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A tour-based SP-off-RP survey for combined time period and mode choice

Florian Aschauer[1] · **Gregor Husner**[1] · **Astrid Gühnemann**[1] · **Gerard de Jong**[2,3] · **Stefan Grebe**[4] · **Alexander Schaffenberger**[5] · **Reinhard Hössinger**[1]

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Abstract
This paper reports on a travel survey conducted in Austria in 2019/2020. The aim was to generate 1250 stated preference (SP) interviews using four types of SP experiments, which were based on revealed tours of respondents (tour-based SP-off-RP). The data were to be used as input for a new national tour-based transport model. The core element is a combined time period and mode choice experiment with several innovative new features, which aim to provide a smooth one-stop shop for both stages (RP and SP) and to depict scenarios that are as realistic as possible and achieve sufficient trade-off. The method defined and implemented for the survey is extensively documented, including all steps of survey preparation, the logic behind and development of the time period and mode choice experiment, adaptive measures in survey design and method, and survey conduct. In addition, the paper measures the response rate, describes the data by means of its key features, discusses its representativeness, draws some conclusions on the lessons learned and quality of the data obtained, and provides an outlook on the usage and availability of the data.

Keywords Travel survey · Stated preference · Survey design · Mode choice · Tour-based models

✉ Florian Aschauer
florian.aschauer@boku.ac.at

1 Institute for Transport Studies (ITS), Department of Landscape, Spatial and Infrastructure Sciences, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

2 The Hague, The Netherlands

3 Institute for Transport Studies, University of Leeds, Leeds, UK

4 CE Delft, Delft, The Netherlands

5 PLANUM Fallast & Partner GmbH, Graz, Austria

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Introduction

Background

In Austria, comprehensive transport forecasts have been conducted since the 1970s. Dedicated transport models as a standard tool for national infrastructure planning and forecasting are in use since the 1990s. Since then a national transport model has been established at the federal level (Obermayer et al. 2011). In 2017–2018, the decision was made to develop a new national transport model "Verkehrsmodell Österreich" (VMÖ), building on more recent data and approaches. The first application will be a comprehensive national forecast (Grebe et al. 2019), which covers the period up to 2040 and beyond (VPÖ 2040+—Verkehrsprognose Österreich (Transport Forecast Austria)). The work on the new model started in April 2019 and is still ongoing. The passenger transport model within the new national model will be a disaggregate tour-based model with five stages (tour frequency, mode, destination and time period choice, network assignment).

Data on travel behaviour of persons in Austria is available from the national travel survey "Österreich Unterwegs" (ÖU; BMK 2015) conducted in 2013/2014. Also, data on zonal characteristics, networks and traffic count data are available. This is sufficient to estimate and apply the proposed passenger transport models, with the exception of models for the choice of time period in combination with the travel mode and models for modes that are not (yet) used on a large scale (Carsharing and Park & Ride). Furthermore, peak pricing in transport is not used in Austria at the moment, so revealed preference data cannot provide information on the possible effects of such policy measures.

To fill the gaps in the data of the ÖU survey, an SP-off-RP survey on time period and mode choice as well as Carsharing and Park & Ride use was developed and carried out in 2019–2020, based on and enhancing international best practice approaches, e.g. mode and time-of-day SP surveys that have been used to estimate time period and mode choice models in the Netherlands (de Jong et al. 2003, 2020). However, these did not include experiments on Carsharing and Park & Ride. On the other hand, RP data such as ÖU cover more modes but can often not provide information with sufficient variation in travel time and travel cost between time periods for model estimation, the non-chosen alternatives are not explicitly known, and travel time and cost are correlated. Because of these problems, an SP-off-RP survey has been selected to obtain the required time period choice information, together with choice information on the 'rare modes' Carsharing and Park & Ride.

The survey first collects information on the respondents' actual travel behaviour, which then forms the context for the SP experiments and also provides the reference levels for the attribute values. Because the new transport model will be tour-based, the survey is also tour-based. A tour is defined as a sequence of trips starting and ending at the same location, which could be the residence or the workplace, resulting in home-based and work-based tours.

Methodological innovations

In total, four SP experiments have been carried out:

- SP1: choice of the main mode of the tour (1849 interviews).
- SP2: choice of time period and mode (1194 interviews).

- SP3 (CS): choice of Carsharing vs. public transport (618 interviews).
- SP4 (PR): choice of Park & Ride vs. car alone (869 interviews).

This paper focusses on the time period and mode choice experiment (SP2).[1] It has been carried out several times in other countries. Previous publications, however, concentrate on the model results. The methodological aspects have only been presented on survey-oriented conferences, where the focus was on the process of data collection. This is the first time that both the data collection process and the details of the time period choice experiment are consistently described in a high-ranking scientific journal with a critical review process to make this approach available for the wider academic audience. Starting from previous approaches as outlined in Sect. "Review of the theoretical and empirical literature on time-of-day choice", we added the following innovative features to increase the response rate, depict realistic scenarios, and achieve sufficient trade-off in a smooth one-stop shop:

- An inclusive survey design where the respondents could choose between online, postal, or telephone participation; previous surveys offered only one option, which could be postal or online;
- Use of reference values for the time and cost attributes that are both mode-specific and specific to the type settlement; previous surveys used only mode-specific reference values;
- Distinction between important attributes that vary factorially (those which establish the trade-offs described below) and less important attributes that vary randomly;
- Implementation of all components using R as a common platform that allowed to generate the choice sets 'on the fly' with full control over all steps (see Sect. "Survey implementation").

Furthermore, we think that the unique quality of this type of experiment was not sufficiently recognized in previous publications. From a transport modelling perspective, it offers all short-term options[2] that a traveller could chose if faced with an increasingly crowded transport system, depending on the preferred mode and also depending on whether the infrastructure provider responds to overcrowding by peak pricing or leaves it to the market to regulate this via congestion. The response options are implemented in a tour-based context and include: (1) stay with the preferred mode and TOD and pay the price in terms of (a) longer car travel duration or (b) over-occupation in public transport or (c) higher travel cost in the case of peak pricing, which can apply to both car and public transport, (2) shift to earlier departure times for one or both trips of the tour, (3) shift to later departure times, or (4) shift to another mode, i.e. from car to public transport or vice versa. The SP screens present these 4 alternatives by 7 attributes each, which provide a fairly complete picture of the alternative schedules: departure and arrival time of both the outbound and return trip, total travel duration of both trips, duration of stay at the destination, total travel cost, time in congestion and occupancy of seats for car and public transport users, respectively.

[1] Because SP1, SP3, and SP4 are common, well established experiments, they are not covered in this data paper.

[2] Longer-tem response options such as changing the place of residence or place of work are not included.

Literature review and scope

Data collection framework

The methodological framework of the SP-off-RP survey is a modified version of a traditional and well known approach in German-speaking countries: the so-called KONTIV survey design ('New KONTIV-Design -NKD'; Socialdata 2009). It and has been used since the 1970s (in an adapted version since 2002) in the German national travel survey (Mobilität in Deutschland (mobility in Germany), MID) as well as in other nationwide household travel surveys. The basic concept of NKD—typically in PAPI form—suggests that households are recruited by mail and additionally motivated by phone if available. Filled-out questionnaires are validated by another phone call. Various reminders and a strict scheduling of all processes shall ensure high response rates.

This design was further developed in Austria to the so-called KOMOD design in the course of a methodological study and published in a handbook (Handbook for standardised travel surveys in Austria—KOMOD, Fellendorf et al. 2011) that is to be used for the standardised implementation of travel surveys in Austria.

When developing the SP-off-RP survey design, we followed the KOMOD recommendations as far as possible: sampling, recruitment, motivation of participants, and the offering of many different options for participation for the sake of inclusiveness. The final design is further elaborated in Sect. "Survey design".

Tour-based SP experiments

A tour-based approach offers certain advantages over a trip-based approach to travel demand modelling (Miller et al. 2003; Omer et al. 2009; Vovsha 2018). Travellers usually do not take independent decisions about the outward trip and the return trip (and intermediate stops) of the same tour, but decide to visit certain destinations, so that the destination of the final trip of the tour is already implied (e.g. to return home) and should not be modelled as a separate trip with a large number of possible destinations. So, behaviourally tours are a more realistic and richer representation than trips. Also, most trips of a tour use the same mode; it is in general undesirable to model that a car (or bike) is left behind somewhere, because the mode decisions for the trips in a tour would be different from each other.

SP experiments on mode choice have been carried out many times and in many countries. The great majority of these are trip-based whereas the first two SP experiments described here (SP1 and SP2) are tour-based. This means that the context of the choice experiment is the tour, and the attributes presented describe both the outward and the return trip.

The decision to base the SP experiments on tours instead of trips was made as part of the pilot study into the new strategic national model (see Grebe et al. 2019). Its main advantage over a trip-based approach is the increased behavioural realism. If the outward and return trips are modelled as independent choices, cars and bicycles may be used in only one of the two trips. In practice, this almost never happens: travellers usually do not travel back to the origin leaving their car or bicycle at the destination. Furthermore, destination choice for a return trip also does not make sense behaviourally: the traveller just wants to get back; the return trip decision is implicit in the decisions on the outward trip.

An SP experiment on mode and time-of-day choice

The focus in this paper is on the mode and time-of-day (TOD) choice experiment; it was one of the main reasons for doing the SP experiments in the first place. The main arguments for using SP instead of RP for TOD choice modelling have been given in Daly et al. (1990), de Jong et al. (2003, 2020) and Hess et al. (2007b) and are repeated here briefly. An important advantage of SP data for the estimation of a TOD model is that they generate their own level-of-service-data (these are defined as alternatives by the researcher, and the respondent chooses the preferred alternative). TOD models on RP data rely on travel times for different time periods, calculated based on congestion-dependent network assignments. Sufficient variation in travel times for different periods can only be obtained in areas with severe congestion. Moreover, information on the responses to wide-spread peak pricing on daily travel demand cannot be obtained in Austria, as such policies are not in place.

Another potential problem of RP data in the context of TOD choices is endogeneity. The only thing that distinguishes the time period alternatives (at least for short periods within the peak) is the difference in travel times, which is entirely endogenous as it depends on the choices made: the only way to get a negative coefficient for travel time in a TOD model is if people choose origin–destination (OD) pairs less often in periods where congestion is worse. But that would in itself limit the congestion on those OD pairs, making travel duration endogenous. One needs longitudinal or SP data to sort this out.

The key trade-offs offered in the TOD choice experiment are in line with those typically offered in such experiments: attractive departure time vs. short travel time, attractive departure time vs. low travel cost (as it can happen with peak pricing), and attractive departure time vs. better travel conditions (lower occupancy in public transport). The inclusion of mode choice along with TOD choice is scarcer in the literature. It was needed in our case to fit the SP-based TOD choice module into the otherwise RP-based structure of the VMÖ modules, which requires a common choice in RP and SP. In the following section, we review the theoretical literature that forms the basis for the modelling of these trade-offs (also see the review in de Jong et al. 2003), as well as the empirical literature.

Review of the theoretical and empirical literature on time-of-day choice

Theoretical basis: scheduling model for trading off clock time versus travel duration

The theoretical basis for modelling departure time under congestion is the equilibrium scheduling model, building on Vickrey (1969). Assuming a single bottleneck situation (one link) commuters decide on their time of travel. Vickrey's model was in continuous time, whereas Small (1982) reformulated it as a discrete choice model for the choice between different time periods. The basic trade-off for the travellers in both specifications is between the disutility of arriving too early or too late (scheduling disbenefits) and the disutility of travel time (i.e., duration of travel).

Commuters may prefer to arrive at the official work starting time, but decide to travel and arrive earlier of later because they want to travel at a less congested period and save travel time. In situations with congestion that is concentrated in certain periods of the day (peaks), there is a trade-off between clock time and duration of travel. The following formulation of this problem is based on Vickrey (1969):

$$V(t) = aC(t) + bMax(0,(PAT - t - C(t))) + gMax(0,(t + C(t) - PAT)) \quad (1)$$

In which V(t): disutility (cost) to a traveller with departure time t; C(t): travel time associated with departure at time t; PAT: preferred arrival time at the destination; α,β,γ: parameters to be estimated.

A traveller arriving precisely at his PAT, will have no disutility from scheduling (2nd and 3rd term are equal to zero), but C(t) might be higher than for other arrival times due to congestion. In the equilibrium of Vickrey's model (assuming homogeneous travellers w.r.t. PAT) the highest value of C(t) will be at PAT. Arriving too soon (2nd term) will yield a disutility, as will arriving too late (3rd term), but the disutility gradients might differ (β can be different from γ). Modelling departure time or arrival time does not matter in absence of anticipated congestion. Vickrey's model assumes that the travellers are aware of the amount of congestion and its impact on travel times (e.g. from daily experience) and that they may respond to this by changing their departure time.

Trading off clock time versus travel cost (in addition to travel duration)

For both specifications, travel cost M(t) can be added, e.g. for tolls varying by TOD, as in Eq. (2):

$$V(t) = aC(t) + fM(t) + bMax(0,(PAT - t - C(t))) + gMax(0,(t + C(t) - PAT)) \quad (2)$$

The idea is that the peak periods have a higher charge than the other TOD periods. The trade-off then becomes one of travelling at the most preferred moment on the one hand, versus quicker and cheaper journeys in the other. The justification for higher charges in the peak periods could be that in this way external costs that travellers impose upon each other are internalised (on average) and in this way the total generalised costs will be closer to the social optimum, in which congestion will be reduced.

Empirical models for trading of clock time versus travel duration and/or travel cost

The first empirical models on this trade-off were based on RP data; they defined time in terms of discrete periods (5 min to several hours). Small (1982, 1987) only looked at TOD choice, while Hendrickson and Plank (1984) studied both mode and TOD choice within a multinomial logit framework. The literature also includes examples of models that combine TOD with route choice (early examples are Arnott et al. 1990; Jou and Mahmassani 1994; Khattak et al. 1995; Havnetunnelgruppen 1999; and a recent example is Lu et al. 2018).

Probably the first studies to use SP data for the estimation of TOD choice models were MVA (1990) and Daly et al. (1990), one looking at peak pricing, the other at congestion to include TOD choice in the Dutch national transport model for the first time. They used three TOD periods (morning peak, evening peak, and rest of the day), there were no links between outward and return trips of the same tour, and a simple multinomial logit was used for modelling. Data was collected using two-step pen-and-paper interviews to have some dependency of the SP experiment on a revealed trip.

A tour-based mode and departure time SP experiment was first carried out in the Netherlands in 2000–2001 to provide data for the re-estimation of the Dutch national transport model, replacing the models from MVA (1990) and Daly et al. (1990). The time and departure time choice modelling literature at that time and the models estimated from the data are described de Jong et al. (2003). They also provide a brief description of the data and survey. It was carried out in two steps using an existing omnibus of respondents and further questions when intercepting travellers en-route. The 2nd stage included the actual time-of-day (TOD) SP experiment carried out by means of CAPI.

This experiment was later also used as a template for a similar SP survey in the West-Midlands (UK) which served for estimating the PRISM model (RAND Europe 2004). Furthermore, a comparison of various models based on these two data sets and a TOD SP for London was undertaken (Hess et al. 2007a,b), with a focus on finding the most appropriate way of nesting TOD and mode choice. The outcomes of this were incorporated in WebTAG, the Department of Transport's guide to transport appraisal in the UK (now called TAG: Department for Transport 2020). A similar SP survey was carried out in Sweden (Börjesson 2008) and in 2019 again in The Netherlands with several improvements (de Jong et al. 2020), e.g. the use CAWI instead of CAPI due to sufficient internet penetration.

Arentze and Timmermans (2007) carried out a stated adaptation experiment among travellers in The Netherlands to investigate the behavioural responses to road pricing. They included both departure time change and mode shift as response options, but they did not look at whether people would depart earlier or later and by how much. In a later paper, Arentze and Timmermans (2007) also analysed long term responses to road pricing, notably changes in residential and work location.

The German national value of transport time (and reliability) survey (Dubernet and Axhausen 2020) is so far the only well-documented SP experiment that includes attributes on departure and arrival times along with travel time and cost. This survey is however not based on the scheduling model but on the mean–variance model of scheduling (Li et al. 2010). It assumes travellers to trade off travel time (mean) against its variability (standard deviation) rather than the disutility of arriving too early or too late.

All other previous papers on SP surveys that include mode and time period choice have so far focussed on the models estimated from the data. None of them has extensively documented the survey process and experiment for readers of scientific journals.

Survey design

Sampling

For this sample, overall representativity (truly random sample) was not the objective. This is because we are using the sample for the estimation of discrete choice models. In maximum likelihood estimation of such models, the part of the likelihood function that matters for the coefficients that are to be estimated is called the kernel. The sampling fractions are not part of the kernel. Consequently, one can estimate the coefficients consistently on a sample that is exogenously stratified (e.g. oversampling of some area type) or, except for the alternative-specific constants, even endogenously stratified (e.g. a mode choice model estimated on a sample that oversamples public transport). The main requirement for our sample is that we have enough observations for each segment for the estimation of separate coefficients, not representativity.

The theory of sampling for discrete choice models was originally only developed for MNL (McFadden 1978; Manski and McFadden 1981). Since then, there has been theoretical and empirical work also for multivariate extreme value distributions (such as nested logit and CNL) and mixed logit, including error components (Guevara and Ben-Akiva 2013a,b). The experiences with sampling of alternatives described in these papers are usually favourable.

The target of this survey was a net sample of 1250 respondents with completed SP experiments, which is segmented into various target subsamples of tour purposes and travel modes as shown in Table 1. The four different SP experiments mentioned in the introduction were carried out with this net sample in different compositions for each respondent. A more detailed overview of the distribution of the individual SP experiments and the associated choice sets across the sample is given in Sect. "Overview of SP experiments".

In analogy to most travel surveys in Austria and abroad (see for instance Ahern et al. 2013) the survey was conducted as a household survey for all persons in the household aged 18 years or older. The households of the gross sample were drawn from the central resident registration data (Zentrales Melderegister, ZMR) of the federal Ministry of Internal Affairs (BMI), which is an almost complete register of all Austrian households. The gross sample was drawn in consideration of a spatial stratification according to six regions (grouped NUTS3 regions) and three levels of urbanization (dense, intermediate and rural).[3]The strata

Table 1 Target net sample (person interviews) of segments

Tour purpose	Transport mode *	Target net sample			
		SP1	SP2	SP3**	SP4**
Business	Car	150	150		
	PT	50	50		
	NMM	50			
Educational/School	Car	50	50		
	PT	100	100		
	NMM	50			
To work	Car	200	200		
	PT	150	150		
	NMM	50			
Other	Car	200	200		
	PT	100	100		
	NMM	100			
Total		**1250**	**1000**	**100**	**100**

[a]Definition for the SP-off-RP-survey: According to the Degree of Urbanisation (DEGURBA)—classification by the European commission (Eurostat 2011); Definition for the Austrian national travel survey 2013/14: According to the Austrian Conference on Spatial Planning's (ÖROK) spatial types (ÖROK 2007). Both definitions are comparable for Austria

*NMM = non-motorized mode (walk or bicycle)

**Target net sample SP3 and SP4: 100 interviews each regardless which tour purpose

[3] The corresponding degree of urbanization of each municipality was taken from the LAU-2 classification of the European Commission (DEGURBA—degree of urbanization). Since only six Austrian state capitals

were sampled proportionally to their size in the Austrian population, but urban municipalities were deliberately oversampled by 15% at the expense of rural ones (i) to balance the expected lower response rate in urban areas and (ii) because a time period choice experiment makes more sense in urban areas with severe congestion. Furthermore, the predefined segments according to travel modes and tour purposes caused an oversampling of some combinations, but the client prioritised the aim to obtain mode and purpose-specific model parameters over the claim of a proportional sample.

A gross sample of 13,000 households was drawn based on an estimated response rate of 10% and one participant per household, which was considered as "worst case". All households were searched for a telephone number in public online sources, because it enables motivation and data validation calls, that way increasing both the likelihood of participation and quality of data. Originally, we found a telephone number for 31% of all households. In the course of the survey, further households deliberately provided their telephone number, which increased the share to 40%. Finally, 5041 households (drawn at random from the 13,000 households in the ZMR sample[4]) were sufficient to achieve (and exceed) the required net sample of 1250 persons. They represent the actual gross sample.

Survey process

The survey design was developed along the recommendations of the KOMOD-design, which mostly relate to sampling and motivation of participants. All households (with and without known telephone number, so-called telephone and non-telephone households) received a postal invitation to participate ("motivation letter") with information on the different options for participation, an individual access code for immediate online participation, contact options to the survey staff, and a postal reply card with a prepaid return envelope, where they could also provide their telephone number. Telephone households received a motivational telephone call a few days later. Two weeks after the motivation letter, a reminder letter was sent to those households from which no feedback had been received yet (i.e. which had neither participated nor actively refused). The survey design allowed the participants to choose between online, telephone and postal participation mode:

- Online: This was the primarily promoted option, as it was the most efficient way of participation for both the participants and survey administrators. After entering the RP data of a person, the SP experiments were generated on the fly, and the questionnaire could be completed immediately.
- Postal: Households who returned the postal reply card received an RP questionnaire with a prepaid return envelope by mail. The completed questionnaires were returned to the survey office, the survey team entered the data, the SP experiments were generated from the RP information and sent back to the households together with a prepaid return envelope. The completed SP questionnaires were again returned to the survey office and entered.
- Telephone: This option was only possible in the RP part, as the SP experiments require

are defined as densely populated (= urban) areas (Vienna, Linz, Graz, Salzburg, Klagenfurt, Innsbruck), the number of target regions was limited to this number.

[4] The proportions of the individual strata (per region and level of urbanization) set out in the original sample plan remained almost unchanged due to this second random draw.

participants to see the choice sets on a screen or printed. If the telephone option was selected, an interviewer called the household, filled in the RP part, generated the SP questionnaire and sent it back to the household by mail.

Further components of the field work were (1) validation calls in case of missing items (mainly related to RP variables needed to create the SP experiments) and (2) a telephone and e-mail hotline, both of which proved to be important additional motivation tools.

It total, the survey included two sample groups (telephone, no telephone), two successive stages (RP, SP) and three options for participation (online, postal, telephone) as shown in Fig. 1. This resulted in a complex process, which caused high demands on data management and well-trained interviewers to respond appropriately to each situation. All survey material including Screenshots of both RP and SP online survey pages (in original German language) is provided in Annex 16.

Survey implementation

The household addresses were processed and administered in an ACCESS database with customized forms for sending letters and questionnaires, administering the telephone calls, and recording the response files. All other steps were implemented in R as a common platform that allows to generate the choice sets'on the fly' with deep integration of all steps. It includes the following components:

- Development of an algorithmic design for each of the four types of experiments using the R package AlgDesign (Wheeler 2022); Sect. "Time period and mode choice experiment (SP2)" provides further details on the design construction;
- Running the interactive online questionnaire on a LAMP stack server using (i) the package shiny (Chang et al. 2024) to define the server logic and the html user interface, as well as (ii) the package RMySQL (Ooms et al. 2023) for the communication of shiny with the MySQL database;
- Construction of the choice sets immediately during the interview between the RP and SP part using as input (i) the attributes of the RP tour provided by the respondent, (ii)

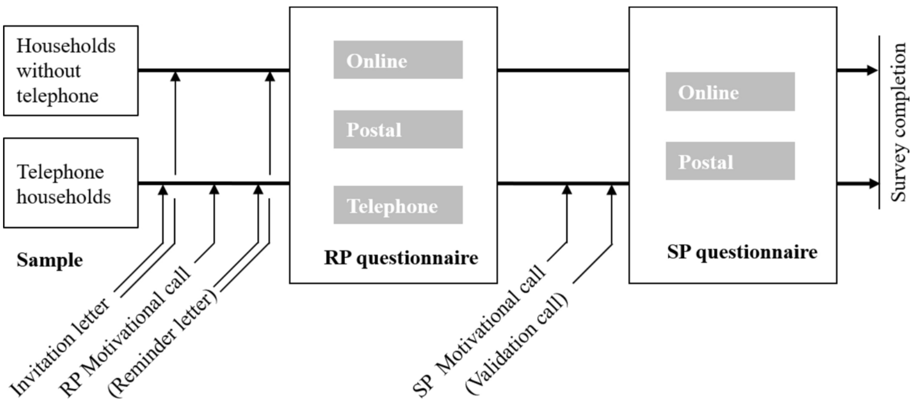

Fig. 1 SP-off-RP survey process: two sample groups (horizontal timelines), two participation stages (large boxes) and three participation modes (grey boxes)

Table 2 Adjustments in the time period and mode choice experiment after pretest analysis

Attribute	Measure
Occupancy of public transport	The attribute "occupancy of public transport" (in %) was apparently too abstract and thus changed to "availability of free seats". The number of levels of was increased to 4 {no, rather no, rather yes, yes} to obtain more variability
Travel cost	The range in the base cost of the tour (excluding toll) was increased from originally {0.9… 1.1} to {0.8… 1.2} to elicit stronger responses to cost changes
Car attributes for PT users on the revealed tour	The incentive for public transport users to switch to the car was too small. We thus made the car more attractive for public transport users by reducing the reference values for duration and cost by 20%. As a result, there is a systematic difference in the SP car attributes between RP public transport users and RP car users

the design matrix, and (iii) a function that processes both inputs to suitable choice sets being displayed on the screen;

- Conduction of an interim analysis of the pretest data using a self-written R code for discrete choice analyses.[5]

All used R codes and supplementary files are available in this GitHub repository[6]: https://github.com/ReinhardHoessinger/ToD-SP-survey

Pretest and adaption measures

A pretest was conducted with a gross sample of 600 addresses (taken from the ZMR sample). It yielded a net sample of 66 participants with around 1000 SP choices. The pretest data was prepared and subject to a descriptive analysis as well as a discrete choice analysis of all four types of experiments. The results are presented in Annex 9 to Annex 12. Based on these, we agreed the following adaptation measures with the clients for the conduction of the main survey.

Regarding the sampling process, it turned out that the quote for the business trips segment can be reached without specific measure, but educational trips fell far below the target quote in the net sample. We thus (1) changed the priority order of tour purposes and transport modes in the tour selection page (see Sect. "Overview of RP survey") and (2) included filter questions at the entrance of the questionnaire to prevent respondents from putting effort into segments which have reached their quote. Table 2 shows the adjustments in the design of time period and mode choice experiment (SP2).[7]

[5] The package apollo (Hess & Palma 2019) was not available at that time; it was first published right at the time when the survey was conducted.

[6] Please note that the production system also involves a MySQL database with the corresponding tables addressed in the R code, which is not included in the repository.

[7] We agreed adaptation measures for the other experiment types too, but they are out of the focus of this paper.

Main survey

The main survey started in September 2019. A total of 4441 motivation letters were sent, of which 1991 to telephone households and 2500 to non-telephone households. By end of November, the required net sample size of 1250 participants was achieved, but some segment-specific subsamples targets were not reached yet. The achievement of all subsample sizes by further using the ZMR sampling procedure deemed not feasible, as some segments were only filled to about 10%. We therefore decided on two alternative recruiting strategies, which should specifically target people with tours of underachieved segments:

- Facebook campaign: It aimed at reaching out for the underrepresented segment of cyclists. The campaign was run from December 2019 to January 2020 and yielded 321 interviews for this segment.
- On-site surveys: They were set up at two universities in Vienna and Lower Austria in December 2019 for two days to reach the targeted number of educational tours. Each participant received a 5€ shopping voucher as incentive. By this means, 147 segment-specific interviews could be achieved.

In January 2020, all segment-specific subsample sizes had been achieved and the main survey ended.

Survey content

Overview of RP survey

The questionnaire includes a household part to be filled in only once per household and a personal part that should be filled out separately by all adults living in the household. The household questionnaire asked for the mobility options available at the household level as well as the frequency of use of delivery services and service providers (see Annex 1). The personal part includes three sections: (1) a personal page with socio-demographic characteristics and available mobility options such as driving license and vehicle availability, (2) an RP part dealing with the selection and description of a revealed tour, and (3) an SP part with the experiments (Annex 2). A key element of Sect. (2) is the concept of a tour. It was introduced using examples and an illustration. Participants were then asked whether they had made a tour within the past month with the following characteristics, which had to be strictly met to generate appropriate SP experiments:

- carried out on a working day (Mon—Fri);
- longer than 2 km (sum of outward and return trip);
- carried out within one day (no overnight stay);
- use of walking, bicycle, public transport or car as a driver as transport mode (no car passengers)

For the participants who denied having made such a tour, the survey ended at this point. The others were asked to select a specific tour according to the following priority: (1) business,

(2) education/school, (3) to work, (4) other. It reflects our ex-ante expectation of which tour segments were likely to be difficult to reach. The respondents were then asked for more details about the selected tour at two levels: (1) Tour level: main purpose; if the starting point and/or destination was in an urban area; whether the tour started from their home, workplace, place of education, or somewhere else (Annex 3). (2) Trip level: departure times of outward and return trip, total tour distance, used travel modes (multiple modes possible) as well as further information on car and/or public transport if these modes were used (see Annex 4).

Overview of SP experiments

Upon completion of the RP section, the SP experiments were generated'on the fly' using various household, personal, and tour characteristics as input. The customisation refers to (1) the types of SP experiments and numbers of repeated choice tasks (see Table 3), (2) the version of the SP2 experiment, which differs between PT and car users on the RP tour, (3) the available travel modes in SP1, (4) the type of public transport in SP1 and SP2, which can be'train' or'public transport without train', and (5) the attributes of the alternatives in SP1 and SP2, which depend on the urbanity type, trip distance, and departure times of outward and return trip. Each respondent received 16 choice tasks distributed across up to four different experiment types depending on the following preconditions:

- SP1 (mode choice): with all persons who had reported a suitable tour.
- SP2 (time period and mode choice): if the tour was made by car or PT and the departure time plus half the trip duration was within the morning (6—9 a.m.) or evening peak (4—7 p.m.).
- CS (car sharing vs. public transport): if the person has a driving license and had already used car sharing or answered the question on possible future use with'yes' or'rather yes'.
- PR (park & ride vs. car alone): if the person has a driving license and had already used park & ride or answered the question on possible future use with'yes' or'rather yes'.

In the following, we describe only the innovative SP2 experiment in detail. The other experiments (SP1, CS, PR) are more conventional and skipped at this point (see Annex 5 and Annex 7 for more details).

Table 3 Determination of the number of choice sets per experiment for each participant

Experiments carried out	Number of choice sets per experiment				Total
	SP1	SP2	SP3	SP4	
SP1	16	0	0	0	16
SP1 + SP2	8	8	0	0	16
SP1 + CS	12	0	4	0	16
SP1 + PR	12	0	0	4	16
SP1 + SP2 + CS	6	8	2	0	16
SP1 + SP2 + PR	6	8	0	2	16
SP1 + CS + PR	12	0	2	2	16
SP1 + SP2 + CS + PR	4	8	2	2	16

Time period and mode choice experiment (SP2)

This experiment consisted of 8 repeated choice tasks, each offering 4 mode alternatives plus "none of these alternatives" as fifth option. The transport mode of the RP tour (car or PT) was displayed 3 times with departure times (1) during peak time, (2) before peak time, and (3) after peak time. The latter two options are burdened by an unfavourable departure time. The 1st option had a departure time close to that of the RP tour (that is why this experiment was only conducted with participants who reported an RP tour at peak time). This favourable property was balanced by unfavourable attributes as follows:

- The tasks 1 to 4 simulate a situation where the infrastructure provider leaves it to the market to regulate the problem of overcrowding, i.e. the car alternative is burdened with longer travel time (congestion), the PT alternative by decreased availability of seats (over-occupation)
- The tasks 5 to 8 simulate a situation where the infrastructure provider responds to overcrowding by peak-pricing, i.e., the 1st alternative is burdened with higher travel cost either in terms of a peak hour toll (car drivers) or a peak hour surcharge (PT users).

The 4th alternative offered a switch to the other transport mode (PT for car drivers on the RP tour and vice versa) with a departure time close to that of the RP tour. Table 4 shows how the alternatives and attributes were arranged on the screen with notes explaining the conditions under which some of the attributes were displayed. A screenshot of a sample page is provided in Annex 16, it shows how the experiment appeared on the screen (in original German language by means of a PT example). All choice tasks (also in the other experiments) had a "no choice" alternative as well. Respondents who selected this alternative were not asked

Table 4 Arrangement of alternatives and attributes in the choice tasks of the TOD experiment

Attribute	RP mode during peak	RP mode before peak	RP mode after peak	Other mode during peak	None
Outward trip	hh:mm—hh:mm	hh:mm—hh:mm	hh:mm—hh:mm	hh:mm—hh:mm	
Return trip	hh:mm—hh:mm	hh:mm—hh:mm	hh:mm—hh:mm	hh:mm—hh:mm	
Total duration of both trips	# min	# min	# min	# min	
thereof time in congestion[a]	# min	# min	# min	# min	
Duration of stay at destination	hh:mm	hh:mm	hh:mm	hh:mm	
Total cost of both trips	#.## €	#.## €	#.## €	#.## €	
thereof peak time surcharge[b]	#.## €	#.## €	#.## €	#.## €	
Availability of free seats[c]	(rather) yes/no	(rather) yes/no	(rather) yes/no	(rather) yes/no	
Your choice (check one)	o	o	o	o	o

[a]Only presented in congestion scenario for car mode;

[b]Only presented in pricing scenario in terms of a peak-hour toll (car) or peak hour surcharge to the PT ticket

[c]Only presented for PT mode

to name their least worst alternative from the remaining options. This strategy was chosen to avoid getting choices for the alternatives we are interested in (such as time periods and modes), for choice situations where the respondents really have no preference for one of these alternatives.

The SP-off-RP approach has the advantage that it deals with realistic choice situations based on a known tour, but it inevitably introduces correlations between those attributes which scale with the tour distance (travel time, congestion time, travel costs etc.). The time period choice introduces further dependencies: to elicit trade-offs between departure time and travel attributes, it is necessary to present the entire daily schedule as alternative (see Table 4). With many mutually dependent attributes, a strictly factorial design with few attribute levels is less capable of achieving great partial independence than random variation with many levels. For this reason, we categorised the attributes into two groups:

- those attributes which establish the key trade-offs in the transport model (travel time including congestion, travel cost including peak hour surcharge, PT occupancy) vary according to a factorial design with 4 levels each;
- the remaining attributes (clock time of outward and return trip, duration of stay etc.) vary randomly (by drawing a random number within a predefined range) in order to avoid anchoring effects; i.e., a preferred choice of alternatives with exactly the same attributes as the RP trip.

A table of the SP2 experiment together with all attributes and their characteristics is provided in Annex 8. The factorial variations were generated in R using an algorithmic design as described in Sect. "Survey implementation". The design was created in 4 steps:

(1) generating a full factorial design using the function gen.factorial();
(2) drawing a D-optimal design of suitable size from the full factorial using the function optFederov();
(3) checking the quality of the D-optimal design using the function eval.design();
(4) drawing blocked designs of required sizes from the D-optimal design using the function optBlock().

The blocked designs served as input for the generation of the SP experiments along with the household, personal, and tour characteristics. After completion of the RP part of the survey, each respondent was assigned a randomly selected block of required size for each type of experiment as shown in Table 3.

Survey response[8]

Ex-ante assessment of response burden and total response rate

We assessed the response burden ex-ante based on the survey content and design using a tool provided by Schmid and Axhausen (2019; see also Axhausen et al. 2015, Axhausen

[8] Note: the calculation of response rates/ times is only possible for the households in the ZMR sample (participants recruited via the Facebook campaign and the on-site survey were excluded), because it requires

and Weis 2010), which quantifies the response burden by means of a points system from social research. This tool also predicts the expected response rate based on the burden using a generalized linear model with logit link function. We used the parameters for a sample without prior recruitment. Based on a response burden of 391 points, the model yields an expected response rate of 21%. The model does not distinguish between participants who received a motivational call and those who did not, although it makes a big difference on the participation rate in our case.

Table 6 shows the result of the response analysis. The proportion of telephone households in the gross sample increased from originally 31% to 40% because some non-telephone households stated their telephone number in the reply card. 29% of all contacted households started to participate (telephone: 41%; non-telephone: 20%), 24% successfully completed it, which corresponds to the overall response rate (telephone: 33%; non-telephone: 18%). The dropout of 16% consists mainly of postal participants because of the higher burden of the two-stage mailing process. The net sample includes a total of 1207 households from the ZMR sample who delivered at least one valid personal interview. 77% of participating households did so online, the remaining 23% by telephone or post. The share of postal participants is larger among telephone households (31 vs. 12%), because telephone numbers (mainly landline) were more often found for households with elderly people, who preferred postal participation.

The actually achieved rate of 27%[9] is above expectations of 21% but settled in the expected range (Fig. 2). It should be noted that the prediction model does not distinguish between telephone-motivated and non-motivated households, while these groups differ greatly in our sample, as can be seen in Table 5: the response rate of telephone households is almost twice as high (33 vs. 18%). The total response rate is a weighted average of both groups, containing 55% telephone households.

Response rates according to AAPOR

The response rate calculator developed by the American Association for Public Opinion Research (AAPOR 2016) is a tool based on the association's self-developed standard definitions for calculating survey outcome rates. By using pre-defined final disposition codes for every single unit of a survey, the calculator quantifies response rates, cooperation rates, refusal rates and contact rates. The outcome rates of our survey (combined online and offline) were calculated using the AAPOR Outcome Rate Calculator Version 4.0 (all) of May, 2016. The overall outcome rates as well as rates for households with and without available telephone number are shown in Annex 14. AAPOR Response Rate 1 corresponds to the rates in the bottom line of Table 5.

knowledge on the gross sample. The number of persons living in the households of the ZMR gross sample is also unknown.

[9] The response rate is higher than that in Table 5, because it is calculated differently, namely, according to Schmid and Axhausen (2019) using the AAPOR calculator (see Sect. "Response rates according to AAPOR"): the number of returned questionnaires (completely and partial) is divided by the number of returned questionnaires (completely and partial) plus all valid households, which means that invalid ones (letters undeliverable) are subtracted from the denominator.

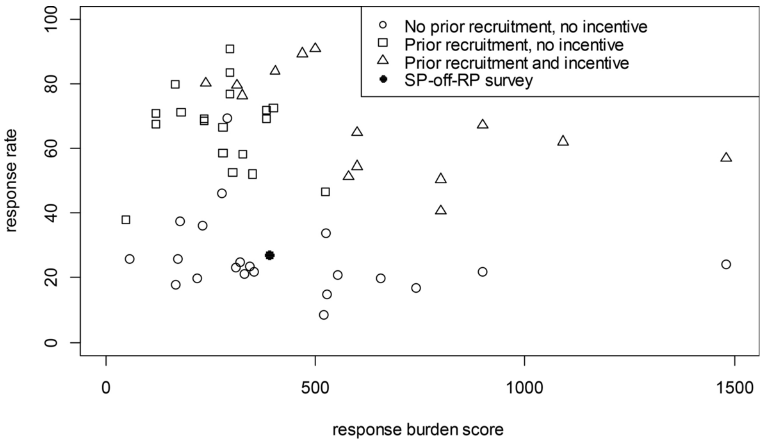

Fig. 2 Response burden and response rates from SP-off-RP survey compared with surveys of Schmid and Axhausen (2019)

Table 5 Response rate and net sample of ZMR households with and without known telephone number

Households in ZMR sample	Number			Percentage [%]		
	Total	With telephone	Without telephone	Total	With telephone	Without telephone
Gross sample	5041	2030	3011	100.0	100.0	100.0
Participation started *	1437	829	608	*28.5*	*40.8*	*20.2*
Online	1150	589	561	*22.8*	*29.0*	*18.6*
By mail/phone	239	199	40	*4.7*	*9.8*	*1.3*
Participation completed	**1207**	**670**	**537**	**23.9**	**33.0**	**17.8**

*The number of households that have started to participate is higher than the sum of online and mail/phone participants because some households dropped out before the participation type could be identified

Temporal response behaviour

Figure 3 shows the duration until response by type of participation. Two aspects should be noted: First, the reminder had a strong impact, as can be seen from the second peak. It argues for a second reminder in a similar survey in the future. Secondly, the low share and long duration of postal participation[10] reflects the huge effort of going through the lengthy two-stage process in a postal way. The multiple mailings up to a complete participation (announcement, RP questionnaire, SP questionnaire, both outward and return) caused that the median duration of postal participation amounts to 45 days compared to 21 days for online participation.

[10] Please note that "postal" also includes telephone RP participants, because there were only a few of them and the SP part had to be completed by post anyway.

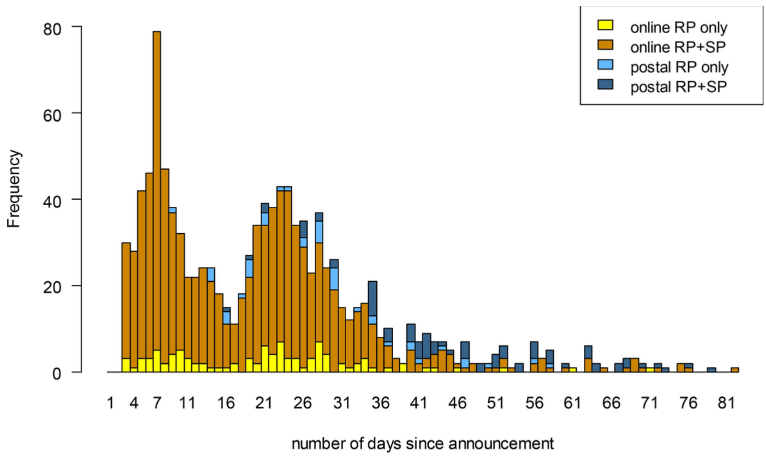

Fig. 3 Duration until response for online and postal participation

Sample description

Composition of net sample and distribution across strata

The net sample consists of 1849 persons with SP interviews, which were recruited from 3 sources:

- ZMR sample: 1381 persons from 1051 households (out of 1661 persons from 1207 households minus 280 persons who did not report a suitable tour);
- Facebook campaign: 321 persons;
- On-site survey: 147 persons.

The number of achieved SP experiments including a breakdown to the predefined segments is provided in Annex 15. Table 6 shows how the 1513 households in the net sample are distributed across the 18 strata defined by regions and levels of urbanization, assuming that each Facebook and on-site participant represents a separate household.[11] The largest deviation is an overrepresentation of urban areas mainly at the expense of rural ones, which has several reasons: urban regions were deliberately oversampled, and the cyclists and students recruited via the Facebook campaign and the on-site survey are also mainly urbanists. The overrepresentation of the eastern region is partly a side effect of the high share of urban residents in this region. Moreover, the on-site survey was entirely conducted in the eastern region.

[11] 6 households could not be assigned to the strata because of missing postcodes of some Facebook participants.

Table 6 Distribution of the net sample across regions and urbanity types; the percentages (in italic) show the deviations from the corresponding shares in the population

Nr	Region	Urban		Intermediate		Rural		Total	
		Number	± [%]	Number	± [%]	Number	± [%]	Number	± [%]
1	Eastern Region	493	*+ 11.2*	138	*+ 1.6*	141	*− 1.5*	**772**	*+ 11.3*
2	Upper Austria	43	*+ 0.5*	73	*− 1.9*	133	*− 1.7*	**249**	*− 3.0*
3	Styria	99	*+ 3.3*	66	*− 1.7*	62	*− 1.8*	**227**	*− 0.2*
4	Salzburg	25	*− 0.1*	28	*− 0.2*	18	*− 1.3*	**71**	*− 1.6*
5	Carinthia	21	*+ 0.3*	13	*− 0.6*	28	*− 1.9*	**62**	*− 2.3*
6	Tyrol + Vorarlberg	32	*+ 0.6*	68	*− 2.4*	32	*− 2.5*	**132**	*− 4.2*
	Total	**713**	*+ 15.8*	**386**	*− 5.2*	**414**	*− 10.6*	**1513**	

The bold values provide important infomation on sums of rows and columns

Table 7 Socio-demographic characteristics in the net sample and in the Austrian population

	Number in SP-off-RP	Share [%] in SP-off-RP	Share [%] in ATS
Household size*			
1	273	18.0	36.5
2	593	39.0	29.8
3	282	18.6	15.3
4 and more	371	24.4	18.5
Gender			
Male	983	53.2	47.9
Female	866	46.8	52.1
Age			
Under 25 years	278	15.0	10.8
25 to 34 years	319	17.3	15.7
35 to 44 years	307	16.6	17.2
45 to 54 years	362	19.6	19.7
55 to 64 years	340	18.4	14.6
65 + years	243	13.1	21.9
Education			
No graduation	5	0.3	0.1
Mandatory school	75	4.1	25.3
Apprenticeship	548	29.7	47.9
High school	557	30.2	14.2
College, university	661	35.8	12.5

*Household size was analysed at the household level, whereas all other characteristics were analysed at the person level

Sample characteristics and representativeness

To assess the representativeness of our obtained SP-off-RP sample, we compared it with the latest Austrian travel survey (ATS) 2013/14 "Österreich Unterwegs" (BMK 2015), which was in turn weighted according to the Austrian population.

The distribution of socio-demographic characteristics in Table 7 reveals the following groups to be under-sampled: single households, women, seniors, and persons with a low level of education. The latter pattern is well known for social surveys. Seniors, on the other hand, were more affected by the larger response burden of postal participation, as they participated predominantly offline (see Sect. "Survey response"). Young people, on the contrary, were over-sampled. This results from the recruitment of cyclists via Facebook and the on-site survey at the universities.

Table 8 shows the distribution of available mobility tools and trip characteristics. The SP-off-RP participants show an excessive availability of all kinds of mobility tools (bicycles, PT permanent tickets, cars, driving licences), which reflects that persons with high mobility levels felt more addressed. The differences in trip characteristics (modal split, start location, distance) have a multitude of reasons: the knock-out criteria for the RP tour as stated in Sect. "Overview of RP survey", the prioritisation of urban tours at peak periods, and the selective sampling of educational tours and cycling tours via Facebook and the on-site survey. Most important (and the reason behind the selective sampling) are the predefined segments of tour purposes and travel modes set out in Table 1, which are not representative in the first place.

This illustrates a specific concept behind the survey: proportional representation of the population was not the first priority, but rather the aim to estimate separate models for different market segments (i.e. tour purposes) with sufficient trade-offs. Consistent estimation of such models is also possible from a selective sample of sufficient size (see Sect. "Sam-

Table 8 Mobility indicators of net sample and representativeness

	Number in SP-off-RP	Share [%] in SP-off-RP	Share [%] in ATS
Bicycle availability			
No	343	18.6	27.8
Yes	1506	81.4	72.2
PT card availability			
Season ticket	642	34.7	20.4
Discount card/reduced	496	26.8	17.2
Car availability			
Never	187	10.1	16.1
Sometimes	382	20.7	14.8
Every time	1280	69.2	69.1
Driving licence			
No	87	4.7	16.3
Yes	1762	95.3	83.7
Modal split of tours			
Walk	39	2.2	9.4
Bicycle	267	15.3	6.4
PT without train	275	15.8	14.5
Train	199	11.4	4.6
Car driver	965	55.3	65.1
Trip start location[a]			
Urban	838	48.0	29.0
Non-urban	907	52.0	71.0
Trip distance: mean distance [km]	1745	19.3	14.6

[a] Definition for the SP-off-RP-survey: According to the Degree of Urbanisation (DEGURBA) - classification by the European commission (Eurostat 2011); Definition for the Austrian national travel survey 2013/14: According to the Austrian Conference on Spatial Planning's (ÖROK) spatial types (ÖROK 2007). Both definitions are comparable for Austria.

pling"). For this reason, no further measures were taken to correct the deviations of the SP-off-RP sample from the population.

Data processing, format, and availability

Data processing and plausibility checks included the following steps:

- Generation of dummy variables for nominal characteristics such as regions and urbanity types;
- Generation of further variables required for the analysis, e.g. duration of stay at the destination from arrival/departure times, deviation of the trip before/after peak from preferred departure time etc.
- Generation of variables to identify non-traders for all 4 SP experiments, i.e. the number of different alternatives chosen by the person, with and without "no choice".
- Calculation of interview duration for online participants in total, for the RP part, and for the SP part per experiment type;
- Outlier check for open response scales (e.g. travel duration and cost of the RP tour) and censoring of outliers to a maximum value determined empirically from the robust sample distribution.

The final sample includes 1849 persons with their household, person, and RP tour characteristics as well as the four associated SP experiments. It was delivered to the client in the following format:

(1) An Excel file with the metadata (in German) in separate sheets: variable list, code plan, distribution statistics and frequency tables, correlations of the choices with the SP attributes and with personal characteristics. Further details are provided in the metadata's "intro" sheet.
(2) Another Excel file with the microdata, again in separate sheets: one sheet with household, person and RP tour characteristics (1 row = 1 person), as well as four separate sheets with the data of each of the four SP experiments (1 row = 1 choice set, linked to the persons by key variables).

The main use case (and the reason for collecting the data) is to inform the development of a new national transport model in Austria. Most importantly, it serves to integrate SP-based time period choice information into an otherwise RP-based model framework, using mode choices to bridge the gap between SP and RP, and enabling the estimation of separate models by tour purpose with sufficient trade-offs. On the occasion of the survey, further information gaps with regard to the transport model were also filled, namely, (1) to gather choice information on the 'rare modes' Carsharing and Park & Ride, and (2) to estimate the travel demand of delivery services and service providers, which is usually neither covered in passenger transport nor in freight transport models.

The data is also available for other use cases upon request from the National Access Point of Austria for mobility data (see link in the declarations below). It can be used for other purposes as well, although it should be noted that the segment-specific sample deviates considerably from the population for some characteristics. The data contains all available household and personal characteristics for weighting, but the weighting itself should be carried out with a specific use case in mind.

Model results of the time period and mode choice experiment

The model for the choice of departure time and travel was estimated separately for four tour purposes (work, business, education, other) and with various specifications and sets of predictors. In this model estimation the choice tasks with "no choice" observations were not used. A simultaneous estimation for the two groups of respondents (car and PT users in the RP situation) was carried out, with several common coefficients across both groups. In this model, the car options presented to the actual car users are grouped together in a car nest; see Fig. 4). Similarly, the pt options presented to the actual pt users are grouped together in a pt nest.. A further breakdown into groups according to sample-specific characteristics (e.g. ZMR households with and without a telephone number) was not considered. The implication of the nesting of mode choice above TOD choice is that there is more substitution between alternatives that refer to the same mode than between alternatives that refer to different modes. The nesting coefficient θ should be between 0 and 1 for consistency with global random utility maximisation.

Table 9 shows the result of the nested logit for each of the four travel purposes. It follows the theoretical model in Eq. (2) discussed in Sect. "Literature review and scope", although the specification is a bit more complicated because we have a tour-based model. It involves joint decision-making on the departure time for the outward and the return trip of the tour. The measures of the statistical fit (Rho-squared with respect to 0) for all the different purposes are lower (0.05 to 0.14 versus 0.20 to 0.26) than those for the SP-based models for combined TOD and mode choice in de Jong et al. (2020), indicating a larger degree of random noise in the Austrian case.

All cost and travel duration coefficients in Table 9 have the expected negative sign and are statistically significant at $\alpha <= 0.05$; this also goes for earlier and later departure time for the outward and return trip. The availability of free seats in public transport has a posi-

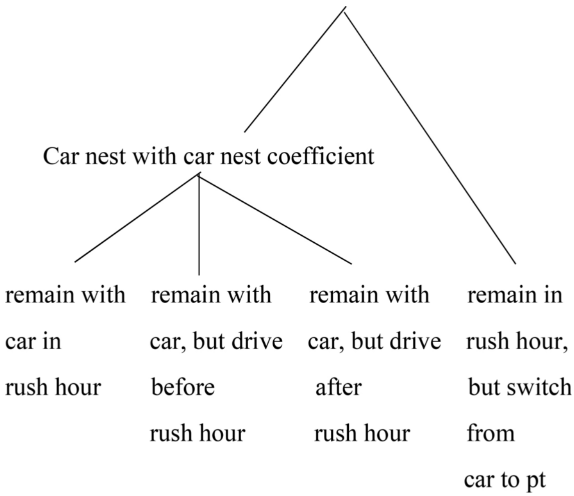

Fig. 4 Nesting structure for SP2-estimation for the actual car users with a car nest

Table 9 SP2-estimation results for the travel purposes work, business, education and other

Model diagnostics	Work		Business		Education		Other	
Observations (choices)	3223		1628		1264		2315	
Final log likelihood	−3858.06		−2081.12		−1661.51		−3008.98	
Rho-squared (0)	0.1365		0.0779		0.0518		0.0624	
Rho-squared (c)	0.0575		0.0434		0.0393		0.0575	
Attributes	Estimate	t-val	Estimate	t-val	Estimate	t-val	Estimate	t-val
ASC: Stay with car	0	(*)	0	(*)	0	(*)	0	(*)
ASC: Stay with pt	0	(*)	0	(*)	0	(*)	0	(*)
ASC: Change from car to pt	−1.4010	(−3.1)	−1.1549	(−2.3)	−1.2619	(−2.6)	−6.8020	(−3.3)
ASC: Change from pt to car	−1.4146	(−2.6)	−0.3293	(−1.3)	−1.7405	(−3.1)	−6.5657	(−3.2)
Generic cost (euro)	−0.0780	(−8.1)	−0.0411	(−4.8)	−0.0927	(−3.9)	−0.1282	(−8.0)
Travel duration car (min)							−0.0312	(−6.9)
Travel duration pt (min)							−0.0987	(−5.2)
Generic travel duration (min)	−0.0277	(−6.2)	−0.0168	(−5.0)	−0.0308	(−3.6)		
Earlier outward departure (min)	−0.0156	(−12.5)	−0.0128	(−12.2)	−0.0089	(−9.8)	−0.0106	(−13.7)
Earlier return departure (min)	−0.0022	(−2.2)						
Later outward departure (min)	−0.0100	(−7.3)	−0.0070	(−4.9)				
Later return departure (min)	−0.0080	(−7.8)	−0.0049	(−4.6)	−0.0045	(−6.2)	−0.0074	(−12.7)
Availability of free seats			0.1646	(2.0)			0.3327	(5.7)
Nest coefficient car	0.3940	(3.3)	0.7152	(3.5)				
Nest coefficient pt	0.4579	(4.1)	0.9484	(3.5)				
Generic nest coefficient					0.5400	(4.2)	0.1447	(3.3)

tive coefficient, i.e. free seats increase the probability of choosing PT. The cost coefficient is generic for all modes (so, ‘a Euro is a Euro’, regardless for what it is spent). The travel duration coefficient was tested mode-specific. For work, business and education, the mode-specific coefficients did not significantly differ from each other, so that the generic coefficients was kept. For'other tour purposes', it differs between the modes, so that the value of travel time saving also differs between car and public transport.

The nest coefficients have a bearing on the substitution pattern between the choice alternatives: they determine whether there is more substitution between TOD periods than between modes. We estimated separate nest coefficients for car and PT for work and business tours and a common coefficient for education and other tour purposes. All these coefficients are in the interval between 0 and 1, as required. For business tours, the nest coefficients of both car and PT do not significantly differ from 1, so that the nested logit reverts in essence to a multinomial logit. All other nest coefficients are significantly smaller than one. It implies that travellers prefer to shift between TOD alternatives than between modes. The estimated nest coefficients have been carried forward to the new national transport model in Austria.

Summary and conclusions

The survey described in this paper was commissioned by the Austrian Ministry for Transport, Innovation and Technology. Its main purpose was to provide input for the Austrian Transport Model and Forecast 2040+, which serve as foundation for the national road and rail infrastructure planning. It was the first nationwide and comprehensive SP survey of travel behaviour in Austria.

The core of the survey consists of four stated preference experiments based on a revealed tour of the choice maker (tour-based SP-off-RP). The most advanced element is a combined time period and mode choice experiment. It follows the tradition of surveys first conducted in the Netherlands and repeated several times in different countries. The parameters estimated from such data have already been published and serve as input for transport models in several countries. But the survey method has so far never been published in any detail. This gives rise to the twofold motivation for this paper: (i) to describe the survey method and the logic behind the experiment according to scientific standards and to make it available to the scientific audience, and (ii) also to describe the innovative components, which contribute to the further advancement of this methodology.

The survey consisted of two stages: a revealed preference (RP) stage, in which the respondents reported their personal characteristics and a revealed tour, and a stated preference (SP) stage, whose experiments were created based on the RP information. We offered three channels for participation: online, telephone (only for the RP part) or mail. The offline channels were offered mainly for inclusiveness, while online participation was given priority in all contacts with the respondents, as it is the only option where both stages can be completed in one go. The combination of prioritization and ease made online participation, in contrast to earlier travel surveys in Austria, by far the predominant channel.

The elaborate design with two-stages and three participation channels made the survey administration quite complex, but the effort was rewarded by an unexpectedly high response rate of 27% (according to AAPOR) compared to 21% estimated ex-ante. Further factors that contributed to a high response rate were (i) an announcement letter from three well-respected national transport institutions (ministry as well as road and rail infrastructure provider), (ii) the telephone motivation, (iii) active telephone and e-mail support, and (iv) the reminder postcard; a second reminder might still have made sense. The complexity of an SP-off-RP survey to fulfill the requirements of the SP2 design thus showed that a pretest was an essential step to be taken prior to the main survey.

The required sample size of 1200 persons with SP interviews was considerably overachieved with 1849 persons in the net sample. A serious issue with respect to the data quality and use is the predefined segmentation by means of required subsample sizes for tour purposes and travel modes. It follows the claim to estimate purpose-specific models with sufficient trade-offs, but it has other implications, too. Achieving predetermined subsample sizes therefore proved inefficient with a continuous sampling method; alternative sampling strategies had to be used to fill the specific net sample gaps.

Another consequence is that the segment quotas are not representatively distributed. Not all deviations of the net sample from the population can be explained by this (e.g. the undersampling of persons with a low level of education), but the quotas have exacerbated the problem, along with the prioritisation of urban tours to obtain more trade-offs for the time period choice experiment. This is not a problem for the estimation of segment-specific coefficients for the new national transport model, as presented in Sect. "Model results of the time period and mode choice experiment". However, weighting is recommended for other use cases which rely on a representative sample. Alternatively, further target group-specific oversampling methods could be applied beyond the spatial stratification in order to better reach the typical, difficult-to-capture socio-demographic groups.

More in general, getting good travel survey data is becoming increasingly more difficult. Since a representative sample is not necessary for discrete choice model estimation, one could justify a further move towards convenience-based samples, also given that further down the modelling chain the modellers are also using traffic count data (either through calibration factors in the model or applying the pivot-point method).

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Authors contributions Florian Aschauer: Conceptualization, Methodology, Formal analysis, Writing (Original Draft); Gregor Husner: Writing (Original Draft); Astrid Gühnemann: Writing (Review & Editing); Gerard de Jong: Writing (Review & Editing); Stefan Grebe: Writing (Review & Editing); Alexander Schaffenberger: Formal analysis, Writing (Review & Editing); Reinhard Hössinger: Supervision, Data Curation, Formal analysis, Writing (Review & Editing);

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The micro- and metadata can be requested for download here: https://mobilitydata.gv.at/en/data/sp-survey-passenger-transport-transport-model-austria

Declarations

Ethical approval Not applicable.

Competing interests The authors declare no competing interests.

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Florian Aschauer recently received his PhD at the Institute for Transport Studies and works at the institute as an assistant researcher in projects focussing on travel behaviour analysis. He wrote his PhD thesis on travel survey methods, including travel and non-travel related data collection methods and survey design.

Gregor Husner works as a graduate assistant at the Institute for Transport Studies and works on developing and conducting various travel surveys. In his master's program in environmental- and bioresource management he focusses on transport-related issues.

Astrid Gühnemann is head of the Institute for Transport Studies at BOKU and Professor of Transport for Sustainable Development. She holds a diploma in industrial engineering and PhD in transport economics. She has more than 25 years experiences in national and international research projects in the field of transport appraisal, systems analysis and modeling.

Gerard de Jong studied spatial economics and did his PhD in econometrics. He has been working on transport models since 1986, both in passenger and freight transport, and contributed to many international, national and regional models. He also has been involved in many stated preference studies. Currently he is director of Significance BV and Research Professor at the Institute for Transport Studies at the University of Leeds.

Stefan Grebe did his MSc and PhD in Physics. After that at Significance he worked on the development of different strategic transport models for passenger transport, freight transport and aviation and participated in several stated preference studies. He now works at CE Delft.

Alexander Schaffenberger studied Civil Engineering at Graz University of Technology and did his diploma in the field of infrastructure. Transportation topics were deepened in his master's program. He works now at PLANUM as transport and mobility planer.

Reinhard Hössinger holds a doctorate degree in transportation science and is Senior Scientist at the Institute for Transport Studies since 2000. He is project leader of several scientific projects and specialised himself in mobility surveys and data analysis using advanced statistical methods such as discrete choice modelling, structural equation modelling, and time use models.