understand how people perceived their trips specific surveying method have to be improved and, as shown in this study, the methodology as to be selected carefully.

ACKNOWLEDGMENTS

This research is financially sponsored by the National Research Funding (FNR) through the AFR-PhD Grant STABLE (No. 7951609) and by the Marie-Curie Career Integration Grant InCoMMune (CIG PCIG13-GA-2013-618234). We also thank the University of Luxembourg for providing the tools and the communication channels and permissions for running the travel surveys.

APPENDIX

TABLE 3 SEM full results

Regression Weights

			Estimate	S.E.	C.R.	P	Standardized estimates
Latent Residential	<---	Socio Demo	-0.383	0.102	-3.748	***	-0.257
Latent Trip	<---	Residential	-1.63	0.182	-8.963	***	-0.572
Kids	<---	Socio Demo	1				0.73
Status	<---	Socio Demo	0.557	0.089	6.281	***	0.53
PhD	<---	Socio Demo	-0.486	0.078	-6.195	***	-0.454
Age	<---	Socio Demo	13.342	1.492	8.943	***	0.641
Workplace Proximity	<---	Residential	1				0.552
Public transport accessibility	<---	Residential	1.699	0.193	8.783	***	0.964
Shops proximity	<---	Residential	0.801	0.114	7.05	***	0.473
Cost	<---	Trip	1				0.882
Time	<---	Trip	8.315	0.751	11.067	***	0.616
Speed	<---	Trip	4.397	0.364	12.076	***	0.702
Satisfaction	<---	Socio Demo	0.071	0.116	0.609	0.542	0.037
Satisfaction	<---	Residential	0.084	0.085	0.986	0.324	0.066
Satisfaction	<---	Trip	-0.24	0.032	-7.566	***	-0.533

Covariances

			Estimate	S.E.	C.R.	P	Standardized estimates
Speed	<-->	Time	-17.429	9.33	-1.868	0.062	-0.152

Standardized Direct Effects

	SocioDemo	Residential	Trip
Latent Residential	-0.257	0	0
Latent Trip	0	-0.572	0
Satisfaction	0.037	0.066	-0.533
Speed	0	0	0.702
Time	0	0	0.616
Cost	0	0	0.882
Shops proximity	0	0.473	0

Public transport accessibility	0	0.964	0
Workplace Proximity	0	0.552	0
Age	0.641	0	0
PhD	-0.454	0	0
Status	0.53	0	0
Kids	0.73	0	0

Standardized Indirect Effects

	Socio Demo	Residential	Trip
Latent Residential	0	0	0
Latent Trip	0.147	0	0
Satisfaction	-0.095	0.304	0
Speed	0.103	-0.401	0
Time	0.091	-0.352	0
Cost	0.13	-0.504	0
Shops proximity	-0.122	0	0
Public transport accessibility	-0.248	0	0
Workplace Proximity	-0.142	0	0
Age	0	0	0
PhD	0	0	0
Status	0	0	0
Kids	0	0	0

Model Fit indicators

SRMR	0.0871	
RMSEA	0.88	(Low 90: 0.072; Hi 90: 0.104)
CFI	0.857	
TLI	0.798	

Degrees of freedom: 39
Chi-square = 137.226
Probability level = .000

REFERENCES

1. Meyer, J. R. (1959). *The economics of competition in the transportation industries* (No. 107). Harvard University Press.
2. Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, 15(2), 73‑80. http://doi.org/10.1016/j.tranpol.2007.10.005
3. Redmond, L. S., & Mokhtarian, P. L. (2001). The positive utility of the commute: modeling ideal commute time and relative desired commute amount. *Transportation*, 28(2), 179–205. http://doi.org/10.1023/A:1010366321778
4. Olsson, L. E., Gärling, T., Ettema, D., Friman, M., & Fujii, S. (2012). Happiness and Satisfaction with Work Commute. *Social Indicators Research*, 111(1), 255–263. http://doi.org/10.1007/s11205-012-0003-2
5. Kahneman, D., Krueger, A. B., Schkade, D. A., Schwarz, N., & Stone, A. A. (2004). A Survey Method for Characterizing Daily Life Experience: The Day Reconstruction Method. *Science*, 306(5702), 1776–1780. http://doi.org/10.1126/science.1103572
6. De Vos, J., & Witlox, F. (2016). Do people live in urban neighbourhoods because they do not like to travel? Analysing an alternative residential self-selection hypothesis. *Travel Behaviour and Society*, 4, 29–39. http://doi.org/10.1016/j.tbs.2015.12.002
7. Mokhtarian, P. L., & Salomon, I. (2001). How derived is the demand for travel? Some conceptual and measurement considerations. *Transportation Research Part A: Policy and Practice, 35(8)*, 695–719. http://doi.org/10.1016/S0965-8564(00)00013-6
8. St-Louis, E., Manaugh, K., van Lierop, D., & El-Geneidy, A. (2014). The happy commuter: A comparison of commuter satisfaction across modes. *Transportation Research Part F: Traffic Psychology and Behaviour*, 26, Part A, 160‑170. http://doi.org/10.1016/j.trf.2014.07.004
9. Páez, A., & Whalen, K. (2010). Enjoyment of commute: A comparison of different transportation modes. *Transportation Research Part A: Policy and Practice*, 44(6), 537‑549. http://doi.org/10.1016/j.tra.2010.04.003
10. Turcotte, M. (2011). Commuting to work: results of the 2010 General Social Survey. Canadian Social Trends, 92, 25-36.
11. Whalen, K. E., Páez, A., & Carrasco, J. A. (2013). Mode choice of university students commuting to school and the role of active travel. *Journal of Transport Geography*, 31, 132‑142. http://doi.org/10.1016/j.jtrangeo.2013.06.008
12. Russell, M., & Mokhtarian, P. (2014). How real is a reported desire to travel for its own sake? Exploring the ‘teleportation’ concept in travel behaviour research. *Transportation*, 42(2), 333–345. http://doi.org/10.1007/s11116-014-9546-1
13. Vincent-Geslin, S., & Ravalet, E. (2016). Determinants of extreme commuting. Evidence from Brussels, Geneva and Lyon. *Journal of Transport Geography*, 54, 240–247. http://doi.org/10.1016/j.jtrangeo.2016.06.013
14. Van Wee, B. (2009). Self-selection: a key to a better understanding of location choices, travel behaviour and transport externalities?. *Transport reviews*, 29(3), 279-292.

15. Cao, J., & Ettema, D. (2014). Satisfaction with travel and residential self-selection: How do preferences moderate the impact of the Hiawatha Light Rail Transit line?. *Journal of Transport and Land Use*, *7*(3), 93-108.
16. Vos, J. D., Mokhtarian, P. L., Schwanen, T., Acker, V. V., & Witlox, F. (2015). Travel mode choice and travel satisfaction: bridging the gap between decision utility and experienced utility. *Transportation*, 1–26. http://doi.org/10.1007/s11116-015-9619-9
17. Ettema, D., Gärling, T., Olsson, L. E., Friman, M., & Moerdijk, S. (2013). The road to happiness: Measuring Dutch car drivers' satisfaction with travel. *Transport Policy*, 27, 171–178. http://doi.org/10.1016/j.tranpol.2012.12.006
18. Ben-Akiva, M. E., & Lerman, S. R. (1985). Discrete choice analysis: theory and application to travel demand (Vol. 9). MIT press.
19. Golob, T. F. (2003). Structural equation modeling for travel behavior research. *Transportation Research Part B: Methodological*, 37(1), 1–25. http://doi.org/10.1016/S0191-2615(01)00046-7
20. Kuppam, A. R., & Pendyala, R. M. (2001). A structural equations analysis of commuters' activity and travel patterns. *Transportation*, 28(1), 33–54. http://doi.org/10.1023/A:1005253813277
21. Bollen KA (1989) *Structural Equations with Latent Variables*. New York: John Wiley & Sons
22. Van Acker, V., Witlox, F., & Van Wee, B. (2007). The effects of the land use system on travel behavior: a structural equation modeling approach. *Transportation planning and technology*, 30(4), 331-353.
23. Byrne, B. M. (2013). *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. Routledge.
24. Mueller, R. O., & Hancock, G. R. (2008). Best practices in structural equation modeling. *Best practices in quantitative methods*, 488-508.
25. Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational research methods*, *3*(1), 4-70.
26. Baumgartner, H., & Homburg, C. (1996). Applications of structural equation modeling in marketing and consumer research: A review. *International journal of Research in Marketing*, *13*(2), 139-161
27. Abou-Zeid, M. (2009). Measuring and modeling activity and travel well-being (Doctoral dissertation, Massachusetts Institute of Technology).
28. Baumgartner, H., & Homburg, C. (1996). Applications of structural equation modeling in marketing and consumer research: A review. International Journal of Research in Marketing, 13(2), 139–161. http://doi.org/10.1016/0167-8116(95)00038-0
29. Chorus, C. G. (2012). Logsums for utility-maximizers and regret-minimizers, and their relation with desirability and satisfaction. *Transportation Research Part A: Policy and Practice*, 46(6), 1003‑1012. http://doi.org/10.1016/j.tra.2012.04.008

30. Bierlaire, M. (2003). BIOGEME: a free package for the estimation of discrete choice models. In *Swiss Transport Research Conference* (No. TRANSP-OR-CONF-2006-048).
31. Ettema, D., Gärling, T., Eriksson, L., Friman, M., Olsson, L. E., & Fujii, S. (2011). Satisfaction with travel and subjective well-being: Development and test of a measurement tool. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*(3), 167–175. http://doi.org/10.1016/j.trf.2010.11.002
32. Sprumont, F., Astegiano, P., Viti. F. (2017). Analyzing the correlation between commuting satisfaction and travelling utility. *Proceedings of World Conference on Transport Research - WCTR* 2016 Shanghai. 10-15 July 2016
33. Pearson, K. (1894). "Contributions to the Mathematical Theory of Evolution." Philosophical Transactions of the Royal Society of London. A 185 (January): 71–110.
34. Arbuckle, J. L. (2010). IBM SPSS Amos 19 user's guide. Crawfordville, FL: Amos Development Corporation, 635.