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Implications of survey methods on travel and non-travel activities: A comparison of the Austrian national travel survey and an innovative mobility-activity-expenditure diary (MAED)

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This paper contributes to the research on non-reporting effects in mixed-method household travel surveys (HTS) in two ways: Firstly, we compare travel activities reported in the established Austrian National HTS (ANTS) with an innovative survey approach, the so-called "Mobility-Activity-Expenditure Diary" (MAED), and secondly we extend the analysis to (i) additional travel estimates and to (ii) non-travel activities. The analysis addresses three main goals: (i) identification of non-reporting effects in the HTS for travel estimates, (ii) analysis of speed-of-response effects on travel estimates, (iii) assessment of the completeness and accuracy of non-travel activities inferred from the trip purposes in the HTS. Underreporting in HTS occurs both on person level and on the trip level, and mainly for peak-hour trips with either short distances or short durations of the subsequent non-travel activity. No significant underreporting was found on the tour level. Speed-of-response effects are small in both surveys but significant for the ANTS. The duration of non-travel activities per activity type corresponds well in the MAED-survey and in the ANTS but the information in the MAED-survey is much richer. The results can be used threefold: (i) to develop correction factors that account for systematic biases in HTS, (ii) to identify omitted items (trip frequency, duration, distance etc.) if HTS data are used without correction factors, and (iii) to demonstrate the importance of high quality field work and validation.

Keywords: *data collection, response burden, speed of response, time use, travel survey methods, mobility-activity-expenditure diary.*

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1. Introduction

Household travel surveys (HTS) are an important data source for transport planning and research. Established HTS are mixed-method approaches that combine paper-and-pencil questionnaires (PAPI), telephone interviews (CATI), web-based questionnaires (CAWI) and personal interviews (Armoogum et al. 2014). Innovative tracking methods with dedicated GPS-devices or smartphones are not yet fully established in survey practice (e. g. for national travel surveys, NTS) but are widely used in research. Reporting quality and non-reporting effects in HTS can significantly influence the quality and usability of the resulting data and thus have been analysed in various studies based on:

i. follow-up validation directly within the HTS, including speed-of-response analyses (Brög and Meyburg 1980, Richardson 2003) and non-response studies (Brög and Meyburg 1980, Richardson 2003, Wittwer and Hubrich 2015),

ii. comparisons of different HTS methods (Armoogum et al. 2014, Madre et al. 2007) and validation with external data sources such as traffic counts (Ashley et al. 2009),

iii. comparisons of HTS and time use surveys (TUS) (Gerike et al. 2015, Armoogum et al. 2008), and

iv. comparisons of HTS with GPS-based innovative survey approaches (Rasouli and Timmermanns 2014, Safi et al. 2017).

Differences have been identified in the proportion of mobile persons, in the number of trips per person day (trip rate), and in the trip characteristics. Validation studies and comparisons of different survey designs directly within the HTS show significant effects of (a) sophisticated and high quality survey designs for all steps from the sampling procedure to data processing, (b) response rates and (c) the speed-of-response. Brög and Meyburg (1980, see also Brög et al. 1982, Brög and Meyburg 1981, Brög 2009, Socialdata 2009) aim to establish a "ground truth" from a PAPI survey with the help of extensive validation of the received questionnaires within their New KONTIV Design (NKD).

Comparisons between TUS and HTS conclude that TUS data generate higher travel estimates (Stopher 1992, Harvey 2003, Hubert et al. 2008). The underlying hypothesis is that activity-based diaries are more intuitive as they put travel in the context of the daily schedule, so that respondents are better able to recall trips and less susceptible to soft refusal. However, these findings only hold if "location changes between two time intervals in the diary without a reported trip in-between" are added to the actually reported trips (Gerike et al. 2015). Comparisons of GPS surveys with HTS reveal a similar pattern (Jin et al. 2014, Rasouli and Timmermanns 2014, Safi et al. 2017). Trip numbers are on average higher in GPS surveys compared to traditional HTS, particularly for discretionary trips.

This paper aims at contributing to this line of research on reporting quality and non-reporting effects in HTS (i) by adding a comparison of travel activities reported in HTS with an innovative survey approach, the so-called "Mobility-Activity-Expenditure Diary" (MAED), and (ii) by extending the analysis to (iia) additional travel estimates that to our best knowledge have not been considered before and to (iib) non-travel activities (called 'activities' in this paper).

We compare the Austrian national travel survey (ANTS) from 2013/14 (BMVIT 2015), a traditional mixed-method HTS, with the innovative hybrid travel/time use MAED-survey. The latter is a self-administered mail-back survey based on the NKD. The travel section is similar to the established HTS, but the MAED adds detailed questions about all activities between any two trips and about all committed expenditures. We consider the MAED dataset as "ground truth" in the comparison, which contains (almost) all trips and activities with high accuracy. This assumption seems justified for three reasons: (i) MAED respondents received an incentive after

successful participation and were thus well motivated to fill out the diary carefully, (ii) trips are reported in the context of the daily schedule, so that respondents are better able to recall trips and cannot draw an advantage from claiming not to have made a trip, and (iii) the MAED-survey includes the same extensive validation as the NKD (developed from Brög and Meyburg 1980).

The following three goals are set for the comparison of the MAED-survey and the ANTS in this paper:

- Identification of non-reporting effects in the travel estimates of HTS: In addition to the usual travel estimates reported in the literature as described above and in section 2, our comparison accounts for additional indicators in order to deepen the understanding of the non-reporting effects. These are in particular (i) tours (defined as a series of trips that begin and end at an individual's home); (ii) temporal pattern of trips in order to understand whether non-reporting is related to the start time of a tour or a trip; and (iii) the duration of the subsequent activity after each trip as possible determinant of non-reported trips.
- Analysis of speed-of-response effects on travel estimates: A particular strength of our database is that detailed field work variables are available for both surveys. They characterise the survey process and are used for analysing the so-called "speed-of-response" effect for the travel estimates. The literature reports ceteris paribus systematic differences in trip rates for respondents who directly answer after the first mailing (early respondents) and respondents who only answer after the last reminder activities (late respondents) (Brög 2009, Richardson 2003). These comparisons of travel estimates for early and late respondents serve two purposes: (i) to estimate the hypothetical travel estimates at 100 percent response rate (Brög 2009) or (ii) to identify biases in travel estimates resulting from speed-of-response effects (Richardson 2003; see also Axhausen and Weis (2010) for a response-burden/self-selection explanation). The latter is elaborated in this paper.
- Assessment of the completeness and accuracy of non-travel activities inferred from the trip purposes in the HTS: Based on methods developed in Gerike et al. (2015), the number and duration of activities are computed for the ANTS and compared with the activities reported in the MAED-survey.

This paper aims at investigating differences between the MAED-survey (considered as "ground truth") and the ANTS (a traditional HTS) for key travel estimates and non-travel activities in order to better understand non-reporting effects in HTS. The results can be used threefold: (i) to identify what information is lost (trip frequency, duration, distance etc.) if HTS data are used without any correction, (ii) to develop correction factors that account for systematic biases in HTS, and (iii) to demonstrate the importance of high quality field work and validation.

The remainder of this paper is organised as follows: In the next section, we review the literature on comparisons of different survey designs and on the speed-of-response effects on travel estimates. The literature review includes all types of comparisons i) to iv) as described above, but the focus is on the comparison of TUS and HTS (iii) because the literature in this field is rich and the MAED-survey is a hybrid between TUS and HTS. We describe the data used in this paper and the methods for data processing and data analysis in section three. The results of the analysis are presented in section four. The final section five discusses the results and gives an outlook for further research.

2. Literature Review

2.1 Non-reporting effects in travel estimates

Hubert et al. (2008) found the number of immobile persons (persons who stay at home on the reporting day) reported in HTS to be twice as high as that reported in TUS for the three countries UK, France and Belgium. The authors assume that the level of soft refusal in HTS diaries accounts for this difference when respondents deliberately do not report any trip in order to reduce their response burden. Madre et al. (2007) compare the share of immobile persons in different HTS. They find greatly varying shares between otherwise similar survey types with soft-refusal given as an important reason for these differences. The quality of the field work and the survey protocol are identified as main determinants of soft-refusal besides the survey method. These findings are supported by Gerike et al. (2013) who find similar immobility rates for the German TUS and HTS and conclude that high quality TUS and HTS yield similar immobility rates and that the differences found e.g. in Hubert et al. (2008) might result from field work quality in addition to the methodological differences between TUS and HTS.

The findings in all comparisons of i. to iv. (as classified in section 1) show consistent underreporting effects in HTS for the number of trips (Armoogum et al. 2014, Brög and Meyburg 1980, Gerike et al. 2015, Rasouli and Timmermanns 2014). Mainly short and irregular trips are underreported in HTS resulting in higher differences in trip rates for discretionary ('leisure') trips compared to subsistence ('work', 'education') and non-discretionary (e.g. 'shopping', 'errands') trips (Bose and Sharp 2005, Gerike et al. 2015, Richardson 2007). The TUS format results in more odd number of trips per person and day (Gerike et al. 2015, Hubert et al. 2008, Stopher 1992). The reason for this effect might be that the travel diaries perform better in supporting respondents to remember and reports trips to the destination and back home compared to TUS diaries. No studies have been found that analyse the influence of duration of the subsequent non-travel activity on trip-underreporting. Gerike et al. (2015) analysed differences in the start time of the first trip and the last trip as one possible further indicator for soft refusal when e.g. last trips on a diary day are systematically underreported in order to reduce response burden. Based on a comparison of the German TUS and HTS, the authors find no significant differences in the start time of the first trip in contrast to the start time of the last trip which was significantly later in TUS compared to HTS. Daily travel times and distances are more consistent in the literature across survey methods; underreporting seems to be mainly an issue of trip rates (Armoogum et al. 2014, Hubert et al. 2008, Schüssler 2010).

Primerano et al. (2008, see also Ho and Mulley, 2013) give an overview of definitions for trip chains (in this paper referred to as tours) as sequences of trips that are linked to each other. The literature reports several variables that impact people's propensity to chain trips, including social circumstances, the spatial environment, and the transport system (Scheiner 2014). No consistent findings exist for the relation between trip chaining and mode choice (De Witte et al. 2013). Typical tours consist of one main activity such as work and additional short activities such as shopping, errands, accompanying or leisure on the way to the main activity or back home (Primerano et al. 2008). We found no literature about comparisons of the number of tours per person and day and their characteristics between different survey types.

2.2 Speed-of-response analysis of travel estimates

The speed-of-response analysis (Brög and Meyburg 1981, Brög 2009) of travel estimates focuses on trip rates as fundamental indicator of travel behaviour. The correct number of trips per person is the core basis for any subsequent analysis of travel behaviour. Speed-of-response studies for HTS mainly find less trips for late respondents compared to early respondents (Richardson 2003). The following reasons for the lower trip rates of late respondents are discussed in the literature (Wermuth 1985, Richardson 2003):

a. Different socio-demographic groups: Early and late respondents might belong to different socio-demographic groups with different travel patterns. Respondents with no or few trips might think that their response is of less value and answer late. Respondents with many trips on the other hand might be less likely to spend their time filling out questionnaires. They might also answer late even though they are interested in the topic of travel.

b. Different travel patterns: Early and late respondents might belong to the same socio-demographic groups but might have different travel patterns, e.g. when the late respondents travel less.

c. Self-selection of diary day: In travel surveys, a specific reporting date is assigned to each respondent. A new reporting date is assigned when the original reporting day has elapsed. People might select a diary day with no or few trips in order to minimize their response burden. In doing so, they can answer truthfully without any non-reporting but still they report too few trips.

d. Item-non-response: Participants might leave out selected trips in their diary because the task of filling out the diary is considered being too time-consuming (intentional non-reporting) or the survey's design makes the task of answering truthfully difficult for them (unintentional non-reporting).

The speed-of-response technique has been used to analyse and correct shortcomings of survey outcomes with a low response rate (Brög and Meyburg 1980, Brög et. al 2009). Richardson (2003) applies the speed-of-response technique and finds decreasing trip rates from early to late respondents but not differences in the socio-economic characteristics of early and late respondents (effect (a) from above). The author finds only slight differences in the number of non-reported trips between early and late respondents (see Brög 2009 for similar findings) and concludes that item-non-response (effect d) from above) should not be the reason for the lower trip rates of late respondents. The author suggests the following explanations for the lower response rates of late respondents: lower actual trip rates (effect b) from above) and self-selection of the diary day (effect c) from above); a preference is expressed for the self-selection mechanism.

2.3 Non-travel activities

Gerike et al. (2015) compute the duration of non-travel activities from both HTS (only for persons with at least two trips on the diary day) and TUS. The type of activity in the HTS between trips is deducted from the trip purpose. Only activities carried out between the end of the first trip of the day and the start of the last trip of the day are included in the analysis for both surveys. The results show a good correspondence between the two surveys for subsistence activities. 35 % of the time between the first and the last trip of the day in TUS are spent on 'work' activities and 10 % on 'education' (HTS 36 %, 9 %). The percentage of time spent on 'shopping' activities is similar in both datasets (5 %). Differences in the other non-discretionary activity types mainly result from two effects: Firstly, coding schemes differ between the two datasets. There are no trip purposes describing 'care for others', 'voluntary' or 'personal care for oneself' in HTS, and there are no activities of the type 'accompanying' in TUS. Secondly, the 'home' activity in HTS that follows each trip back home cannot be clearly assigned to any of the activity types. The share of 'leisure' activities in TUS (24 %) is significantly higher than in HTS (20 %) in the time between the first and the last trip. These findings show that we can reliably infer from HTS on subsistence activities, but only for respondents with more than two trips per day and only for the time between the first and the last trip.

2.4 Summary of the literature review and research gaps

Corresponding to the three goals defined above for this paper, we derive the following research gaps from the literature review:

- Goal 1, identification of non-reporting effects in the travel estimates of HTS: There is a need to further analyse non-reporting effects in HTS, in particular to better understand the effects of the temporal distribution of trips and of subsequent activities on non-reporting effects in HTS. In addition, non-reporting analysis on tour level is required for a better understanding of the non-reporting effects identified so far in the literature.
- Goal 2, analysis of speed-of-response effects on travel estimates and goal 3, assessment of the completeness and accuracy of non-travel activities inferred from the trip purposes in the HTS: Only few studies have been carried out so far in these two fields with partially inconclusive and contradictory results.

3. Data sources and methodology

3.1 Survey description

This section describes the surveys that have been analysed for this paper. A detailed summary of both surveys' characteristics can be found in Appendix A.

Mobility Activity Expenditure Diary (MAED)

The MAED-survey was conducted in spring and autumn of 2015 as a self-administered mail-back survey with a one-week reporting period and detailed questions about all trips as well as all activities for each diary day. The questionnaire contains a travel diary part based on the NKD with an expanded 'trip purpose' section in order to retrieve detailed information about activities (see Rösel et al. 2015 for a detailed description of the diary). This 'activity section' corresponds to a simplified scheme derived from a widely used time use diary format, the HETUS (Eurostat 2004, 2009).

The addresses of survey participants were a random selection of Austrian households for 18 pre-defined strata. These were arranged by region and level of urbanisation (urban, intermediate, rural). A telephone number could be identified for around 50 % of sampled households. Only employed persons were eligible to take part in the MAED-survey as a wage rate was needed for modelling the trade-off-processes between time and money using the transport economic models described in Jara-Diaz et al. (2008).

Figure 1 gives an overview of the survey procedure. The announcement postcard was sent to all sampled households followed by a first phone call to the households with telephone number. Households without telephone number were asked to provide their contact details via return of the announcement postcard. If these households answered and provided their contact details, they received the survey material and were treated similarly to the households with a listed telephone number from then on. The first phone call to households with available phone number served two purposes: Only employed persons were selected with the help of a screening question about the employment status of all household members. They were directly asked whether the survey material could be sent to them. The material was sent to them after they had agreed to take part in the survey. After having received the survey material, respondents were called for motivation and support at least once. Respondents sent the survey material back to the survey team after completing the survey for their reported week. Comprehensive plausibility checks followed immediately, similar to the procedure in the NKD (Brög 2009, Socialdata 2009). Respondents were called back in order to correct implausibilities and to complete missing items. Each participant with complete questionnaires received an incentive of €40 (voucher) after their data had been validated and no more calls for retrieving missing data were necessary.

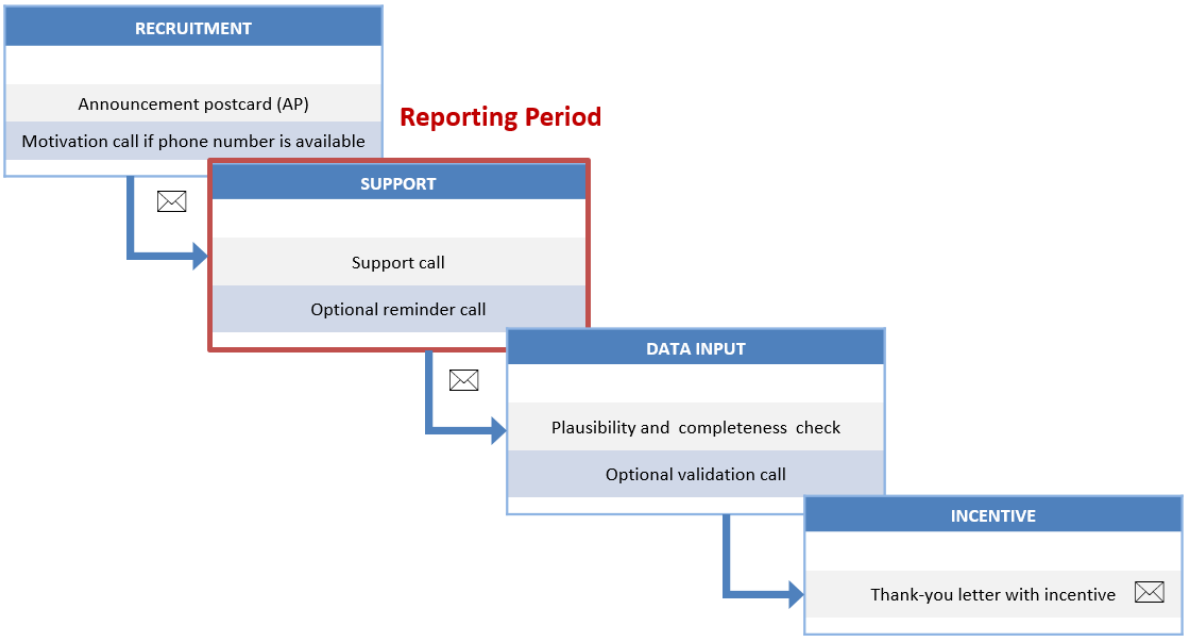

Figure 1. Survey procedure of the MAED-survey

Austrian National Travel Survey (ANTS)

The ANTS was carried out from October 2013 to November 2014 on behalf of the Austrian Ministry for Transport, Innovation and Technology. The survey method followed the guidelines of the KOMOD-Handbook (Fellendorf et al. 2011) with three options for participation (PAPI, CATI, CAWI). The survey material was based on the New KONTIV-design (Socialdata 2009) with the major modification of two consecutive reporting days. Contrary to the MAED-survey, households of the ANTS received the questionnaire unsolicitedly shortly after the announcement postcard, followed by motivational telephone calls. Up to four reminder postcards including new reporting dates were sent to the households who had not responded yet. Postal household addresses were sampled from the Austrian civil register and telephone numbers were added similarly to the MAED-survey.

3.2 Data processing

Appendix A gives an overview about key characteristics of the MAED-survey and the ANTS (original and matched sample). For data processing, respondents from the ANTS were selected for further analysis as follows in order to ensure comparability with the MAED-survey: Firstly, only employed persons who had their reporting days from April to June or from October to December (field work-periods of the MAED-survey) and only with their first reporting day were selected. Secondly, both datasets were matched at the level of person reporting days in order to take advantage of the weekly diary of the MAED-survey. For each person reporting day in the MAED data we selected one person in the filtered ANTS which exactly matched the following categorical variables: level of urbanisation, type of weekday, gender, age, education, availability of a car and of a public transport season ticket. We purposefully included PAPI, CAWI and CATI respondents from the ANTS into the matching procedure in order to acknowledge the final goal of this paper: the better understanding of non-reporting effects in established mixed-method HTS. The sample description and key travel estimates for the ANTS by survey method (separately for PAPI, CAWI and CATI) as listed in Appendix B show the differences between the survey methods within the ANTS.

We define immobile persons as those who did not report a single trip for their reporting day. Trip data in both surveys was curtailed by setting a boundary for trip distance to 100 kilometres. Trips that continued over midnight were included in the dataset with the end time set to midnight.

Response variables (also called field work variables) were computed for both surveys as the basis for the speed-of-response analyses. Two types of variables were computed:

i. five variables which describe the household's response duration in different phases of each survey and

ii. three variables describing frequencies of attempted telephone calls

For creating response variables equally applicable to both survey designs, the ANTS response data was additionally filtered for households that took part via PAPI-method (75 % of all households) in the survey. Figure 2 gives an overview of the variables describing the household's response (see Appendix C for a detailed summary of all variables).

The methods used for computing the type and duration of non-travel activities in the ANTS and in the MAED-survey are described in Appendix D. An activity coding scheme was developed that translated activity types from the MAED-survey and trip purposes from the ANTS into a common activity types. A list of the original activity types is provided in Appendix E

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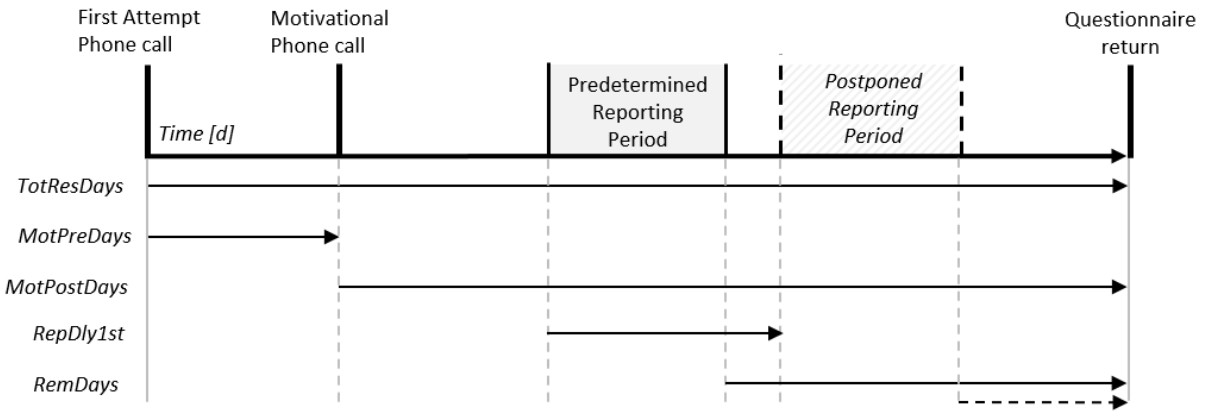


Figure 2. Response variables describing response durations in different phases of both surveys.

3.3 Sample description

Table 1 gives an overview of the matched sample's characteristics. Data from the Austrian National census as collected by Statistik Austria (*'Registerzählung 2011'*) is listed in addition to the matched MAED/ANTS-sample in order to compare socio-demographic characteristics of the matched sample used for this paper with those of the overall Austrian population of employed persons, according to the ILO-definition (ILO 1993). For comparing sample characteristics at household level, the Statistik Austria sample was reduced to households with an employed reference person[6]. The original weighted and filtered ANTS sample is included in Table 1 in order to identify possible differences to the matched MAED/ANTS-sample respectively to Statistik Austria.

The matched MAED and ANTS samples correspond very well by definition as most of the variables listed in Table 1 have been used for matching in the data processing step. Compared to

[6] The household's reference person according to Statistics Austria is defined as the oldest person of the nuclear family (for single-family households) or as the oldest person, that represents the middle generation of that family (for two- or multi-family households).

the official statistics from Statistik Austria, females are slightly overrepresented in the matched MAED/ANTS-sample. The groups of young and low-educated persons are underrepresented in the matched MAED/ANTS-sample. These are typical pattern known also from other household travel surveys (Armoogum et al. 2014) and visible also in the original weighted ANTS-data in Table 1. The MAED/ANTS-sample contains fewer single-person households and fewer households in urban areas compared to the official statistics. Lower response rates in urban areas compared to rural areas are one reason for this phenomenon. Both persons and households of the matched sample show the typical high availability of mobility tools, e.g. vehicles, season tickets or car club memberships, for employed persons. The high proportion of MAED/ANTS-participants from rural areas also causes the higher rate of car ownership.

Table 1. Sample characteristics of matched MAED and ANTS data, filtered ANTS data and Austrian National Census

	MAED 2015 matched	ANTS 2013/14 matched	ANTS 2013/14 filtered, weighted	Stat. Austria 2011
n households	485	3,741	5,829	-
n persons	738	4,830	9,436	-
n person reporting days	4,830	4,830	9,436	-
Gender*				
Male	49.4	49.4	53.1	53.3
Female	50.6	50.6	46.9	46.7
Age*				
15-19	1.9	0.5	0.7	5.0
20-29	6.5	8.7	13.6	19.5
30-39	19.0	18.6	19.1	22.6
40-49	37.0	34.9	31.3	29.1
50-59	31.4	33.6	31.8	20.0
60+	4.2	3.8	3.5	3.8
Highest level of education*				
Compulsory school	2.5	3.9	4.8	17.8
Apprenticeship, college	37.6	36.2	48.2	50.9
Matura	24.2	26.5	20.5	15.9
University, FH	35.6	33.5	25.9	15.4
Household size				
1 person	9.0	7.9	12.5	30.2
2 persons	28.1	29.1	30.0	23.1
3 persons	22.5	23.9	24.4	19.0
4 or more persons	40.4	39.1	33.1	27.7
Level of Urbanisation [7]*				
Urban	21.9	21.9	23.8	33.5
Intermediate	27.9	32.0	28.6	29.9
Thin	50.1	46.1	47.6	36.7
Personal mobility tools available */**				
Car	94.3	94.3	94.9	76
Public Transport pass (Season ticket, zone ticket	31.8	31.8	25.2	22***
Household's availability of vehicles **				
Bicycle	89.9	89.2	91.5	71
E-Bicycle	6.7	4.5	6.7	
Moped/Motorbike	23.7	25.5	25.2	
Car	95.5	93.9	95.4	89

* matching variable, ** not collected by Statistik Austria, but by the Austrian Ministry for Transport, Innovation and Technology, *** season tickets only

3.4 Analysis methods

Figure 3 shows the analytical framework used for this paper. The overall aim of this paper is to analyse non-reporting effects in HTS. These effects are distinguished into direct and indirect effects. Direct effects are analysed by comparing results in travel estimates in both surveys. Indirect effects consider the speed-of-response as mediating variable based on the hypothesis that the survey design influences the response duration of participants and that this survey duration

[7] Definition for the MAED-survey and Statistik Austria: According to the Degree of Urbanisation (DEGURBA) - classification by the European commission (Eurostat 2011); Definition for the ANTS: According to the Austrian Conference on Spatial Planning's (ÖROK) spatial types (ÖROK 2007). Both definitions are comparable for Austria.

in turn is related to the travel estimates. We analyse the differences between the travel estimates and activities in both surveys using descriptive statistics and t-tests.

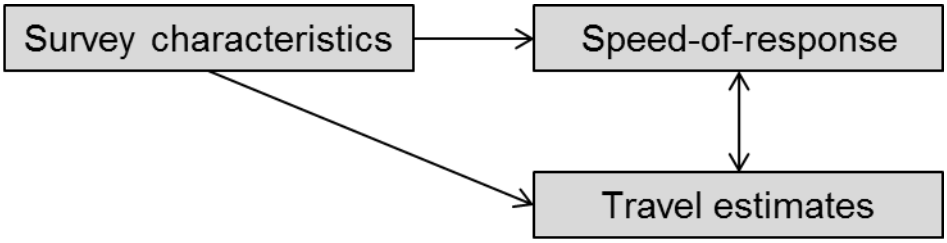


Figure 3. Analysis framework

The response variables described in section 3.2 and Appendix C are used for investigating the indirect effects. The variable "TotResDays" is used for analysing the overall differences in trip rates between early and late respondents as in Brög et al. (2009) and Richardson (2003). The overall effect of different trip rates as a function of the speed-of-response is decomposed into its several components as described in the literature (see section 2.2): Differences in the socio-demographic characteristics of early and late respondents are analysed in order to test reason a) (different socio-demographic groups). The variable "RepDly1st" is used to test reason c) (self-selection of travel day). Reason d) (item-non-response) is tested similarly to the estimation of the direct effects but looks now at differences in travel estimates for early and late respondents of each survey. Reason b) (different travel pattern) is discussed indirectly based on the insights gained on the reasons a), c), d). The role of a possible fatigue-effect in participants of the MAED-survey is analysed by means of a linear model with regard to the reporting day and the according type of weekday (Working day, Saturday, Sunday).

4. Results

4.1 Overview of standard travel estimates

Table 2 gives an overview of the core travel estimates of both surveys. The overall proportion of mobile persons is significantly higher in the MAED-survey with 91.8 % compared to ANTS with 89.0 %. The likely reason for this difference is soft refusal in the ANTS.

The overall number of tours per day does not differ significantly. 64.7 % of the person days have one tour in the MAED-survey (60.2 % in ANTS), 27.6 % have two tours in the MAED-survey (30.5 % in ANTS) and 7.7 % have more than two tours (9.3 % in ANTS). The trip rate is with 3.81 trips per person day significantly higher in the MAED-survey compared to ANTS (3.59). The trip rates in the MAED-data follow the typical pattern described in the literature (see e.g. Armoogum et al. 2014).

The average trip distance of 13.9 km is higher in the ANTS compared to the MAED-survey with 11.1 km, and also the average total daily distance travelled of 49.9 km is higher in the ANTS (MAED: 42.3 km). The duration of single trips and the daily travel time values follow the same pattern. Consequentially, the higher number of trips per person reporting day in the MAED-survey does not compensate for the survey's lower distance and duration per trip. The difference in average trip distance is even larger when analysing working days only (MAED: 10.4 km, ANTS 14.0 km), which is mainly due to the large difference in trip distances of commuting trips for respondents in intermediate communities (MAED: 12.3 km, ANTS 20.1 km). Differences in commuting distances in urban areas (MAED: 8.0 km, ANTS 10.2 km) and rural areas (MAED: 16.8 km, ANTS 21.1 km) are not as large. The higher share of persons in intermediate communities in the ANTS generates longer average trip distances over all area types and trip purposes even though differences for trip purposes other than commuting are not substantial.

The higher trip rates in the MAED-survey confirm the initial hypothesis that the MAED-survey succeeded in motivating participants to report their trips more completely. The lower trip distance and trip duration in the MAED-survey can be attributed to two effects: (i) differences in commuting distances as described above and (ii) underreporting of short trips in the ANTS resulting in a lower trip rate on the one hand and a higher average trip distance / duration on the other hand.

The modal split values of the MAED-data and the ANTS show typical distribution for samples of employed persons and correspond well even though the differences are found to be significant. This level of significance can be attributed to the large sample size for the trips.

Socio-demographic characteristics and key travel estimates are listed separately for the original, filtered (in case of ANTS) and matched datasets in Appendix F in order to provide detailed information about the influence of filtering and matching on these variables.

The general pattern of underreporting found so far is analysed in more detail in the following sections. Direct effects are analysed in section 4.2 (travel estimates) and section 4.4 (activities). Section 4.3 is dedicated to the indirect effects of the speed-of-response as introduced in section 3.4.

Table 2. Travel estimates for MAED and ANTS (matched sample)

	MAED 2015	**ANTS 2013/2014**	χ^2	p-value
n person reporting days	4,830	4,830		
n mobile person reporting days	4,434	4,298		
n trips	16,910	15,431		
Share of mobile persons				
Overall	**0.92**	**0.89**	22.40	< 0.001
Working day	0.97	0.93	80.2	< 0.001
Saturday	0.88	0.86	1.45	0.228
Sunday*	0.71	0.76	4.75	0.029
Number of trips per mobile person				
Overall	**3.81**	**3.59**	5.52	< 0.001
Working day	3.99	3.67	6.62	< 0.001
Saturday	3.74	3.63	1.07	0.287
Sunday*	2.84	3.12	-3.18	0.002
Number of tours per mobile person				
Overall	**1.47**	**1.44**	1.93	0.053
Working day	1.48	1.44	2.30	0.021
Saturday	1.56	1.53	0.62	0.536
Sunday*	1.34	1.38	-1.16	0.247
Distance of trips [km]				
Per trip	11.1	13.9	-13.32	< 0.001
Per day	42.3	49.9	-7.13	< 0.001
Duration of trips [min]				
Per trip	23.8	26.8	-8.18	< 0.001
Per day	90.8	96.3	-3.24	0.001
Mode choice				
Public Transport	9.3	11.5	42.40	< 0.001
Car	72.2	68.7	46.80	< 0.001
Bicycle	5.7	6.5	7.44	0.006
Walk	12.8	13.3	2.06	0.151

* including holidays and public holidays

4.2 Detailed analysis of item-non-response for tours and trips

Tours

The above analysis shows that the overall number of tours per day does not differ significantly between the MAED-survey and the ANTS. The proportion of tours with only one trip (e. g. strolling or walking the dog) is almost the same in both surveys (MAED-survey: 7.4 %, ANTS: 6.8 %). On the contrary, there are differences in the number of tours with two (56.5 % in MAED, 64.6 % in ANTS) or three trips (19.3 % in MAED, 14.2 % in ANTS). These might be an indication for item-non-response in the ANTS when e. g. short in-between trips on the way back home are not reported. The temporal distribution of tours might be another indication for soft refusal when e.g. late tours are underreported. The number of tours starting in the hours of the morning-peak (6 a.m. to 8 a.m.) and afternoon-peak (3 p.m. to 6 p.m.) is slightly higher in the MAED-survey

compared to the ANTS, and lower for the off-peak periods, but the differences are not significant. Soft refusal seems therefore not to be an issue for tours. Also late tours of the reporting day seem to be well-reported in both surveys.

Trip characteristics

The average number of trips per reporting day differs significantly between the MAED-survey (3.81 trips per day) and the ANTS (3.59 trips per day). The share of persons with two (30.3 % in MAED, 36.4 % in ANTS) and three trips (17.4 % in MAED, 12.7 % in ANTS) on their reporting day is significantly different in both surveys. The proportion of persons with four or more trips is almost the same in both surveys. The significantly lower trip rates in the ANTS show that the higher proportion of persons with two trips on their reporting day in the ANTS and with three trips in the MAED-survey results from missing trips within tours in the ANTS, rather than from missing trips back home in the MAED-survey as assumed e. g. by Hubert et al. (2008).

Similarly to the tours, the proportion of trips beginning in the peak-hours in the MAED-survey is higher compared to the ANTS. However, unlike for tours the difference for trips is significant.

The overall high number of trips in peak-hours is a direct result of the requirement for respondents in the matched sample to be employed. Underreporting in ANTS is highest in the afternoon-peak when people travel back home and do not report their trips on the way back from their main activity. The number of trips in the MAED-survey is 12.6 % higher compared to the ANTS in the afternoon-peak from 3 p.m. to 6 p.m. (7.9 % in the morning-peak from 6 a.m. to 8 a.m. and 3.4 % in off-peak hours). We analyse these underreporting-effects further in the following graphs for different trip characteristics.

Figure 4 presents the distribution of trips per trip distance from both surveys. The number of trips per person below or equal to 20 km distance is significantly higher in the MAED-survey (3.25) compared to the ANTS (2.90) in this distance class. No significant differences exist for the middle distance classes. The number of trips per person above 50 km is significantly lower in the MAED-survey (0.15) compared to the ANTS (0.22). This difference results from longer commuting trips in the ANTS as discussed above. Short trips are strongly underreported in the ANTS in the afternoon-peak, whereas underreported trips in the morning-peak have medium distances. A possible explanation for this effect might be that activities with short durations take place following these trips as shown in Figure 5. Trips with a subsequent activity of ten minutes or less in the morning-peak are strongly underreported in the ANTS (18.0 % less than in the MAED-survey). Figure 4 and Figure 5 together show that trips in the ANTS are substantially underreported if either the trip itself has a short distance or the activity subsequent to the trip has a short duration (see Stopher et al. 2007 for similar findings). The distribution of trips per trip duration shows similar pattern as described above for the trip distances.

Figure 6 shows that mainly car trips (including also motorbikes) are underreported in the ANTS. The high absolute difference of 0.29 car trips per person day results from the high modal share of car trips in both surveys (see Table 2) but also the relative difference is highest for car trips: Respondents in the MAED-survey have on average 7.5 % more car trips compared to ANTS. Differences in the trip rates are not significant for any of the other modes.

Figure 7 shows the number of trips per person and trip purpose. The number of trips per person with the purpose 'back home' is significantly higher in the MAED (1.43) compared to ANTS (1.33). Two effects interact here: The overall trip rate is higher and tours are longer in MAED compared to the ANTS. Longer tours with more trips per tour reduce the number of trips back home but this effect is more than compensated by the overall higher number of trips per person in the MAED-survey. The number of 'shopping' trips per person show the biggest difference, with 0.49 in the MAED-survey compared to 0.28 in the ANTS. This trip purpose is heavily affected by underreporting in the ANTS throughout the day, especially in the afternoon-peak.

Differences between the two surveys in the number of trips with the purpose 'errands' might be an artefact and disappear when the purposes 'errands' and 'other' are grouped together.

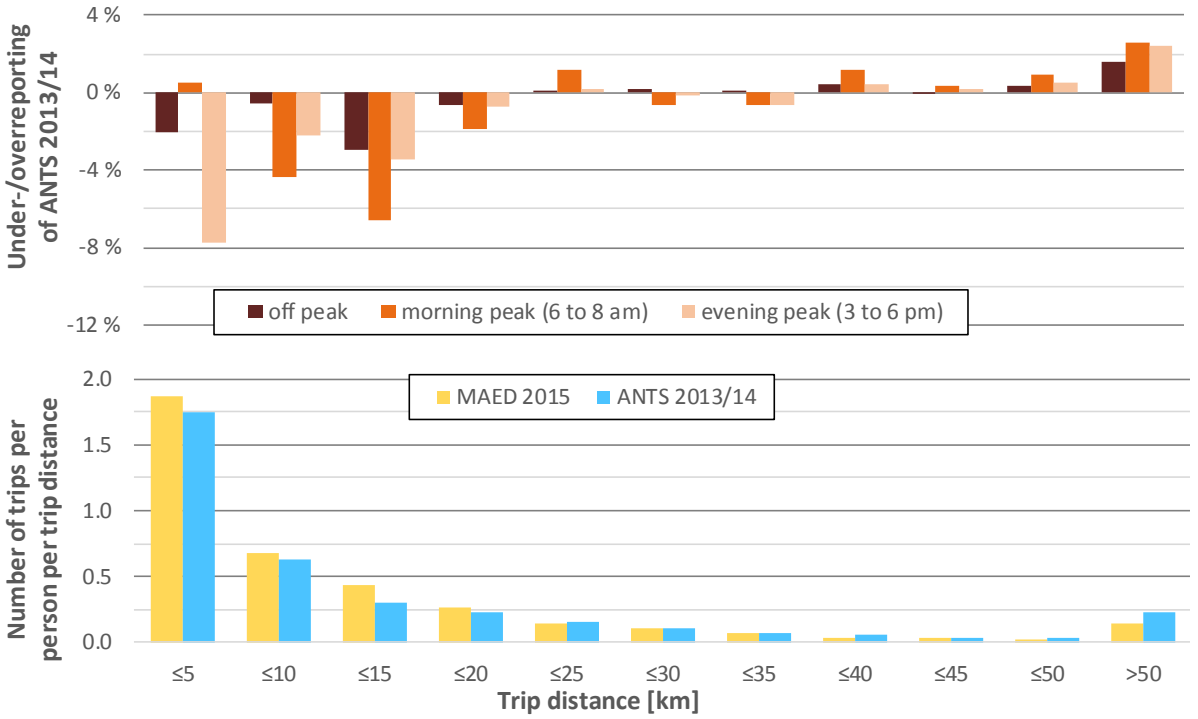


Figure 4. Distribution of trip distances of all trips per person per day (below) and respective under-/overreporting of ANTS 2013/14 (above).

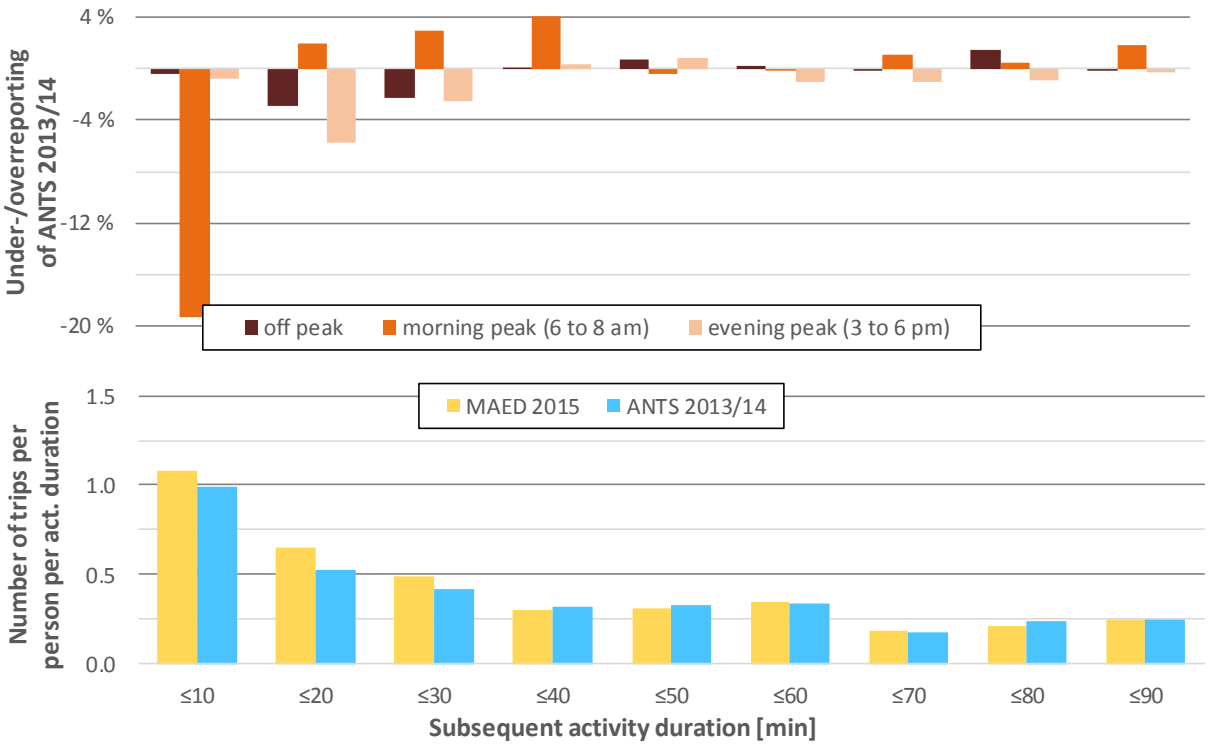


Figure 5. Distribution of trips with regard to their subsequent activity duration (up to 90 minutes; below), and respective under-/overreporting of ANTS 2013/14 (above). Only persons with at least two trips are included.

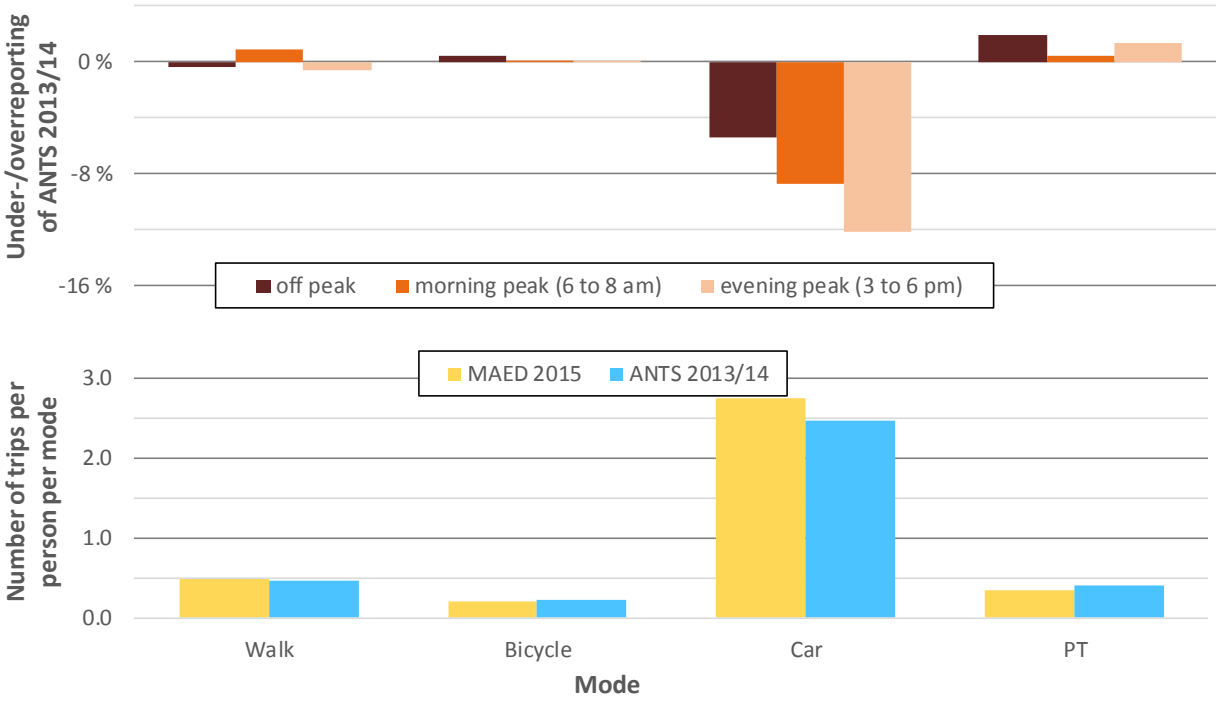


Figure 6. Distribution of modes of all trips per person per day (below) and respective under-/overreporting of ANTS 2013/14 (above).

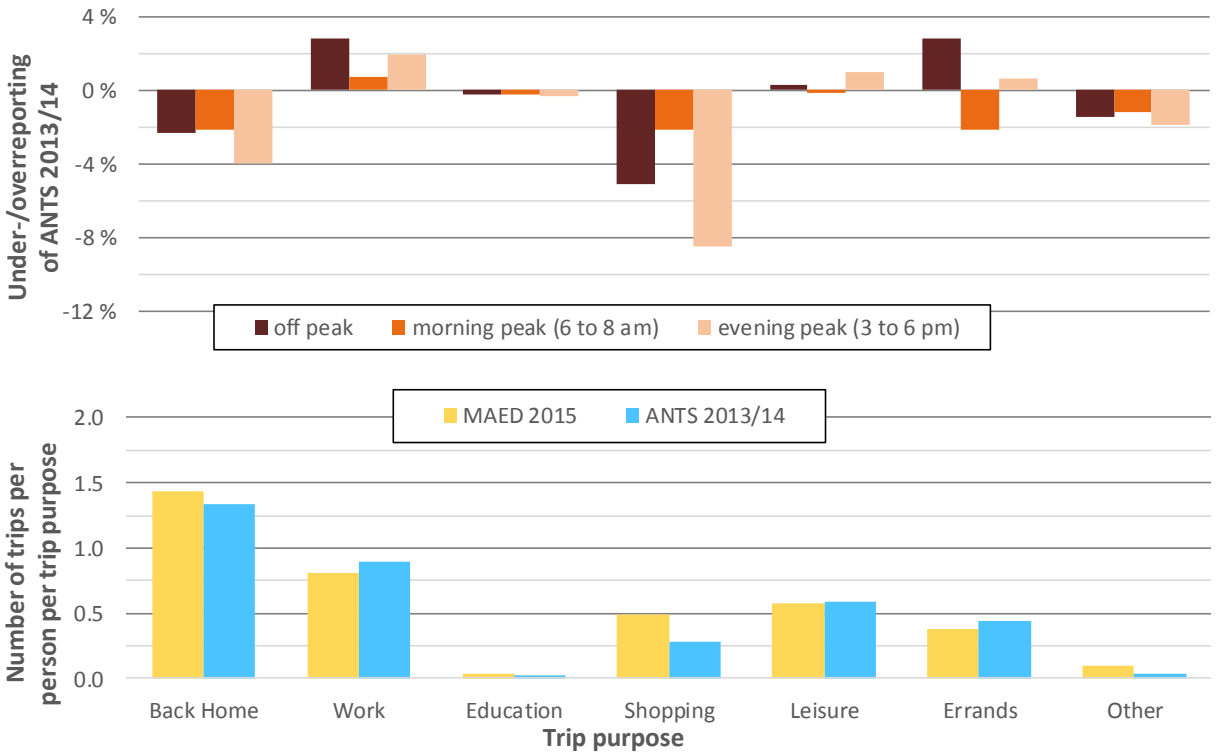


Figure 7. Distribution of trip purposes of all trips per person per day (below) and respective under-/overreporting of ANTS 2013/14 (above).

4.3 Speed-of-response analysis

Correlations between the field work variables were tested in order to investigate the indirect effects of the survey methods on the speed-of-response and the trip rate (see Table 3). A significant correlation was found between the overall response time ("TotResDays") and the trip rate for the ANTS but not for the MAED. Different from "TotResDays", the variable "MotPostDays" excludes the time needed until the motivational phone call. It is significant for the MAED but not for the ANTS. This shows that the effect of a decreasing trip rate with an increasing response time exists in both surveys but the effect size is very low and in the MAED-survey hardly significant as visualised in Figure 8. This figure shows the trip rate and the share of mobile persons for each decile of respondents in the order of their speed of response. Almost no difference between the deciles exist for the share of mobile persons. The difference for the trip rates is very small though significant for the ANTS. We applied a linear model for the ANTS to estimate trip rates for different total response time, measured by the variable "TotResDays". The estimated trip rate would increase from 3.59 to 3.63 trips per day if all respondents answered within 15 days at the latest.

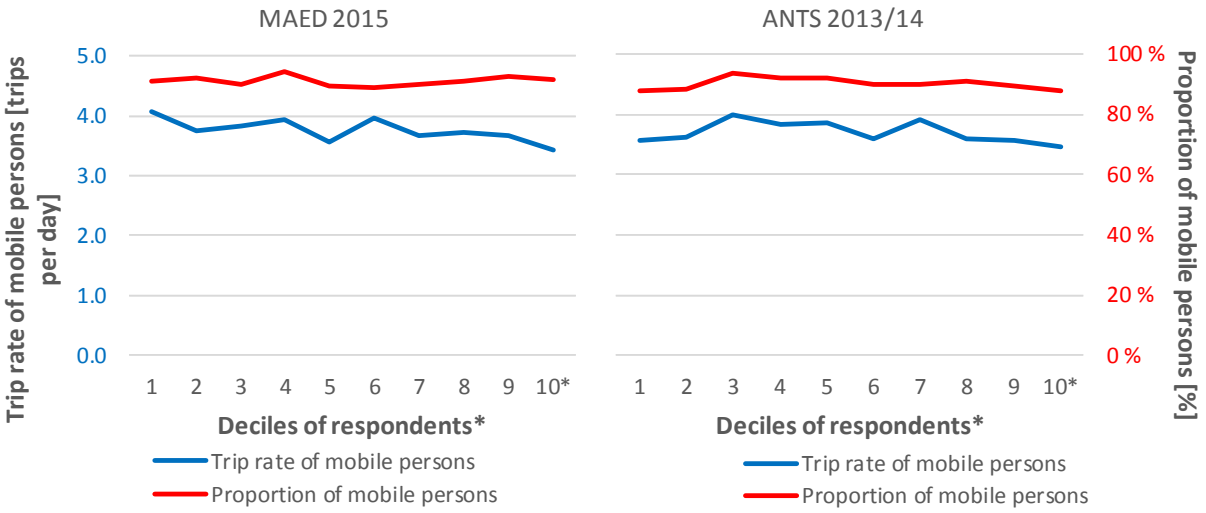
The variable "RemDays" as the number of days from day after last reporting day to the arrival of the questionnaire is significant for the MAED-survey, but effect size is again very low. This effect may not be a response effect strictly speaking, but rather it might be related to the survey incentive of € 40 when conscientious people fill out the questionnaires more accurately (and thus report more trips) and send their questionnaire back quicker compared to respondents who care less about the incentive. The linear model applied to estimate trip frequency if all respondents sent back their questionnaire within five days at the latest shows that the survey's overall trip rate of mobile persons would go up from 3.81 to 3.89 trips per day.

No significant correlations are found between trip rates and the frequencies of attempted phone calls ("TotCallAttFrq", "TotCallDays", "TotCallFrq") nor the duration from the first phone call attempt to the actual first contact in either of the surveys ("MotPreDays"). There is no correlation between the trip rate and the efforts to reach the respondent on the phone for the first time. We also found no significant correlations when analysing the impact of response effects by field variables on the share of mobile persons for both surveys (see Appendix G).

Table 3. Impact of response effect on trip rate

	MAED 2015				**ANTS 2013/2014**			
	ρ	*p-value*	$\bar{x}$	*SD*	*ρ*	*p-value*	$\bar{x}$	*SD*
TotResDays	-0.075	0.101	27.44	13.04	-0.073*	0.002	13.39	10.82
MotPreDays	-0.023	0.621	4.45	6.63	-0.015	0.623	4.66	3.65
MotPostDays	-0.096*	0.033	20.76	8.96	-0.050	0.108	8.10	8.33
RepDly1st	-0.018	0.689	2.23	5.15	-0.088**	0.000	0.96	3.98
RemDays	-0.116*	0.011	6.91	6.25	-0.039	0.100	9.08	8.54
TotCallAttFrq	-0.049	0.283	5.87	4.68	-0.023	0.341	5.68	4.75
TotCallDays	-0.056	0.217	4.66	3.41	-0.019	0.435	4.18	2.86
TotCallFrq	0.006	0.897	2.57	1.32	-0.033	0.174	1.40	1.21

* significant at the 5 % level, ** significant at the 1 % level



* Respondents are classified into deciles depending on their speed-of-response. "1" on the x-axis stands for the 10 % fastest respondents, "10" stands for the 10 % slowest respondents etc.

Figure 8. Trip rate and proportion of mobile persons (means) as a function of the speed-of-response.

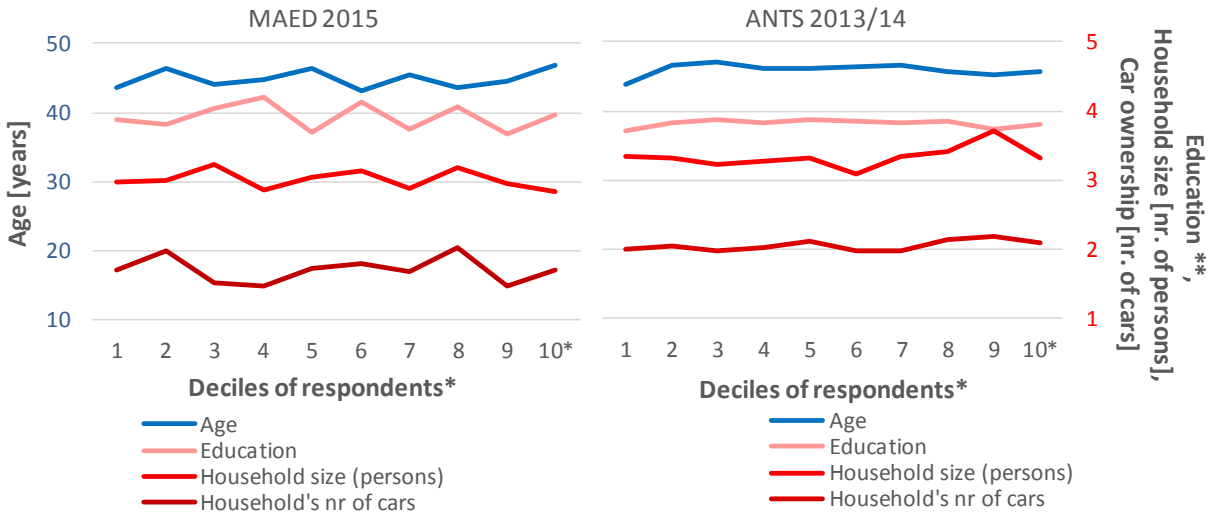
Fatigue as a possible reason for a decreasing trip rate within the MAED-participants' reporting week was not found. The linear model applied showed that the trip rate is hardly affected by the reporting day (β_o = -0.003, p = 0.85). In the following we examine possible reasons for the decreasing trip rate based on the finding from the literature review described in section 2.2:

a. Different socio-demographic groups: Figure 9 shows the socio-demographic characteristics for each decile of respondents along its speed-of-response. No significant differences were identified; socio-demographic characteristics are stable across all deciles.

c. Self-selection of travel day: The variable "RepDly1st" is used for testing the effect of self-selection. It is significant for the ANTS but not for the MAED-survey. Respondents who postpone their reporting day in the ANTS state significantly less trips compared to respondents who directly report their travel for the predetermined reporting day. The model applied to estimate the trip rate of ANTS if all respondents reported on first scheduled reporting day shows that the overall trip rate would increase from 3.59 to 3.63.

d. Item-non-response was analysed in section 4.2 without considering the speed-of-response. The analyses were repeated with the different deciles of respondents differentiated by their speed-of-response. No differences were found between the early and the late respondents who both show the underreporting effects found in section 4.2 without significant differences.

From the above analyses we conclude that differences exist neither in the socio-demographic characteristics of early and late respondents (effect a) in section 2.2) nor in their item-non-response pattern (effect d)). The reason for the overall decreasing trip rate found in variable "TotResDays" for the ANTS should therefore either be the self-selection of the travel day (effect c)) and/or different travel pattern (effect b)). The self-selection effect is significant for the ANTS and definitely contributes to the decreasing trips rates for late respondents. In addition, there might be the effect b) of different travel pattern but this needs further investigation and cannot be clearly disentangled based on the available information.



* Respondents are classified into deciles depending on their speed-of-response. "1" on the x-axis stands for the 10 % fastest respondents, "10" stands for the 10 % slowest respondents etc., ** Education scale:1=no educational degree; 5=university degree.

Figure 9. Socio-demographic characteristics (means) as a function of the speed-of-response.

4.4 Analysis of activities

Table 4 compares the activity duration per type in both surveys. The main activity type for the MAED-survey is computed as described in section 3.2 and compared with the activity types that were derived from the trip purposes in the ANTS. Only persons with at least two trips are included in Table 4 in order to have at least one activity episode other than home in the ANTS for each person included. These are 89.3 % of all respondents in the MAED-survey and 85.5 % in the ANTS. Activity durations for all persons are provided in Appendix H.

No significant differences exist for the activity types 'home' and 'work'. Daily travel time is higher in the ANTS compared to the MAED-survey as discussed above. The overall activity duration for 'education' is low for both survey but slightly higher in MAED, since the sample contains few part-time working students. Activity duration for the type 'shopping' is only slightly higher in the MAED-survey compared to the ANTS even though the number of 'shopping' trips is much higher as was shown in section 4.2. This supports the hypothesis that mainly activity episodes of short duration are underreported in the ANTS. Overall the differences in the activity types 'errands', 'shopping', 'leisure' and 'other' are difficult to interpret and might result partly from different definitions of the activity types in the two surveys. The overall activity duration for all these activity types is exactly the same for the MAED-survey and the ANTS (120 minutes).

The last column in Table 4 shows the ratio of the number of activities per detailed activity type over the number of activities per main activity type between two trips in the MAED-survey (called activity frequency thereafter). Each activity episode in the ANTS can by definition only have one type (generated based on the trip purpose of the preceding trip) whereas for the MAED-survey, information about each detailed activity episode is available throughout the reporting day. We use this detailed information to gain a better understanding of how much information is missing in HTS on activities carried out other than the main trip purpose. The analysis in Table 4 shows that the activity ratio is almost 1.00 for the activity types 'shopping' and 'errands'. This means that 'shopping'/'errands' activities are rarely mixed with activities of other types in between two trips and that the trip purposes 'shopping'/'errands' in the ANTS allow to comprehensively classify the subsequent activity episode before the next trip. Higher values for the activity frequency are found for the other activity types.

Table 4. Activity duration in the MAED-survey and the ANTS (matched sample, persons with two or more trips)

Activity category	Mean activity duration MAED [min]*	Mean activity duration ANTS [min]	*t-value*	*p-value*	**Activity ratio MAED ****
Home	925.7	926.2	-0.09	0.932	4.39
Travel	91.0	96.6	-3.27	0.001	1.00
Work	295.2	292.7	0.45	0.652	1.57
Education	7.3	4.6	2.68	0.007	1.59
Errands	14.2	24.6	-7.18	<0.001	1.07
Shopping	18.4	14.0	4.59	<0.001	1.06
Leisure	80.6	72.3	2.57	0.010	1.20
Other	6.3	9.0	-2.41	0.016	1.12

* Main activity type, ** Number of detailed activities per main activity type in MAED

Table 5 cross-tabulates the main and the detailed activity types for the MAED-survey. The columns in Table 5 list the duration for each detailed activity type that is contained in the main activity type of this row. The sum of each row corresponds to the duration for this activity type listed in Table 5. Table 5 shows that the time at home is mainly used for 'sleeping' and 'leisure', as was found in Gerike et al. (2015). The activity type 'errands' with a duration of 181.3 minutes (only at home) consists of personal care, domestic work, taking care of children, banking etc. 'Work' and 'education' activities as main activity types are partly combined with 'leisure' activities. Overall the mean number of 1.63 for the activity ratio across all activity types seems to be low but no literature was found to check the plausibility of this result.

Table 5. Activity duration per detailed and main activity type (matched sample, persons with two or more trips)

Main activity	Sleep	Travel	Work	Education	Errands	Shopping	Leisure	Other	**Mean activity duration MAED [min]****
Home	473.2		24.6	3.3	181.3	0.8	241.2	1.1	925.7
Travel		91.0							91.0
Work	0.4		285.1	0.1	0.8	0.4	8.5		295.2
Education			0.0*	6.7	0.0*	0.0*	0.5		7.3
Errands	0.0*		0.2		13.3	0.1	0.5	0.1	14.2
Shopping			0.0*		0.1	17.6	0.6		18.4
Leisure	0.4		0.5		1.0	0.4	78.2	0.0*	80.6
Other	0.0*		0.1		2.2	0.0*	1.7	2.3	6.3

* <0.05 min, ** Main activity type

5. Discussion and conclusion

This paper analyses non-reporting effects in the ANTS as an example for a standard mixed method HTS in comparison with the MAED-survey as an innovative hybrid survey design with elements from TUS and HTS. The MAED-survey is considered as "ground truth" in this comparison. The analysis addresses three main goals with the following conclusions:

- Identification of non-reporting effects in HTS for travel estimates: Standard mixed method HTS capture the number and temporal distribution of trip chains (called tours in this paper) well. Underreporting as a result of item-non-response occurs on two levels: (i) on the person level in terms of a too low rate of mobile persons, and (ii) on the level of trips. The overvalued share of immobile persons in HTS may be considered by calculating travel estimates only for mobile persons; it might be corrected by increasing the share of mobile persons by approximately 3.5 %. A better option would however be to call immobile persons back during validation and ask them insistently if they had any trips on the diary day. The trip estimates for mobile persons in HTS need to be corrected with special attention to short trips (< 5 km) in the afternoon-peak and medium-distance trips (5 − 20 km) in the morning-peak when these are followed by short non-travel activity episodes (< 10 minutes). The transport mode of the non-reported trips is determined by the transport mode chosen for the whole tour. The main reason for the higher number of persons with odd number of trips in the MAED-survey was found to be the underreporting of trips within tours of three or more trips in the ANTS, especially in the afternoon-peak. Differences in the length of tours in the MAED-survey and the ANTS are higher on working days compared to Saturdays, because short shopping or errand trips in combination with e. g. work trips are mainly carried out on working days, whereas Saturdays have the highest number of tours but a small number of trips per tour. Plausibility checks and data processing for HTS should therefore not only be done on the trip level but also on the tour level.
- Analysis of speed-of-response effects on travel estimates: These play only a minor role for the aforementioned non-reporting effects. The MAED-survey shows no significant relationship between the trip rate and the overall response time. There was no evidence found for self-selection in the MAED-survey. For the ANTS we found a decreasing effect of the response time on the trip rate similar to most other studies. The effect size is very low but highly significant. No differences in the socio-demographic characteristics of early and late respondents and their item-non-response were found, so that self-selection of a reporting day or actual different travel patterns remain as possible reasons for the overall decreasing trip rates of late respondents in the ANTS. Given that the speed-of-response effect on the trip rate is small and dependent on the survey procedure, the question must be raised whether the decreasing trend should be extrapolated to a 100 % response rate or whether the speed-of-response should be assumed to have no effect on the trip rate. This question can only be answered by non-response studies as done e.g. by Richardson (2003). From our findings we conclude that the analysis of HTS data can be done without considering speed-of-response effects.
- Assessment of the completeness and accuracy of non-travel activities inferred from the trip purposes in the HTS: Home-based activities account for 64 % of the total time but are not specified by their type in HTS. From the MAED-survey we know that the main activity types that people perform at home are 'sleeping', 'personal care', 'domestic work' and 'leisure'. This is a mixture of mandatory and freely chosen activities that need to be distinguished in most analyses. If we consider only persons with at least two trips on their reporting day, we find a good correspondence of activity durations in the MAED survey and the ANTS. Despite some minor deviations that should be analysed further, we conclude that we can reliably infer from HTS-data not only travel estimates but also main activities.

Overall, the MAED-survey proved effective as a basis for analysing non-reporting effects in HTS. The MAED-survey is, however, far too costly for being a prototype for future HTS. Standard HTS do not need to collect data on all non-travel activities nor on expenditures. They can and should keep their scope; they need to focus on trips and their determinants but more sophisticated

validation methods such as the ones applied in the MAED-survey can help improving data quality for HTS and could probably increase the overall efficiency of the HTS. The insights gained from this paper can be used to advance methods for data processing of HTS in terms of correcting the share of mobile persons and in terms of trip imputation. Corrections are necessary on the trip level, whereas trip-chains (tours) should be used as a means for imputing trips correctly into the respondents' overall daily schedule. The developed method for analysing the different aspects of the speed-of-response effect proved effective. We were able to disentangle the different aspects and to identify the reasons behind the overall decreasing trip rates of late respondents in the ANTS. Future studies could extend the speed-of-response analysis by applying this method to other person groups beyond employed persons, which were analysed in this paper. The analysis of non-travel activities showed that HTS can be used to gain reliable data for activity-based models e. g. for generating daily schedules, however, with the limitation that no information is available for home-based activities. A detailed analysis of trips that were initially not reported in the questionnaire but stated in the validation phone call could provide further insights about item-non-response in general and as a function of the speed-of-response. Further findings on non-reporting effects can be expected from comparing the HTS with innovative survey methods such as GPS-based travel surveys.

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Appendix

Appendix A. Survey descriptions of MAED 2015 and ANTS 2013/2014 (original and matched sub sample used for this paper)

Survey	**MAED 2015**	**ANTS 2013/2014**	**MAED 2015**	**ANTS 2013/2014**
Dataset	**Original**	**Original**	**Matched sub-sample in this paper**	
Survey method	PAPI (postal)	PAPI (postal), CAWI, CATI	As Original	
Survey design	trip-based section (KONTIV) activity based section (HETUS) consumer expenditure section	KONTIV	As Original	
Questionnaires	Household Person Trip-Activity Diary Expenditures	Household Person Trip Diary	As Original	
Incentives	EUR 40 (voucher)	-	As Original	
Spatial information	Geocoded addresses	Geocoded addresses	As Original	
Survey Area	Austria Six target areas, each with rural, intermediate and urban communities	Austria All communities	As Original	
Response Rate	11.9 %	26.2 %		
			Applied filter in data processing for comparability	
Target population	Employed persons based on ILO definition (ILO 1993)	Household members > 6 years	As Original	Employed persons
Survey Period	04-06/2015, 09-12/2015	10/2013 – 11/2014	As Original	12/2013, 04-06/2014, 09-11/2014
Reporting Date	Seven consecutive days	Two consecutive days	As Original	First of the two reporting days (fatigue effect)
			Matching criteria	
			level of urbanisation, type of weekday, gender, age, education, availability of car and public transport season ticket	
Sample size	748 persons of 490 households	38,220 persons of 17,070 households	738 persons of 485 households	4,830 persons of 3,741 households
Data size	5,236 reporting days 18,203 trips	76,440 reporting days 196,604 trips	4,830 reporting days 16,910 trips	4,830 reporting days 15,431 trips

* only PAPI with available telephone number for the speed-of-response analysis

Appendix B. Sample characteristics and key travel estimates for the ANTS by survey participation method

		ANTS 2013/14 original, weighted							
Participation method		**all**		**CAWI**		**PAPI**		**CATI**	
n households	[% households]	5,829	[100]	1,125	[19]	4,279	[73]	425	[7]
n persons	[% persons]	9,436	[100]	1,700	[18]	7,134	[76]	602	[6]
n trips	[% trips]	29,622	[100]	4,664	[16]	23,279	[79]	1,679	[6]
Gender									
Male		53.1		55.8		52.5		52.2	
Female		46.9		44.2		47.5		47.8	
Age									
6-34		23.1		26.9		22.6		17.9	
35-54		60.6		61.2		60.3		63.3	
55+		16.3		11.9		17.1		18.8	
Highest level of education									
Not specified		0.6		2.9		0.0		1.2	
Compulsory school		4.8		4.3		4.8		6.3	
Apprenticeship, college		48.2		37.7		50.7		48.1	
Matura		20.5		23.2		20.0		18.8	
University, FH		25.9		31.8		24.5		25.5	
Household size									
1 person		12.5		20.6		10.3		13.6	
2 persons		30.0		29.2		30.2		30.1	
3 persons		24.4		20.6		25.4		24.2	
4 or more persons		33.1		29.5		34.2		32.0	
Level of Urbanisation									
Urban		23.8		29.4		22.9		17.9	
Intermediate		28.6		30.5		28.2		28.0	
Thin		47.6		40.1		48.9		54.1	
Share of mobile persons									
Overall*		**0.88**		**0.84**		**0.90**		**0.87**	
Working day		0.92		0.88		0.93		0.93	
Saturday		0.84		0.81		0.86		0.78	
Sunday**		0.74		0.67		0.76		0.71	
Number of trips per mobile person									
Overall*		**3.36**		**2.99**		**3.47**		**2.87**	
Working day		3.39		3.19		3.46		3.03	
Saturday		3.49		2.97		3.65		2.63	
Sunday**		3.15		2.71		3.26		2.58	
Number of tours per mobile person									
Overall		**1.40**		**1.28**		**1.44**		**1.24**	
Working day		1.38		1.31		1.40		1.34	
Saturday		1.42		1.24		1.48		1.15	
Sunday**		1.41		1.29		1.29		1.21	
Distance of trips [km]									
Per trip		13.4		16.2		13.1		9.4	
Per day		45.0		48.0		44.9		35.8	
Duration of trips [min]									
Per trip		20.2		18.7		20.5		19.9	
Per day		67.9		55.3		70.3		76.3	
Mode choice									
Public Transport		12.1		12.7		12.2		8.6	
Car		69.9		67.6		70.7		64.3	
Bicycle		5.8		6.9		5.7		2.8	
Walk		12.2		12.8		11.5		24.3	

* (i)Overall share of mobile persons and (ii) overall number of trips per mobile person as core travel estimates where tested across participation methods by ANOVA, both highly significant (p-value < 0.001) ** including holidays and public holidays

Appendix C. Response Variables

Variable type [unit]	Variable Name	Label Remark	Boundary for outliers min	mix
Response duration [days]	TotResDays	*TotalResponseDays:* number of days from 1st attempted call to arrival of completed questionnaire The variable "TotResDays" can be seen as the main overall response variable: it measures the response duration from the first phone call attempt until the completed questionnaires were received by the survey team. It includes all parts of the survey beginning from the time needed to get a person on the phone for the first phone call and eventually to motivate the household for taking part in the survey, to the time needed for completing the questionnaires as well as possible postponements of the survey period, to possible delays in sending the completed questionnaires back to the survey team. The validation period is not considered as the timeline for the validation was only determined by the survey team and the respondents had no influence on its duration.	0	70
	MotPreDays	*Motivation(Agreement)PreDays:* number of days from 1st attempted call to motivation call (willingness to participate) The variable "MotPreDays" measures the number of days between the first attempted phone call (with the intention of asking whether the announcement letter was well received and whether the household accepts receiving the questionnaires) and the so-called motivational phone call (when the household agrees to take part in the survey). The duration of "MotPreDays" is influenced by the number of phone call attempts before the respondent was actually talked to for the first time both for the first phone call and for the motivational phone call.	0	30
	MotPostDays	*Motivation(Agreement)PostDays*: number of days from motivation call to arrival of questionnaire The variable "MotPostDays" measures the time between the motivational phone call and the receipt of the completed questionnaires by the survey team. Different from "TotResDays", "MotPostDays" does not include the time needed to get a person on the phone for the first call and for the motivational call. Persons who are hard to reach on the phone might have a longer "TotResDays" but the same "MotPostDays".	0	50
	RepDly1st	*ReplyDelay1st:* number of days from 1st scheduled reporting day to actual 1st reporting day The variable "RepDly1st" stands for the time between the (first) predetermined and the actual reporting period and measures how often respecively for how long the reporting period was postponed.	0	20
	RemDays	*ReminderDays:* number of days from day after last reporting day to arrival of questionnaire The variable "RemDays" measures the time between the day after the last day of the actual reporting period until the completed questionnaires were received by the survey team.	0	30
Telephone calls [frequ.]	TotCallAttFrq	*TotalCallAttemptedFrequency:* number of all calls attempted	0	25
	TotCallDays	*TotalCallDays:* number of days with calls attempted	0	15
	TotCallFrq	*TotalCallFrequency:* number of all calls in which conversation with the participant has occurred	0	7

Appendix D. Methods for computing the duration and type of non-travel activities in ANTS and in the MAED-survey

Activity duration was computed for the ANTS based on the trip purposes as follows:

- The whole reporting day was assigned to "home" for the immobile persons who did not report any trip on the reporting day.
- The time from midnight (0:00) to the start of the first trip and the time from the end time of the last trip to midnight (24:00) was assigned to "home".
- The time between the start time and the end time of each trip was assigned to "travel".
- The time between the end time of each trip and the start of the subsequent trip was assigned to the trip purpose of preceding trip.

The detailed activity episodes in the MAED-survey were transformed into „main activities" in order to harmonise the level of detail with the ANTS. The transformation was guided by the following question: What activity type would be obtained, if the respondents of the MAED-survey filled in a conventional travel diary? In order to resemble this situation, we used the following procedure:

- The time between the start time and the end time of each trip was assigned to "travel".
- The time between the end time of each trip and the start time of the subsequent trip was assigned:
  - To "home" if the arrival location of preceding trip (location of the activity) was the home address,
  - To the activity category with the longest duration for all other arrival locations.

Appendix E. Matched classification of activities from MAED (HETUS-based categories) and ANTS (trip purposes) to the common activity classification

Matched activity type	**MAED 2015** Original activity type	**ANTS 2013/14** Original trip purpose
Home	All activity types with location "home" or after the last trip	Back home
Travel	Travel	Travel
Work	Work*	to Work Business
Education	Education*	School / Education
Shopping	Shopping*	Shopping
Leisure	Leisure* Eating*	Leisure Private Visit
Errands	Domestic/housekeeping* Personal, errands*	Private errand Pick-up/drop-off Accompaniment
Other	Other*	Other

* with location ≠ "home"

Appendix F. Sample characteristics and key travel estimates for both the MAED and ANTS original (MAED) respectively filtered (ANTS) and matched datasets.

	MAED 2015 original	MAED 2015 matched	ANTS 2013/14 filtered, weighted	ANTS 2013/14 matched
n households	490	485	5,829	3,741
n persons	748	738	9,436	4,830
n person reporting days	5,236	4,830	9,436	4,830
n trips	18,203	16,910	29,622	15,431
Gender				
Male	50.0	49.4	53.1	49.4
Female	50.0	50.6	46.9	50.6
Age				
15-19	2.3	1.9	0.7	0.5
20-29	6.8	6.5	13.6	8.7
30-39	18.7	19.0	19.1	18.6
40-49	35.7	37.0	31.3	34.9
50-59	31.9	31.4	31.8	33.6
60+	4.6	4.2	3.5	3.8
Highest level of education				
Compulsory school	2.7	2.5	4.8	3.9
Apprenticeship, college	36.0	37.6	48.2	36.2
Matura	24.3	24.2	20.5	26.5
University, FH	37.0	35.6	25.9	33.5
Household size				
1 person	14.5	9.0	12.5	7.9
2 persons	29.4	28.1	30.0	29.1
3 persons	22.0	22.5	24.4	23.9
4 or more persons	34.1	40.4	33.1	39.1
Share of mobile persons				
Overall	**0.92**	**0.92**	**0.88**	**0.89**
Working day	0.97	0.97	0.92	0.93
Saturday	0.88	0.88	0.84	0.86
Sunday*	0.71	0.71	0.74	0.76
Number of trips per mobile person				
Overall	**3.80**	**3.81**	**3.36**	**3.59**
Working day	3.97	3.99	3.39	3.67
Saturday	3.74	3.74	3.49	3.63
Sunday*	2.84	2.84	3.15	3.12
Number of tours per mobile person				
Overall	**1.47**	**1.47**	**1.40**	**1.44**
Working day	1.47	1.48	1.38	1.44
Saturday	1.55	1.56	1.42	1.53
Sunday*	1.34	1.34	1.41	1.38
Distance of trips [km]				
Per trip	11.0	11.1	13.4	13.9
Per day	41.8	42.3	45.0	49.9
Duration of trips [min]				
Per trip	24.2	23.8	20.2	26.8
Per day	91.9	90.8	67.9	96.3
Mode choice				
Public Transport	10.9	9.3	12.1	11.5
Car	69.5	72.2	69.9	68.7
Bicycle	5.8	5.7	5.8	6.5
Walk	13.8	12.8	12.2	13.3

* including holidays and public holidays

Appendix G. Impact of response effect on share of mobile persons (mobility)

	MAED 2015				**ANTS 2013/2014**			
	ρ	*p-value*	$\bar{x}$	*SD*	*P*	*p-value*	$\bar{x}$	*SD*
TotResDays	0.013	0.778	27.44	13.04	0.005	0.821	13.39	10.82
MotPreDays	0.074	0.115	4.45	6.63	-0.042	0.175	4.66	3.65
MotPostDays	-0.053	0.240	20.76	8.96	-0.014	0.646	8.10	8.33
RepDly1st	0.010	0.826	2.23	5.15	-0.045	0.063	0.96	3.98
RemDays	-0.071	0.117	6.91	6.25	0.023	0.338	9.08	8.54
TotCallAttFrq	-0.002	0.965	5.87	4.68	0.029	0.228	5.68	4.75
TotCallDays	-0.007	0.874	4.66	3.41	0.035	0.143	4.18	2.86
TotCallFrq	-0.056	0.218	2.57	1.32	0.000	0.994	1.40	1.21

Appendix H. Activity duration in the MAED-survey and the ANTS (matched sample, including immobile persons)

Activity category	Mean activity duration MAED [min]*	Mean activity duration ANTS [min]	*t-value*	*p-value*	**Activity ratio MAED****
Home	969.6	978.4	-1.47	0.141	4.91
Travel	83.2	85.7	-1.55	0.121	1.00
Work	270.5	258.9	2.13	0.033	1.59
Education	7.0	4.0	3.22	0.001	1.64
Errands	13.2	22.1	-6.51	0.000	1.08
Shopping	16.5	13.2	3.38	0.001	1.06
Leisure	73.1	70.0	1.02	0.306	1.20
Other	5.8	7.7	-2.01	0.044	1.12

* Main activity type, ** Number of detailed activities per main activity type in MAED