Surveying and analysing mode and route choices in Switzerland 2010 – 2015

Claude Weis, TransOptima GmbH, Zurich

Matthias Kowald, Hochschule RheinMain, Wiesbaden

Antonin Danalet, Swiss Federal Office for Spatial Development (ARE), Ittigen

Basil Schmid, Institute for Transport Planning and Systems, ETH Zurich, Zurich

Milenko Vrtic, TransOptima GmbH, Olten

Kay W. Axhausen, Institute for Transport Planning and Systems, ETH Zurich, Zurich

Nicole Mathys, Swiss Federal Office for Spatial Development (ARE), Ittigen

Abstract

Every five years, the *Mobility and Transport Microcensus* (MTMC), a one-day CATI diary survey representative of the Swiss population in terms of socio-economics and trip characteristics, is carried out. In the year 2015, for the second time after 2010, an additional stated preference (SP) survey on respondents´ mode and route choices was linked to the MTMC. The combination of revealed preferences (RP) from the MTMC interview and stated preferences from the follow-up survey provides a valid set of parameters for a new generation of regional and national transport demand models in Switzerland that are sensitive in terms of trip purposes, target groups and spatial patterns. These models, in turn, are needed for reliable transport forecasts and thus build the foundation of future transport policy in Switzerland. Willingness-to-pay indicators savings are found to be rather stable over time, which bodes well for their use in cost-benefit analyses.

Keywords

RP and SP survey, stated choice experiment, repeat study, choice modelling, transport demand modelling

1 Introduction

Every five years, the Federal Statistical Office (FSO) and the Swiss Federal Office for Spatial Development (ARE) carry out the *Mobility and Transport Microcensus* (MTMC), a one-day CATI diary survey representative of the Swiss population in terms of socio-economics and trip characteristics (FSO and ARE, 2017). In the year 2015, for the second time after 2010, an additional stated preference (SP) survey on respondents´ mode and route choices was linked to the MTMC. The combination of revealed preferences (RP) from the MTMC interview and stated preferences from the follow-up survey aims to provide a valid basis for a new generation of regional and national transport demand models in Switzerland that are sensitive in terms of e.g. trip purposes, target groups, and spatial patterns. These models, in turn, are needed for reliable transport forecasts and thus build the foundation of future transport policy in Switzerland.

A combined RP/SP study with complex choice situations and multiple elements of generalised costs requires a survey method that collects information from a large and spatially representative sample of Swiss residents. To our knowledge this is the first report on such a combined RP/SP survey on the national level with a sample size of around 60´000 respondents in the MTMC and more than 4´500 respondents in the SP survey that is designed as a repeat study. In this paper, we present the survey, the resulting data and the resulting statistical models. The paper focusses on three main aspects:

(1) The SP survey was formulated as a stated choice (SC) experiment on mode and route choices with individually tailored choice situations. The choice situations for each respondent were based on one of their trips reported in the MTMC interview. Variations of respondents' own familiar trips were used to increase the realism of the experiments, stimulate their interest and facilitate the handling of the presented choice situations. As SP surveys impose substantial amounts of response burden on participants by having them engage in and make decisions pertaining to hypothetical situations, the aforementioned issues are crucial in order to increase response rates. Thus, our first objective is to describe the survey method and provide an example of a practical and population-wide application of SP experiments based on real-life RP behaviour.

(2) The SP method allows to model respondents' behavioural reactions to changes in mode and route attributes. The results can be utilised in cost-benefit analyses and especially in transport demand models of an inferential population's current behaviour. The large and

nationwide sample allows the inclusion of effects relating to different trip purposes, socioeconomically and behaviourally defined target groups, and different geographical areas of Switzerland. The spatial dimension is added to increase the forecast quality of the Swiss passenger transport model (ARE 2014, 2019). Presenting the potentials for spatial segmentation of the RP/SP-data is thus our second objective.

(3) Surveying information with similar RP and SP survey instruments in the years 2010 and 2015 (each sample including more than 4'000 respondents) allows an analysis of changes in respondents' preferences between the two surveys. A repeated measurement within a five-year span can also be used to evaluate the continuity and reliability of SP experiments on mode and route choices in general. The third objective of the paper is thus to present the comparison of data and results over time.

The paper is structured as follows: Section 2 reviews the relevant literature and introduces the theoretical framework that was employed to develop the survey method and perform the analyses. Section 3 reports on the experimental design and survey method. Models for respondents' mode and route choices, as well as the spatial heterogeneity within these preferences, are presented in section 4. A discussion on the development of major effects in transport mode choices in Switzerland between the years 2010 and 2015 is presented in section 5. Finally, conclusions are drawn in section 6.

2 Theoretical framework and literature review

Choice models have a long tradition in transport planning and have been used since McFadden (1975) introduced the random utility maximisation theory (RUM). In the following years the approach became widely used, as RUM-based forecasts were more accurate than forecasts from aggregated models (for a history of forecast approaches in transport planning, see Boyce and Williams 2016).

Customer choices can either be observed directly in real life situations, resulting in RP data, or they can be surveyed in hypothetical choice situations, resulting in SP data. RP data, on the one side, have the obvious advantage of being a representation of respondents' actual behaviour. On the other side, they have several disadvantages resulting in econometric challenges (for a discussion see Louvière, Hensher and Swait 2000): They often include only little variation and some effects might be highly correlated, raising issues of multicollinearity. Furthermore, non-existing markets, hypothetical effects, and future demands and supplies cannot be addressed in RP surveys. SP data overcome these issues by asking respondents to make trade-offs in hypothetical choice situations. These choice situations are based on experimental designs, essentially providing two advantages: Firstly, the experimental design includes only selected attributes and asks respondents to exclusively consider these effects when making their choices. Secondly, it allows controlling for correlation between the included attributes (Train 2009). The drawback from this increase in control, however, is a potentially reduced choice situation, framing and hence influencing respondents' trade-offs decisively (Beck *et al.* 2017). Thirdly, SP choice situations allow testing the effects from hypothetical policy instruments such as mobility pricing, which has not been introduced in Switzerland so far.

Combining RP information with SP data can help to overcome this limitation of the SP approach. Such a combination has the advantage of providing insights into actual behaviour and RP preferences, whilst the SP part and resulting clear trade-offs complement this real world information for non-existing markets and hypothetical choice alternatives or attributes (Hensher 1994).

In transport planning, SP and combined RP/SP surveys are used to analyse the effects of general costs on mobility behaviour and the related choices of mode, route, departure time and destination. These studies often focus on the value of time (VOT) and the value of reliability (VOR) (for an overview on European studies see e.g. Wardman *et al.* 2016). Recent developments in this field are found in the VOT studies for Great Britain (see Batley *et al.* 2017, Department for Transport 2015), the Netherlands (see Significance *et al.* 2012), Scandinavian countries (see Börjesson and Eliasson 2012, Fosgerau *et al.* 2007, Ramjerdi *et al.* 2010), Germany (see Axhausen *et al.* 2014, Dubernet and Axhausen 2019), and Switzerland (see Axhausen *et al.* 2004 and 2008, Fröhlich *et al.* 2012, Weis *et al.* 2012, Dubernet *et al.* 2018). SP studies allow cost-benefit analyses for infrastructure projects, where travel time savings often make up the largest share of gains (Mackie *et al.* 2001; for similar results in Switzerland and Germany see ARE 2016, BMVI 2016). In addition, results from SP studies can be employed as an empirical foundation in transport demand models and transport forecasts (Ortúzar and Willumsen 2006, Willumsen 2014). In Switzerland, the national transport demand model for personal travel uses parameters estimated from national RP/SP studies in the model stages of trip distribution (destination choice), mode choice, and assignment (route choice) (see ARE 2014, 2015, and 2019). However, collecting data for such use in a transport demand model increases the complexity of the choice experiment.

SP studies relying on RP data have the advantage that respondents are familiar with the choice situations, which in turn increases data quality. Asking the respondents to consider all alternatives and attributes at the same time requires cognitive efforts on their side and thus results in a high response burden. This burden increases with an increasing complexity of the choice situations. A high burden, thus, often results in a low data quality, due to effort-saving answer strategies and fatigue effects (Groves 2004). However, the more realistic and familiar a choice situation is, the less effort it takes to be contextualised and the more reliable respondents' answers are (Camerer and Mobbs 2017). Thus, employing respondents' RP choices as the basis for an SP experiment can help to increase data quality. Individually tailored stated choice situations for each respondent in combination with realistic alternatives and attributes enhance an easy imagination of the experimental setting by making the situation more easily accessible. Furthermore, presenting attributional stimuli and behavioural alternatives might be an interesting experience for respondents as it encourages a reflection of their current behavioural patterns and routines.

Finally, there are only few repeat SP and combined RP/SP studies in the field of transport planning. Moreover, existing studies usually focus on VOT issues (for examples see Gunn, 2001 for the Dutch national VOT study 1988 and 1997; Significance *et al.* for the Dutch national VOT study 1997 and 2010; for the development of UK VOT over time see Hague Consulting Group *et al.* 1999). Repeat studies on complex and multi-attributional choice situations, as needed to develop and update transport demand models, are rare, if available at all. To the best of our knowledge, there is no precedent for a combined RP/SP repeat study on a national level with a sample size above 4'000 respondents.

The contribution of our paper is threefold. First, we outline the construction of a large scale SP survey for mode and route choice using RP data to increase realism and reliability of the SP results. Second, we describe the corresponding estimation of a choice model and third, we test the stability of willingness-to-pay values between the survey periods 2010 and 2015.

3 Experimental design and survey method

The aim of the Swiss MTMC is to collect RP information from a representative sample of the Swiss resident population aged six years and older. The survey, which is part of the Swiss population census, is carried out every five years. It employs a stratified sampling technique to represent the Swiss resident population in terms of selected socio-demographics and spatial distribution. Information is collected by the means of computer assisted telephone interviews (CATI) during approximately 25 minutes on average. In the years 2010 and 2015, samples of around 60'000 respondents were obtained. Each iteration of the MTMC runs for one full year and thus captures seasonal differences in travel behaviour. The interviews consist of different modules, focussing on respondents' daily mobility, socio-economic information on households and individuals, the availability of mobility tools (vehicles and public transport season tickets), occasional journeys (such as holidays), and attitudes towards selected aspects of Swiss transport policy (FSO and ARE 2017). In terms of daily mobility, respondents are asked to report all stages and activities they performed on a predetermined date, usually the day before the CATI interview. Since 2010, a specific characteristic of the MTMC has been the geocoding of all motorised stages and destinations using a routing tool for car trips and consolidated time table data for public transport. Starting in 2020, trips by bike will also be geocoded (for general information on the MTMC and the route capture see Ohnmacht and Kowald 2014; for an overview on the MTMC data see FSO and ARE 2017; also see Smith 2017; Smith, Ruzsics and Axhausen 2017).

The MTMC exclusively collects RP information. Since 2010, a follow-up SP survey has been conducted to collect data on hypothetical choices, primarily as an empirical foundation for regional and national transport demand models. The SP study asks respondents to choose between two or three predefined alternatives in terms of transport modes or routes, each alternative being characterised by a number of attributes (for an introduction to stated choice methods see Louviere *et al.* 2000, Train 2009).

3.1 Experimental design

Combining the MTMC interviews with an SP experiment makes it necessary to interdigitate mode specific information from the RP study with the experimental designs of the SP-survey: one mode choice experiment and two route choice experiments, one for private motorised transport and one for public transport.

The experiments employ three transport modes as alternatives: Human powered mobility (HPM; e.g. walking and cycling), private motorised transport (PMT; e.g. car and motorbikes), and public transport (PT; e.g. bus, light rail, and train). Mode specific attributes were defined in 2010 and used in transport demand models (for details on qualitative interviews and the process to define alternatives and modes see ARE 2012a, 2012b). In 2015, these alternatives and mode specific attributes were revised, resulting in small changes in the variation of the attributes. Keeping the SP surveys in2010 and 2015 comparable allows the observation and analysis of changes in respondents' preferences over time. If preferences are stable over time, data pooling between the two surveys is permissible, which in turn allows the reduction of statistical uncertainty on the full sample or separate analysis on sub-samples due to the overall larger sample.

All attributes for PMT and PT are presented in Table 1. In terms of HPM, only travel times were included in the SP experiments and held constant across all choice situations. All attributional variations are defined as relative changes in relation to a respondent's RP trip characteristics as reported during the MTMC interview. Attributes that were not directly obtainable from the interviews were calculated with the agent based simulation tool MATSim, which is developed at ETH Zurich and TU Berlin (Horni *et al.* 2016). The respondents' personal situation was taken into account when calculating these attributes, e.g. PT travel costs were calculated depending on the ownership of different PT travel cards (for detailed information on the calculation of attributes see ARE 2017).

Table 1 Attribute values: Mode choice

Alternative/Attribute	Variation of empirical value
Private motorised transport	
Travel time [min]	-20% / -10% / +30%
Parking search time [min]	-25% / +25% / +50%
Fuel cost [CHF]	-10% / +20% / +30%
Road toll [CHF]	50% / 100% / 200% of -.06 CHF/km
Parking costs [CHF]	-10% / +20% / +30%
Delay risk [%]	10% / 20% / 30%
Delay time [min]	50% / 100% / 150% of 0.1 x travel time (max. 30 min)
Public transport	
In-vehicle time [min]	-30% / -10% / +30%
Access / egress time [min]	-50% / +/-0% / +50%
Travel costs [CHF]	-10% / +20% / +30%
No. of transfers [-]	-1 / +/-0 / +1
Headway [min]	-1 / +/-0 / +1 level*
Capacity utilization [-]	-1 / +/-0 / +1 level**
Delay risk [%]	10% / 20% / 30%
Delay time [min]	50% / 100% / 150% of 0.1 x travel time (max. 30 min)

* Headway levels: 5, 7, 10, 15, 20, 30, 60, 90, 120 min

** Level of capacity utilization: low, median, high, overload

Source: ARE (2017)

A slightly different set of attributes was used for describing the route choice alternatives. Most prominently, the main means of transportation (i.e., the vehicle type that most of the trip is spent in) was added to the PT experiment. This additional attribute allows the calculation of penalty factors for less comfortable sub-modes (e.g., bus in comparison to train) in transport demand and assignment models. The attribute values of the route choice experiment are shown in Table 2.

Table 2 Attribute values: Route choice

Alternative/Attribute	Variation of empirical value
Private motorised transport	
Travel time [min]	-30% / -10% / +30%
Travel costs [min]	-10% / +20% / +30%
Road toll [CHF]	50% / 100% / 200% of -.06 CHF/km
Public transport	
Main means of transportation	-1 / +/-0 / +1 level
In-vehicle time [min]	-30% / -10% / +30%
Access / egress time [min]	-50% / +/-0% / +50%
Travel costs [CHF]	-10% / +20% / +30%
No. of transfers [-]	-1 / +/-0 / +1
Transfer wait time [min]	-50% / +/-0% / +50%
Headway [min]	-1 / +/-0 / +1 level
Capacity utilization [-]	-1 / +/-0 / +1 level

Source: ARE (2017)

Due to the high number of mode specific attributes, the list was split into two attribute sets; as reference attributes, travel time, in-vehicle time and travel costs were included in both sets. Depending on mobility tool ownership, trip length and mode choice of the reported RP trip, personalised questionnaires presenting the available options were allocated to the respondents. Most respondents were presented with 16 choice situations, eight mode choices and eight route choices.

3.2 Survey method and experiences from the field

The respondents' trips from the MTMC were used to tailor individual SP choice situations. In terms of recruitment, MTMC respondents were asked for participation in a follow-up study at the end of their CATI interview between June, 20th and September, 28th 2015. Those who agreed to participate and to the analysis of their combined data from both studies were sent the SP questionnaire. However, before questionnaires were printed out and sent, some data pre-processing was necessary:

(1) The MTMC asks respondents to report their mobility at a stage level (i.e. all trip legs with different transport modes are described). The SP study, however, is trip based. For this reason, MTMC stages that were part of a single trip had to be aggregated. Reported transport modes from the individual stages were aggregated to a main mode for the trip, using a hierarchical approach. Finally, this main mode had to be further aggregated, as the macroscopic transport models that are in use in Switzerland differentiate between only four modes (walk, bike, car, and public transport).

(2) In case a person reported a trip for education or business purposes in the MTMC, this trip was selected as a basis for the SP survey, as the MTMC includes such trips in smaller proportions than trips for other purposes. In the absence of such trips, the longest reported work, shopping or leisure trip was selected in order to obtain a sufficiently large sample for longer trips.

(3) The agent-based transport demand modelling software MATSim was used to derive the attributes for the reported and selected trip and for its non-chosen alternative modes. These attribute values were then varied according to the experimental design. This procedure resulted in the individually tailored questionnaires for each respondent.

The whole process between recruitment and dispatch of the questionnaires was standardised and took between one and two weeks. This temporal proximity between the MTMC interview and the SP survey was meant to increase the recognisability of the trips presented to the respondents.

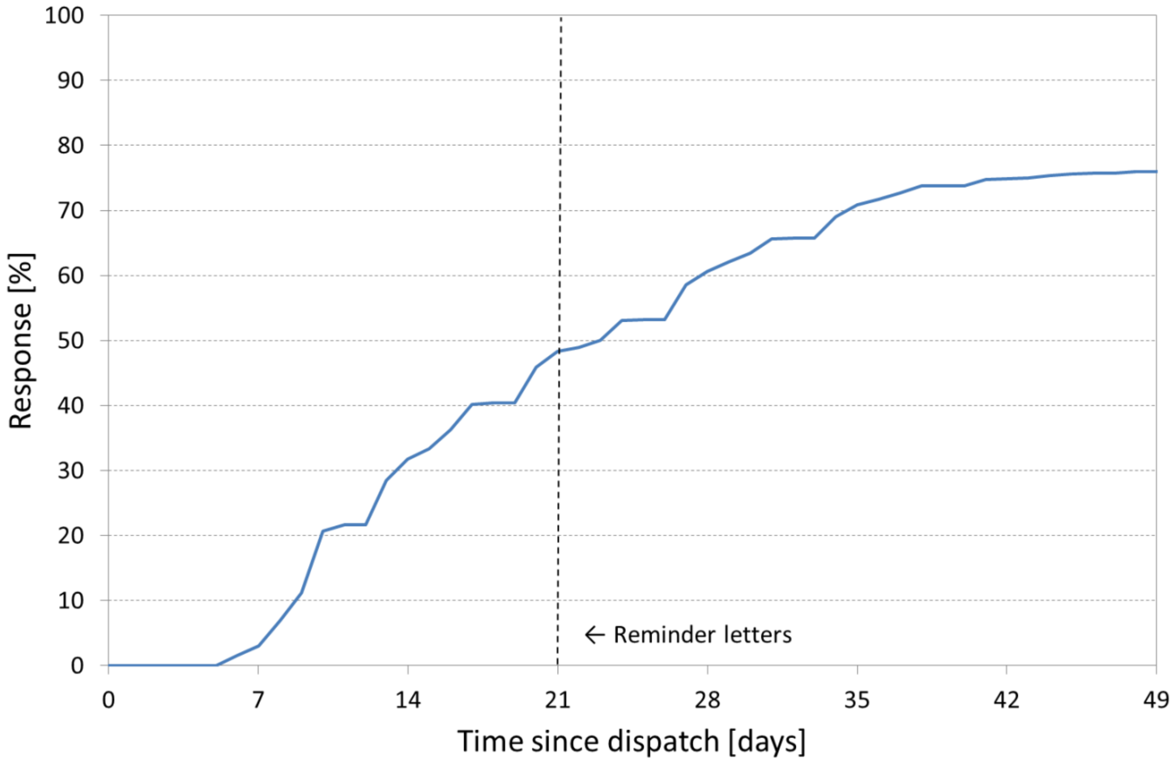
The questionnaires were printed and sent via postal mail. The respondents were asked to participate as soon as possible. Participants who had not returned their questionnaire within three weeks of the original dispatch received a reminder letter and an additional copy of their questionnaire. Overall, recruitment for the SP study was carried out over a span of 16 weeks, so that the survey was in the field for around 20 weeks including reminders and late responses. An overview of the process is provided in Figure 1.

During the 14 weeks of recruitment, 12’865 respondents participated in the MTMC. 7’812 (60.7%) of them agreed to participate in the SP study. However, some of those respondents were not of interest for the SP study, e.g. because they did not report a trip with a relevant purpose or mode. Therefore, only 6’099 questionnaires were dispatched, of which 4’693 were returned, resulting in a remarkably high cooperation rate of 76.9% (for an overview of response rates for similar experiments see Axhausen *et al.* 2015). Figure 2 shows the cumulative cooperation rate over the weeks following the dispatch of the questionnaires. It can be seen that most respondents needed around a week to return the questionnaire. An increase is visible after a time lag of around seven days after the reminder letters were sent. The high response rate and the clear effect of the reminder letter point to a well working multi-contact strategy, as suggested in the literature on survey studies (Dillman 2000).

Figure 1 Process of recruitment and tailoring of individual SP-questionnaires

Week		1	2					3	4	5				
Procedure	**Day**	Mon – Sun	Mon	Tue	Wed	Thur	Fri	Mon – Fri	Mon – Fri	Mon	Tue	Wed	Thur	Fri
Recruitment	*Mon – Sun*													
Data processing	*Monday*													
Aggregate stages to trips	*Tuesday*													
Choosing trips for SP experiment	Wednesday													
Routing of trips (PMT & PT)	*Wednesday*													
Generate questionnaires (experimental design)	*Thursday*													
Print & send questionnaires	*Friday*													
Send reminders	*Friday*													

Figure 2 Response rates over time



The data quality can be considered high as there were only low shares of item non-response in the SP experiments. Around 85% of respondents filled out all of their mode and route choice situations. In addition, there are no extraordinarily high values for non-trading behaviour (for details see ARE 2017). This can be interpreted as an indicator for the absence of fatigue effects although the response rate was high and the choice situations had a repetitive character. It should however be kept in mind that respondents replied to a relatively long and complex CATI (MCMT) and agreed afterwards to participate in the SP. This means that our sample might be biased towards persons with relatively low opportunity costs of time and/or an interest in mobility issues (see ARE 2016 for details on the socio-demographics of the different samples). This sample does however still allow us to estimate an unbiased choice model, as the attributes indicating selectivity are included in the model (Ben-Akiva and Lerman 1985).

4 Choice modelling

In this chapter, we describe a multinomial logit model estimated with the software *Biogeme* (Bierlaire, 2003). The development of the model focuses on its later application in transport models, and in particular in the Swiss passenger transport model (ARE 2014, 2019). The model highlights the importance and possibility to distinguish between and compare effects from different spatial areas.

4.1 Data and model specification

The dataset contains 6'099 revealed and 61'266 stated choices, for a total of 67'365 observations. The revealed choices represent only mode choices, while the stated choices contain both mode and route choices (32'802 mode choices, 22'033 route choices by car, 6'431 route choices by public transport). The model controls for panel effects (use of individual cluster-robust standard errors, see Baltagi 2008), scale effects for different utility levels between RP and the various SP experiments (see Hess *et al.* 2007, 2008) and socio-economic characteristics of the respondents. Furthermore, interaction terms between trip characteristics (such as travel time and costs) and income and trip distance, and segmentations by trip purpose and spatial typology are included.

Each participant in the SP survey made between 1 and 17 choices during the experiment. With such panel data, there is serial correlation: the choices made by the same person share unobserved factors (e.g. a preference for car based on specific needs). With unobserved factors, the error terms between choices made by the same individual cannot be assumed to be independent. Moreover, the *n*-th choice might influence the *n+1*-th choice. Examples of such dynamics are habits in mode choice or learning effects when facing congestion on a specific road in route choice. For an example of a dynamic model correcting for serial correlation, see Danalet *et al.*, 2016.

In the model presented in this paper, we assume that there are no such dynamics. We also do not estimate a mixture model with random effects, since the number of observations is large. Instead, we use the methodology proposed by Daly and Hess (2010) to address the panel structure. A standard logit model with panel data would lead to consistent but inefficient estimates. The naive log-likelihood of the model would sum on the number of observations nt, as if they were independent:

$$L = \sum_{n} \log \prod_{t} p_{cnt} = \sum_{nt} \log p_{cnt}$$

where p_{cnt} is the probability that individual n made choice c in situation t.

We follow Daly and Hess (2010) and use the true log-likelihood function by summing over the number of individuals n:

$$L = \sum_n \log p_{\{c\}n}$$

where $p_{\{c\}n}$ is the probability that individual n made the sequence of choices $\{c\}$.

Daly and Hess' approach calculates the errors using the robust (or "sandwich") estimator and the true log-likelihood function. For more details about this approach, see Daly and Hess (2010).

When simultaneously estimating a model with revealed and stated data, it is crucial to account for different utility levels, or called scale effects, between the RP and the different SP experiments. Among the SP data, there are three experiments: mode choice, route choice by car and route choice by public transport. Therefore, four scale variables, one for each choice situation, were defined, one of the four being fixed to 1 for identification purposes.

4.2 Attributes in the model, interactions with distance and income and segmentation by trip purpose and spatial typology

The model includes alternative specific constants for each mode and attributes describing the characteristics of the trip with a particular transport mode, the general characteristics of the trip and socio-economic characteristics (including information about mobility tool ownership). However, it is assumed that individuals react differently to costs and travel time depending on their income or the distance of the trip. For cost or time attributes (denoted x), the utility function is:

$$V = \ldots + \hat{\beta}\left(\frac{y}{\bar{y}}\right)^{\lambda} x + \ldots,$$

where y is a continuous interaction term (distance or income), $\bar{y}$ is an arbitrary reference value of the interaction term y (20 km for distance, 7'000 CHF/month per household for income) and λ is the estimated elasticity of β with variations of the interaction term y. A detailed list of all attributes, including interactions, can be found in Table 5 the Appendix.

Some parameters of the model were differentiated depending on the trip purpose, namely those for trip duration, parking space search time, access time to PT, waiting time for PT, number of changes for PT, frequency of service for PT, ownership of cars and public transport season tickets. The assumption is that these attributes have different impacts on the choices of individuals depending on the purpose of their trips. Furthermore, the place of residence of each individual was associated to a spatial typology differentiating between urban, rural and intermediary municipalities. This typology has been defined by the Swiss Federal Statistical Office using population density, size and accessibility of Swiss communes (FSO, 2017). This typology was employed to segment the parameters for the duration of the trip, the costs, the owning of public transport season tickets and the number of changes in public transport. Previous analyses showed that travel behaviour is very different between urban and rural areas (Simma & Axhausen 2001, Pucher & Renne 2005, Axhausen *et al.* 2010, Atasoy *et al.* 2012, Meyer de Freitas *et al.* 2018). Therefore, these differences were tested in the Swiss context in 2015 and eventually integrated in the Swiss passenger transport model.

4.3 Results and model validation

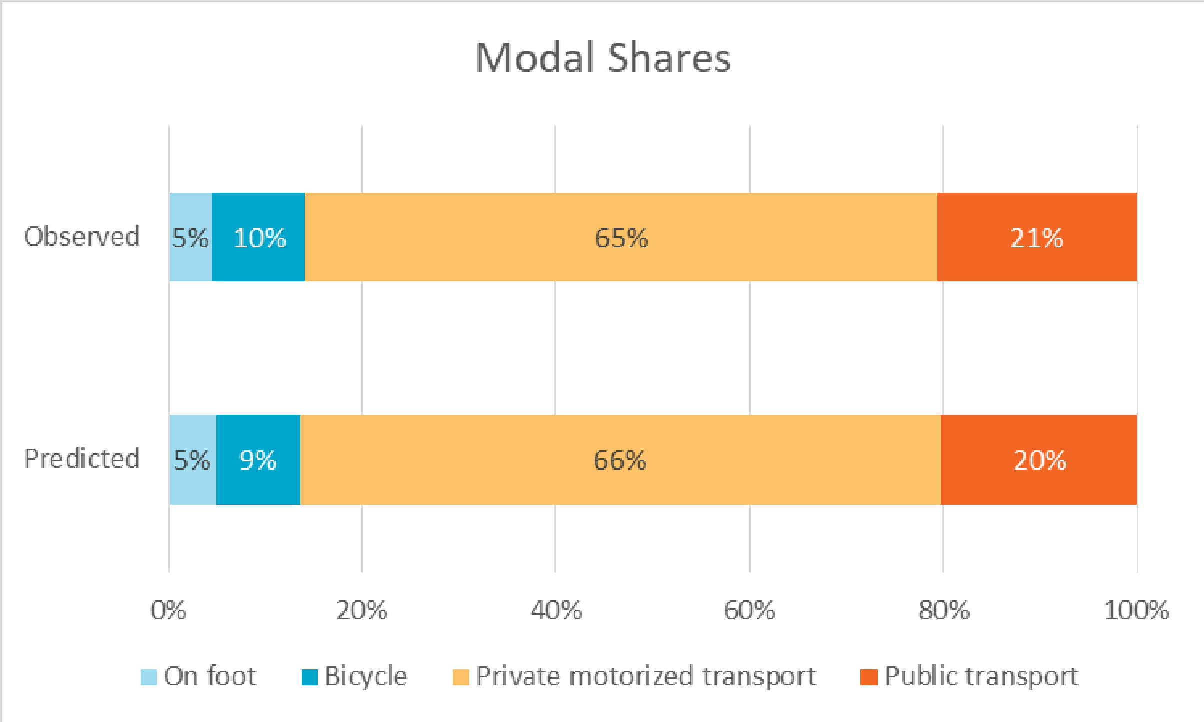
The model results are displayed in Table 5 (see Appendix). All parameters have the expected sign. The scale parameters are larger for the route choices by car and by public transport than for the RP choices, as expected (Hess *et al.* 2007, 2008). The interaction parameters associated with distance and income are all negative. It shows that the sensitivity to the corresponding attributes (travel time, costs, road charge, delay, number of changes, frequency) decreases trip distance and household income, as intuitively expected.

The older a respondent, the less likely he or she is to choose human powered modes (especially biking). Men tend to travel more often by bike and by car. With higher incomes, the probability of traveling on foot or by public transport decreases. For trips to work or to the place of studying, people tend to travel less by car. The car is more often used for shopping and business trips, or to give people lifts. People having a car available tend to use it, and similarly, people holding a season ticket are more likely to use public transport in comparison to people who do not. All results are matching expectations.

Finally, the parameters for travel time, cost, number of changes by public transport and season ticket ownership (for which a significant effect was found) were further differentiated by the spatial typology mentioned. A full segmentation of all parameters could not be rejected using a likelihood ratio test. However, only some parameters were differentiated in the final model in order to reduce the complexity of the model; only the differentiations with the most meaningful t-tests were retained.

The model with spatial segmentation was estimated for 80% of the sample (randomly chosen from the revealed and stated preferences). The estimated results were then applied to the remaining 20% of the sample. Figure 3 compares the predicted modal shares of the model with what people actually chose (the actual choice for revealed data and the answers in the survey for the stated data). The differences between the observed and predicted market shares are all below 1%. This cross-validation procedure shows that the model, although complex, is not overfitting the data.

Figure 3 Predicted and observed modal shares for 20% of the observations (n = 13'396)



4.4 Willingness to pay

The willingness to pay (WTP) represents how much people are willing to pay to save one unit of an attribute, typically travel time. For the attribute x it is computed using the following formula:

$$WTP_x = \frac{\beta_x \cdot \left(\frac{distance}{20}\right)^{\lambda_{distance,\,x}}}{\beta_{cost} \cdot \left(\frac{distance}{20}\right)^{\lambda_{distance,\,cost}} \cdot \left(\frac{income}{7'000}\right)^{\lambda_{income,\,cost}}}$$

20 kilometres and 7’000 CHF are used as reference values for distance and income in this formula. The values of the willingness to pay for (1) shorter trip durations by car and by PT, (2) trips with less changes and increasing frequency in public transport, (3) a better reliability of the trip (decreasing delays) by car and by PT all vary with the distance, the purpose of the trip and the income of the person (see detailed results in ARE, 2017).

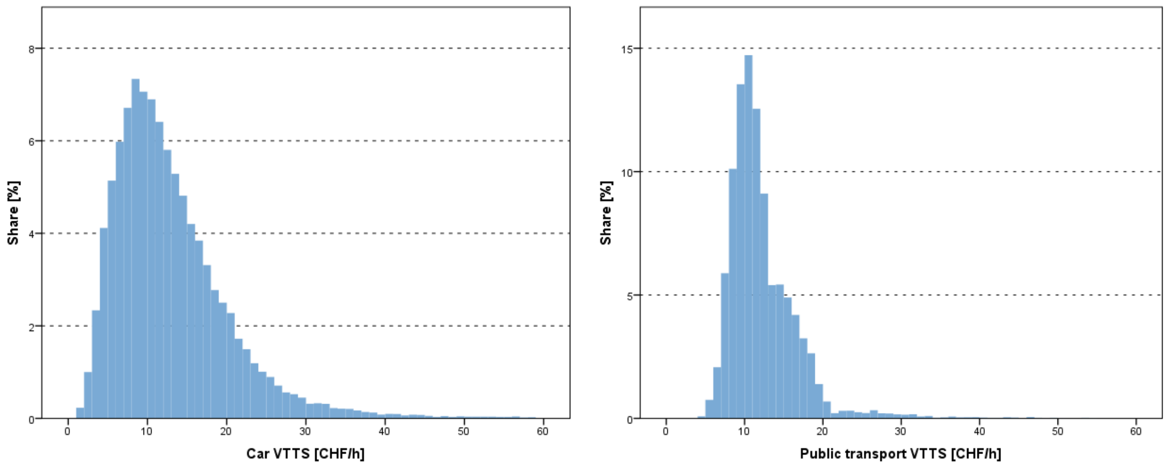
The WTP was computed for all trips of the MTMC 2015, including the trip distance and purpose and the income of the traveling person. An average of the WTP was then computed using individual weights to get values representing the Swiss resident population (more details about the weights, see FSO, 2018). Table 3 presents the average WTP for the Swiss resident population by trip purpose for the different attributes considered. These values correspond to the expectations and to previous results (König *et al.*, 2004 for the values used in the official Swiss VTTS guideline; Fröhlich *et al.*, 2013 and Widmer *et al.*, 2017 for more recent results).

The distribution of the value of travel time savings (VTTS = WTP for a decrease in travel time) in the sample of the MTMC 2015 can be seen in Figure 4 for PMT for PT.

Table 3 Weighted willingness-to-pay values [CHF/unit] (standard deviation in parentheses)

Attribute		All	Work	Education	Shopping	Business trips & giving lifts	Leisure
On foot	Trip duration [h]	6.0 (5.2)	6.7 (3.5)	11.6 (10.2)	4.5 (2.4)	26.1 (6.1)	6.1 (4.1)
Bicycle	Trip duration [h]	9.9 (6.6)	7.9 (3.7)	8.2 (4.4)	9.9 (5.0)	32.6 (14.2)	10.3 (6.0)
PMT	Trip duration [h]	13.2 (8.6)	14.6 (6.6)	15.8 (7.8)	10.3 (5.8)	24.6 (18.0)	12.1 (6.9)
	Parking search time [h]	25.7 (9.8)	26.4 (8.9)	19.8 (5.3)	23.2 (3.5)	41.7 (24.9)	24.3 (4.6)
	Delay [h]	26.9 (17.6)	23.6 (11.6)	22.8 (12.1)	21.8 (13.7)	44.3 (29.4)	30.0 (18.5)
PT	Trip duration [h]	12.3 (4.6)	12.4 (3.3)	13 (3.5)	10.9 (2.5)	29.1 (7.5)	11.2 (3.3)
	Acess and egress time [h]	13.3 (12.1)	16.0 (9.4)	15.9 (11.9)	12.8 (9.8)	34.5 (30.9)	8.2 (9.3)
	Number of changes [-]	1.3 (1.0)	1.1 (0.4)	1.5 (0.7)	1.3 (0.6)	4.1 (3.9)	1.3 (0.6)
	Waiting time [h]	9.1 (13.1)	8.6 (6.3)	7.1 (6.4)	9.2 (7.8)	45.0 (52.6)	6.7 (5.3)
	Frequency [h]	4.0 (2.4)	3.4 (1.1)	5.1 (3.1)	5.3 (1.7)	11.8 (5.7)	3.0 (0.9)
	Delay [h]	30.8 (11.5)	28.5 (8.2)	26.8 (7.9)	26.7 (9.8)	57.0 (19.3)	34.2 (10.9)

Figure 4 Distribution of the value of time for PMT (left) and PT (right)



5 Differences in valuation indicators between 2010 and 2015

Having conducted the SP survey in 2010 and 2015 using comparable methodological approaches, provides the opportunity to examine whether the valuation of the most common level-of-service (LOS) attributes have changed or remained the same. This is important in the context of cost-benefit analyses and the consistency of decisive inputs for the benefit side, such as e.g. the value of travel time (e.g. Schmid *et al.*, 2019). On top, we investigate the dependency of these willingness-to-pay (WTP) values with respect to distance and income, and if this dependency has changed between the two datasets (ARE, 2017).

Two pooled RP/SP MNL-models including the same set of LOS attributes and respondent characteristics for each of the survey period 2010 and 2015 are run (ARE., 2017). Cluster-robust standard errors are calculated (see section 4.1) and are obtained for the ratio of coefficients (i.e. the valuation indicators, which are defined by the ratio of LOS and the travel cost coefficient) by using the Delta method (Daly *et al.*, 2012).

The valuation indicators are first obtained for an income of CHF 7'000 per month and a travel distance of 20 km, the values used to normalize the non-linear interactions. This is useful in order to determine the standard errors of the indicators for these fixed normalization values. In a second step, the developments of the most important valuation indicators depending on distance and income are presented graphically.

Results are presented in Table 4. The average valuation indicators differ significantly and substantially for bike travel time ($p < 0.05$), walk travel time ($p < 0.01$), the number of PT transfers ($p < 0.01$) and the PT access time ($p < 0.01$). Especially the value of travel time savings (VTTS) for active modes (walk and bike) exhibits very large differences. While the VTTS for PT and PMT is comparable and indeed very close between the two surveys, the valuation of PT access time in the 2015 dataset is more than twice as large as in 2010. This also applies to the PT waiting time, although here the difference is not significant. In contrast, the valuation of the PT transfers measured in terms of travel time by PT and their monetary valuation are almost half as large in 2015 ($p < 0.01$). All other valuation indicators (PMT parking search time and PT headway) are neither significantly nor substantially different. Importantly, the VTTS for PMT is basically identical in the two surveys.

Table 4 Differences in valuation indicators between the 2010 and 2015 dataset (standard errors in brackets)

Attribute		2010 N = 3’605 Obs. = 52’208	2015 N = 6’099 Obs. = 67’365
PMT	Travel time (CHF/h)	16.3 (0.6)	16.5 (0.4)
PT	Travel time (CHF/h)	12.6 (0.8)	11.6 (0.6)
Bike	Travel time (CHF/h)	*41.5** (4.7)	*19.6** (7.0)
Walk	Travel time (CHF/h)	**46.8** (4.1)	**18.0** (4.6)
PT	Transfers (CHF/transfer)	**2.0** (0.2)	**1.0** (0.1)
PT	Transfers (min. travel time/transfer)	**9.7** (0.9)	**5.1** (0.5)
PMT	Parking search time (CHF/h)	22.2 (3.4)	23.4 (6.7)
PT	Headway (CHF/h)	4.9 (0.5)	3.0 (0.5)
PT	Waiting time (CHF/h)	4.6 (2.1)	11.2 (1.5)
PT	Access time (CHF/h)	**5.6** (1.1)	**13.9** (1.9)

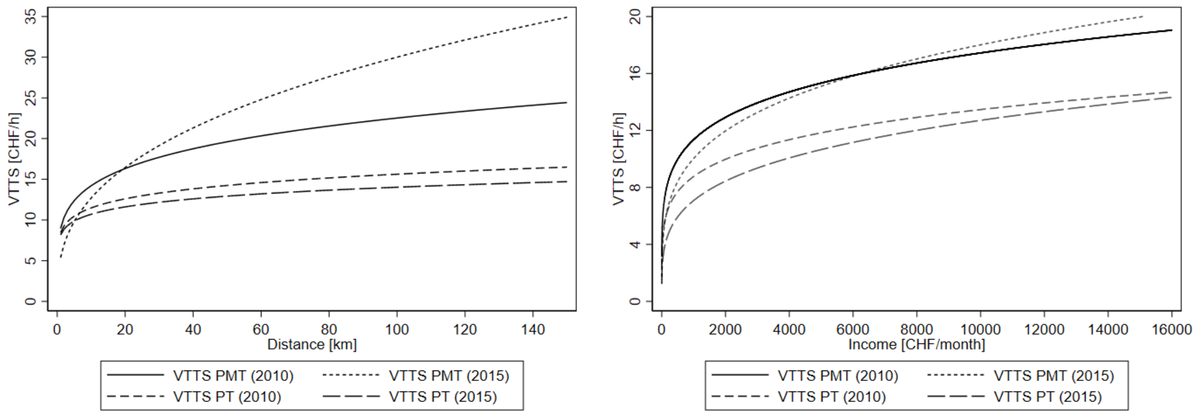
Bold: Difference significant at 1% level. *Italic**: Difference significant at 5% level. Normal font: Difference not significant at 5% level. Difference tests are based on cluster-robust (at the individual-level) standard errors and calculated using the Delta method.

If we first consider the ranking of the VTTS between the four means of transport, we see in the datasets for 2010 and 2015 a similar relative valuation as in many other studies. Walk and bike travel times are often valued substantially higher than PMT travel time, followed by PT travel time (e.g. Wardman *et al.*, 2007; Axhausen *et al.*, 2014; Wardman *et al.*, 2016; Schmid *et al.*, 2019). Nevertheless, the VTTS for walk and bike in the 2010 dataset are implausibly high. The key driver of this difference is the less negative effect of travel costs in the 2015 dataset, which would lead to identical VTTS only if the coefficients of travel time also change proportionally in the same direction (as in the case of PMT and PT). Importantly, this does not mean that the travellers were generally more cost-sensitive in 2010 than in 2015. An explanation for these differences is related to the data itself (note that subsequent values are related to all those cases, where the walk or bike alternatives were available, and not necessarily chosen): While the RP walk travel time (i.e. for all routes < 15 km; it should be noted that in the 2015 dataset the walk and bike alternatives were always available, while in the 2010 dataset walk is only available up to 15 km and bike only up to 50 km) in the 2010 dataset is 58 minutes on average, in the 2015 dataset it is 72 minutes (p-value of the difference < 0.01). Average walk distances are also significantly higher (4.5 km in 2010 vs. 5.8 km in 2015; $p < 0.01$), while walking speeds have decreased (5.8 km/h in 2010 vs. 5.2 km/h in 2015; $p < 0.01$). A similar difference, albeit somewhat more conspicuous, can be observed for the RP bike travel time (i.e. for all routes < 50 km): 19 min. in 2010 vs. 54 min. in 2015 ($p < 0.01$). While average distances have increased significantly (5.1 km in 2010 vs. 12.6 km in 2015; $p < 0.01$), the average speed has fallen from an average of 21.5 km/h (2010) to 14.8 km/h ($p < 0.01$). Thus, the trips with active modes tend to be longer in 2015, while the travel times in 2010 were calculated very sporty. Assuming that respondents have similar preferences (i.e. choice probabilities) for active modes of transport in the two surveys (note that we found insignificant alternative specific constants for walk and bike of similar magnitude in both models), and the fact that the RP data explicitly assumes values of LOS attributes for each respondent (unlike in the SP tasks, respondents do not necessarily make the actual RP choices based on the attribute values contained in the dataset), these differences automatically lead to substantially lower VTTS for walk and bike in the 2015 dataset (where the values look more reliable than the ones in 2010).

A similar argument applies to the number of transfers: While this average number in the 2010 RP dataset is 0.46, in the 2015 dataset it is 1.03, i.e. more than two times higher ($p < 0.01$). Ceteris paribus, this would imply that the effect of transfers in the model decreases by about one half. Note that in the RP data, such substantial differences can neither be found for the PMT and PT travel times nor for the PT waiting and access time: All exhibit similar mean values and follow similar distributions between the two datasets (see also ARE, 2012a; ARE, 2016). Following this line of reasoning, the larger values in the 2015 dataset are in terms of waiting and access time actually due to a change in behaviour. While PT travel time is valued slightly (but insignificantly) less negatively in 2015 (for example, due to more opportunities for more productive time use in public transport (see e.g. discussions in Mokhtarian and Salomon, 2001; Wardman *et al.*, 2016; Schmid *et al.*, 2019), PT access and waiting time are much less likely to be used for relaxing and/or working.

We also look at differences in interaction effects between LOS attributes, distance and income, and their impact on the valuation indicators. Focusing on PMT and PT, Figure 5 shows the development of the VTTS for PMT and PT as a function of distance (with income fixed at 7'000 CHF/month), as derived and discussed in Section 4.4. While the VTTS for PT evolves similarly, the VTTS for PMT increases visibly stronger in 2015 than in the 2010 dataset. This is mainly due to the decreasing negative effect of travel costs for longer distances that can partly be explained by a higher average income in the 2015 dataset (ARE 2017): Higher travel costs for longer distances discourage high income travellers less to conduct such trips. Importantly, however, the influence of income on the VTTS (with distance fixed at 20 km), shows very similar patterns between the two datasets.

Figure 5 Differences in the VTTS for PMT and PT as a function of distance (left) and income (right).



To summarise, our results indicate that the average VTTS for PMT and PT do not vary much between the two survey years. For transport policy, this consistency in the valuation of travel time is important in cost-benefit analyses for Swiss road and rail infrastructure projects. Estimates of the valuation of travel time savings for biking and walking could be improved for 2015. A valuation of roughly 18 to 20 CHF per hour is reasonable and in line with recent literature (e.g. Schmid, 2019). Finally, the valuation of PT access and waiting time is substantially higher in 2015 than in 2010.

The difficulty is that changes in VTTS can come from inconsistent estimates or from real changes in behaviour. It is therefore important, that the survey methodology stays consistent over time and that the RP data has to be consistently routed, calculated and carefully checked. Changes in the underlying distributions, the experimental design, the representation of the attributes in the questionnaire or the sample characteristics in general, may lead to substantially and significantly different results.

6 Conclusion

The survey data presented here lay the groundworks for a wide range of applications, including:

- the estimation of various discrete choice models, as illustrated in the present paper;
- the establishment and update of a set of model parameters for regional and national transport demand models, encompassing a wide scope of possible attributes, which in turn allow forecasting transport behaviour and analysing future scenarios related to mobility and spatial development;
- the assessment of the impact of potential policy measures on the Swiss population’s travel behaviour;
- the appraisal of future scenarios related to mobility and spatial development.

The very similar survey methodology in the years 2010 and 2015 and stability in the behavioural parameters allow pooling the data and thus increasing the possible scope and significance of the resulting models. Segmentations are thus feasible not only by trip purpose and spatial typology (as shown here), but can be tailored for specific target groups defined by socioeconomic characteristics.

As far as the field work goes, the chosen methodology of deriving the SP experiments from respondents’ RP data, coupled with the multi-contact strategy, proved to be very efficient in terms of attaining high response rates and a superior data quality. Having the representative MTMC data as a base for computing the key indicators such as VOT serves the robustness and credibility of the results.

The next instalment of the MTMC, including a third SP survey, is underway to be carried out in 2020. It will again be situated in a similar context of mode and route choices, and the questionnaires will be presented in a comparable form. An innovation will be the option for respondents to fill in the SP survey online rather than on paper and experiments focussing on departure time choice. The resulting data will allow a further expansion of the time series of similar SP data and be used, among others, for updating the Swiss VOT guidelines.

7 Literature

ARE (Federal Office for Spatial Development) (2012a) SP-Befragung 2010 zum Verkehrsverhalten im Personenverkehr, Federal Office for Spatial Development, Bern. www.are.admin.ch/statedpreference

ARE (Federal Office for Spatial Development) (2012b) Übersicht zu Stated Preference-Studien in der Schweiz und Abschätzung von Gesamtelastizitäten, Federal Office for Spatial Development, Bern. www.are.admin.ch/statedpreference

ARE (Federal Office for Spatial Development) (2014) Nationales Personenverkehrsmodell des UVEK - Aktualisierung auf den Basiszustand 2010, Federal Office for Spatial Development, Bern. www.are.admin.ch/npvm

ARE (Federal Office for Spatial Development) (2015) Modelltechnische Möglichkeiten der Weiterentwicklung des nationalen Personenverkehrsmodells, Federal Office for Spatial Development, Bern. www.are.admin.ch/npvm

ARE (Federal Office for Spatial Development) (2016) Perspektiven des Schweizerischen Personen- und Güterverkehrs bis 2040 – Synthesebericht, Federal Office for Spatial Development, Bern. www.are.admin.ch/transport-outlook

ARE (Federal Office for Spatial Development) (2016) SP-Befragung 2015 zum Verkehrsverhalten im Personenverkehr, Federal Office for Spatial Development, Bern. www.are.admin.ch/statedpreference

ARE (Federal Office for Spatial Development) (2017) Analyse der SP-Befragung 2015 zur Verkehrsmodus- und Routenwahl, Federal Office for Spatial Development, Bern. www.are.admin.ch/statedpreference

ARE (Federal Office for Spatial Development) (2019) Modelletablierung Nationales Personenverkehrsmodell (NPVM) 2017 - Schlussbericht, Federal Office for Spatial Development, Bern. www.are.admin.ch/npvm

Atasoy, B.A.G. and M. Bierlaire (2013) Attitudes towards mode choice in Switzerland, disP - The Planning Review, 49:2, 101-117, DOI: 10.1080/02513625.2013.827518

Axhausen K.W., B. Schmid and C. Weis (2015) Predicting response rates updated, Working paper 1063, IVT, ETH Zürich.

Axhausen K.W., K. Meister, M. Balmer, F. Ciari, A. Horni, M. Rieser and R.A. Waraich (2010) Large-Scale Agent-Based Travel Demand Optimization Applied to Switzerland, Including Mode Choice, Working Paper 625, IVT, ETH Zürich, DOI:10.3929/ethz-a-006100288.

Axhausen K.W., I. Ehreke, A. Glemser, S. Hess, C. Jödden, K. Nagel, A. Sauer and C. Weis (2014) Ermittlung von Bewertungsansätzen für Reisezeiten und Zuverlässigkeit auf der Basis eines Modells für modale Verlagerungen im nicht-gewerblichen und gewerblichen Personenverkehr für die Bundesverkehrswegeplanung, FE-Projekt-Nr. 96.996/2011, BMVBS, Berlin.

Axhausen K.W., Hess S., König A., Abay G., Bates J.J. and M. Bierlaire (2008) Income and distance elasticities of values of travel time savings: New Swiss results, Transport Policy, 15(3), 173-185.

Axhausen K.W., Hess S., König A., Abay G., Bates J.J. and M. Bierlaire (2004) Swiss value of travel time savings, Presentation at the European Transport Conference, Straßburg, October 2004.

Baltagi B. (2008) Econometric Analysis of Panel Data, John Wiley & Sons Ltd., West Sussex.

Batley R., Bates J.J., Bliemer M.C.J., Börjesson M., Bourdon J., Ojeda Cabral M., Chintakayala V.P.K, Choudhury C.F., Daly A.J., Dekker T., Drivyla E., Fowkes T., Hess S., Heywood C., Johnson D., Laird L., Mackie P.J., Parkin J., Sanders S., Sheldon R., Wardman M. and T. Worsley (2017) New appraisal values of travel time saving and reliability in Great Britain, Transportation, 46, 583-621.

Beck M.J., Hess S., Ojeda Cabral M. and I. Dubernet (2017) Valuing travel time savings: A case of short-term and long-term choices, Transportation Research Part E, 100, 133-143.

Ben-Akiva, M. and S.R. Lerman (1985) Discrete Choice Analysis, Theory and Application to Travel Demand, The MIT Press, Cambridge

Bierlaire M. (2003). BIOGEME: A free package for the estimation of discrete choice models, Proceedings of the 3rd Swiss Transportation Research Conference (STRC), Ascona, Switzerland.

BMVI (2016) Bundesverkehrswegeplan 2030 - Gesamtplan, Final Report, Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin.

Börjesson M. and J. Eliasson (2012) Experiences from the swedish value of time study, working report, 2012(8), Royal Institute of Technology, Centre for Transport Studies, Stockholm.

Boyce D. and H. Williams (2016) Forecasting urban travel: Past, present and future, Edward Elgar Publishing, Cambridge.

Camerer C. and D. Mobbs (2017) Differences in behavior and brain activity during hypothetical and real choices, Trends in cognitive sciences, 21 (1), 46-56.

Chalasani V.S. (2005) Enriching household travel survey data. Experiences from the Microcensus 2000, presentation at the 5th Swiss Transport Research Conference (STRC), Monte Verita, March 2005.

Daly A., S. Hess and G. de Jong (2012a) Calculating errors for measures derived from choice modelling estimates, Transportation Research Part B: Methodological, 46 (2), 333-341.

Danalet A., L. Tinguely, M. de Lapparent and M. Bierlaire (2016) Location choice with longitudinal WiFi data, Journal of Choice Modelling, 18, 1–17, DOI:10.1016/j.jocm.2016.04.003

Department for Transport (2015) Understanding and valuing impacts of transport investment: Values of travel time savings, Technical Report, Department for Transport, London.

Dillman, D.A. (2000) Mail and internet surveys – The tailored design method, Wiley, New York.

Dubernet I., T. Dubernet and K.W. Axhausen (2018) Comparing short- and log-term values of travel time savings derived from a joint modelling framework, Presentation at the 97th Annual Meeting of the Transportation Research Board, Washington D.C., January 2018.

Dubernet I. and K.W. Axhausen (2019) The German value of time (VOT) and value of reliability (VOR) study: The survey work, Transportation, in press.

Federal Statistical Office (FSO) (2012) Mobilität in der Schweiz: Ergebnisse des Mikrozensus Mobilität und Verkehr 2010, Statistical Office and Federal Office for Spatial Development, Neuchâtel and Bern. www.are.admin.ch/mtmc

Federal Statistical Office (FSO) and Federal Office for Spatial Development (ARE) (2017) Verkehrsverhalten der Bevölkerung: Ergebnisse des Mikrozensus Mobilität und Verkehr 2015, Statistical Office and Federal Office for Spatial Development, Neuchâtel and Bern. www.are.admin.ch/mtmc

Federal Statistical Office (FSO) (2017), Gemeindetypologie und Stadt/Land-Typologie 2012, Neuchâtel.

Federal Statistical Office (FSO) (2018), Microrecensement mobilité et transports 2015, Rapport méthodologique: plan d'échantillonage, taux de réponse et pondération, https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/erhebungen/mzmv.assetdetail.4262242.html.

Fosgerau M., K. Hjorth and S. Lyk-Jensen (2007) The danish value of time study, final report, Technical University Denmark, Danish Transport Research Institute, Copenhagen.

Fröhlich P., C. Weis, M. Vrtic, P. Widmer and P. Aemisegger (2014) Einfluss der Verlässlichkeit der Verkehrssysteme auf das Verkehrsverhalten, Report SVI 2012/003, Schriftenreihe, 1472, UVEK, Ittigen.

Fröhlich P., C. Weis, A. Erath, M. Vrtic and K.W. Axhausen (2013) SP-Befragung 2010 zum Verkehrsverhalten im Personenverkehr, Travel Survey and Metadata Series, 48, IVT, ETH Zurich, Zurich.

Fröhlich P., K.W. Axhausen, M. Vrtic, C. Weis and A. Erath (2012) SP-Befragung zum Verkehrsverhalten im Personenverkehr, Forschungsbericht, Bundesamt für Raumentwicklung (ARE), Bern.

Groves R.M. (2004) Survey errors and survey costs, Wiley, Hoboken.

Gunn H.F. (2001) Spatial and temporal transferability of relationships between travel demand, trip cost and travel time, Transportation Research E, 37, 163-189.

Hague Consulting Group, Accent Marketing and Research and Departement for Environment, Transport and the Regions (1999) The value of travel time on UK roads, The Hague.

Hensher D.A. (1994) Stated preference analysis of travel choices: The state of practice, Transportation, 21, 107-133.

Hess S., A. J. Daly, T. Dekker, M. Ojeda Cabral and R. Batley (2017) A framework for capturing heterogeneity, heteroskedasticity, non-linearity, reference dependence and design artefacts invalue of time research, Transportation Research Part B: Methodological, 96, 126–149.

Hess S., A. Erath and K. W. Axhausen (2007) Reducing bias in value of time estimates by joint estimation on multiple datasets: A case study in Switzerland, Vortrag an der European Transport Conference, Noordwijkerhout, Oktober 2007

Hess S., A. Erath and K.W. Axhausen (2008) Estimated value of savings in travel time in Switzerland: Analysis of pooled data, Transportation Research Record, 2082, 43-55.

Horni A., K. Nagel and K.W. Axhausen (eds.) (2016) The multi-agent transport simulation MATSim, ubiquity press, open scholarship.

König, A., K. W. Axhausen and G. Abay (2004) Zeitkosten im Personenverkehr: Eine Schweizer Studie, *Strasse und Verkehr*, 90 (10) 20-27.

Louviere J.J., D.A. Hensher and J.D. Swait (2000) Stated choice methods – Analysis and application, Cambridge University Press, Cambridge.

Mackie P.J., S.R. Jara-Diaz and A.S. Fowkes (2001) The value of travel time savings in evaluation, Transportation Research Part E: Logistics and Transportation Review, 37, 91106.

Meyer de Freitas L., H. Becker, M. Zimmermann and K.W. Axhausen (2019) Modelling intermodal travel in Switzerland: A recursive logit approach, Transportation Research Part A: Policy and Practice, 119, 200□213. https://doi.org/10.1016/j.tra.2018.11.009.

Mokhtarian P.L. und I. Salomon (2001) How derived is the demand for travel? Some conceptual and measurement considerations, Transportation Research Part A: Policy and Practice, 35 (8), 695-719.

Ortúzar J.D. and L.G. Willumsen (2006) Modelling transport, Wiley, Chichester.

Ramjerdi F., S. Flügel, H. Samstad and M. Killi (2010) Summary: Value of time, safety and environment in passenger transport time, Technical report, 1053B/2010, Institute for Transport Economics, Norwegian Centre for Transport Research, Oslo.

Rose J.M., M.C.J. Bliemer, D.A. Hensher and A.T. Collins (2008) Designing efficient stated choice experiments in the presence of reference alternatives, Transportation research part B: Methodological, 42 (4), 395-406.

Rose J.M. and M.C.J. Bliemer (2009) Constructing efficient stated choice experimental designs, Transport reviews, 29(5), 587-617.

Small K.A. (2012) Valuation of travel time, Economics of transportation, 1(1), 2-12.

Schmid B., F. Aschauer, S. Jokubauskaite, S. Peer, R. Hössinger, R. Gerike, S. R. Jara-Diaz and K. W. Axhausen (2019) A pooled RP/SP mode, route and destination choice model to investigate mode and user-type effects in the value of travel time savings, Transportation Research Part A: Policy and Practice, 124, 262-294.

Schmid B. and K.W. Axhausen (2019) Predicting response rates of all and recruited respondents: A first attempt, IVT working paper 1416, IVT, ETH Zurich.

Significance Vrije Universität Amsterdam and John Bates Services (2012) Values of Time and Reliability in Passenger and Freight Transport in the Netherlands, Report for the Dutch Ministry of Infrastructure and the Environment, The Hague.

Simma A. & K.W. Axhausen (2001) Structures of commitment in mode use: a comparison of Switzerland, Germany and Great Britain. Transport Policy, 8(4), 279-288. doi:10.1016/s0967-070x(01)00023-3

Smith A. (2017) Updated mobility analysis: Through MZ2015, Arbeitsberichte Verkehrs- und Raumplanung, 1309, IVT, ETH Zurich, Zurich.

Smith A., K. Ruzsics and K.W. Axhausen (2017) MZ15 English: Pre-processed micro-census 2015 data, Travel Survey Metadata Series, 65, IVT, ETH Zurich, Zurich.

Train K.E. (2009) Discrete choice methods with simulation, Cambridge University Press, Cambridge.

Vrtic M., K.W. Axhausen, R. Maggi and F. Rossera (2003) Verifizierung von Prognosemethoden im Personenverkehr, SBB und ARE, Bern.

Wardman M., M. Tight and M. Page (2007) Factors influencing the propensity to cycle to work, Transportation Research Part A: Policy and Practice, 41 (4) 339-350.

Wardman M., V.P.K. Chintakayala and G. de Jong (2016) Values of travel time in Europe: Review and meta-analysis, Transportation Research A, 94, 93-111.

Weis C. and K.W. Axhausen (2009) Benzinpreis und Bahnnutzung, Forschungsbericht, SBB, Bern.

Weis C., M. Vrtic, B. Schmid and K. W. Axhausen (2017) Analyse der SP-Befragung 2015 zur Verkehrsmodus- und Routenwahl, Research Report, Swiss Federal Office for Spatial Development (ARE), IVT, ETH Zurich, Bern.

Weis C., Vrtic M., Widmer P. and K.W. Axhausen (2012) Influence of parking on location and mode choice: A stated choice survey, Presentation at the 91st Annual Meeting of the Transportation Research Board, Washington D.C., January 2012.

Widmer P., T. Buhl, M. Vrtic, C. Weis, L. Montini and K.W. Axhausen (2016) Einfluss des Parkierungsangebots auf das Verkehrsverhalten und den Energieverbrauch, Report SVI 2008/002, Schriftenreihe, UVEK, Ittigen.

Willumsen L.G. (2014) Better traffic and revenue forecasting, Maida Vale Press, London.

8 Appendix: Model results

Table 4 Model results

Mode	Parameter		Trip purpose				
		all	work	education	shopping	business	leisure
Generic	Travel costs [CHF]		-0.207	-0.209	-0.181	-0.128	-0.166
	Delay risk [%]	-0.625					
	Delay time [min]	-0.080					
	Interaction terms:						
	Delay/distance	-0.350					
	Cost/income	-0.196					
Walk	Constant		1.040	2.280	-0.287	2.230	-0.595(*)
	Travel time [min]		-0.083	-0.093	-0.052	-0.135	-0.040
	Interaction terms:						
	Travel time/distance	-0.297					
	Gender: male	-0.061(*)					
	female (ref.)						
	Age [years]: linear	0.393					
	squared	-0.042					
	Income [CHF/month]: linear	0.036(*)					
	squared	-0.003(*)					
	Region: 1	0.176					
	2 (Ref.)						
	3	-0.253					
	Spatial type: urban (Ref.)						
	suburban	-0.173					
	ländlich	-0.061(*)					
Velo	Constant		-3.140	-2.220	-3.450	-2.150	-3.230
	Travel time [min]		-0.052	-0.064	-0.074	-0.112	-0.047
	Interaction terms:						
	Travel time/distance	-0.321					
	Gender: male	0.403					
	female (ref.)						
	Age [years]: linear	0.633					
	squared	-0.080					
	Income [CHF/month]: linear	0.211					
	squared	-0.009					
	Region: 1	0.950					
	2 (Ref.)						
	3	0.886					
	Spatial type: urban (Ref.)						
	suburban	-0.220					
	ländlich	-0.035(*)					
PMT (ref.)	Constant						
	Travel time [min]		-0.063	-0.063	-0.048	-0.053	-0.042
	Parking search time [min]	-0.066					
	Parking costs [CHF]		-0.150	-0.173	-0.203	-0.151	-0.152
	Interaction terms:						
	Travel time/distance		-0.280	-0.181	-0.213	-0.242	-0.322
	Fuel costs/distance	-0.672					
	Road toll/distance	-0.520					
	Car available: no (Ref.)						
	yes	0.826					
PT	Constant		-0.305(*)	0.373(*)	-0.740	-0.731	-0.895
	Travel time [min]		-0.041	-0.045	-0.038	-0.047	-0.032
	Acess / egress time [min]		-0.057	-0.055	-0.059	-0.043	-0.024
	Transfer wait time [min]		-0.017	-0.037	-0.029	-0.035	-0.018
	Number of transfers [Anzahl]		-0.223	-0.310	-0.348	-0.249	-0.213
	Headway [min]		-0.011	-0.008	-0.009	-0.016	-0.008

	Interaction terms:							
	Travel time/distance			-0.341	-0.243	-0.350	-0.341	-0.385
	Transfers/distance		-0.213					
	Headway/distance		-0.575					
	Travel costs/distance		-0.480					
	Capacity utilization [cat.]: squared		-0.036					
	Main mode:	rail (Ref.)						
		tram	-0.268					
		bus	-0.251					
	Season ticket:	none (Ref.)						
		half-price cared	0.291					
		regional ticket	1.480					
		flat-rate ticket	1.540					
	Gender:	male	-0.066(*)					
		female (ref.)						
	Age [years]:	linear	0.109(*)					
		squared	-0.008(*)					
	Income [CHF/month]:	linear	-0.032(*)					
		squared	0.001(*)					
	Region:	1	0.374					
		2 (Ref.)						
		3	0.087					
	Spatial type:	urban (Ref.)						
		suburban	-0.209					
		ländlich	-0.273					
Scale parameters	RP		1.000					
	SP 1 (Ref.)		1.000					
	SP 2		3.460					
	SP 3		2.090					
	Sample size		67‘365					
	Number of estimated parameters		124					
	Adjusted ρ^2		0.377					