

International Steering Committee for Transport Survey Conferences

Workshop Synthesis: Behavioral changes in travel – challenges and implications for their identification and measurement

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Abstract

Transportation policy measures aim to motivate people to change their travel behavior (e.g. to use sustainable modes of transportation instead of a car). Furthermore, life events (e.g. birth of a child, retirement) often result in changes in travel behavior. On the other hand, structural processes (e.g. the exchange of differently car-socialized cohorts) might result in changes in travel volumes as well, but the underlying reasons for this cannot be regarded as behavioral changes. A major goal in the workshop was to find a comprehensive definition of behavioral change. Based on this definition, methodological approaches have been discussed and distinguished from each other and methods for the identification and measurement of behavioral changes by use of different methodical approaches have been revealed.

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1. Introduction and problem description

We live in an era of dynamics and the need for more or less fundamental behavioral adaptations, mainly in terms of modal behavior, but also in general lifestyles. In view of the challenges of climate change, transportation planning and transportation policy measures aim to motivate people to change their behavior. Surveys on travel behavior measure travel quantities at a certain point in time. Repeated surveys show that demand volumes potentially remain unchanged over time. One of our jobs as transportation researchers is to evaluate the effectiveness of measures and interventions and to estimate how these measures affect travel demand volumes. Another important task is in making

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appropriate forecasts on travel demand development. Usually, travel demand processes have multiple and interweaved underlying causes. Therefore, we should not be tempted to draw hasty conclusions: if, for example, stable travel quantities are measured over time, this does not necessarily point to a stable development in the future. Parameters can change, some will, in the long run, dominate others. It is therefore necessary to analyze how different factors sum up to these travel quantities.

In terms of the survey data, we need to break down the changed quantities into the different underlying reasons and processes. The identification and measurement of changes, but moreover their interpretation and assignment to causes (policies and interventions, structural as well as life-style changes, changed attitudes and random effects), is of central importance.

The following issues were discussed in the workshop:

- What is a behavioral change in travel?
- Which data and survey methods are available and used?
- How can these surveys and data provide what kind and amount of relevant information in order to identify and measure behavioral changes?
- What about the role of new and upcoming sources like passive data? How can this data fulfill a role according to the researchers or politicians’ requirements?
- Which research priorities and recommendations result from the discussion?

2. Definitions and information required for the measurement and identification of ongoing processes

Against the background of the complexity of this issue, Figure 1; **Error! No se encuentra el origen de la referencia.** tries to give a systematic overview of the different definitions, causes and reasons of changed travel demand figures (changed “travel quantities”). Moreover, Figure 1 attempts to distinguish *changes in behavior* from *changed travel quantities*.

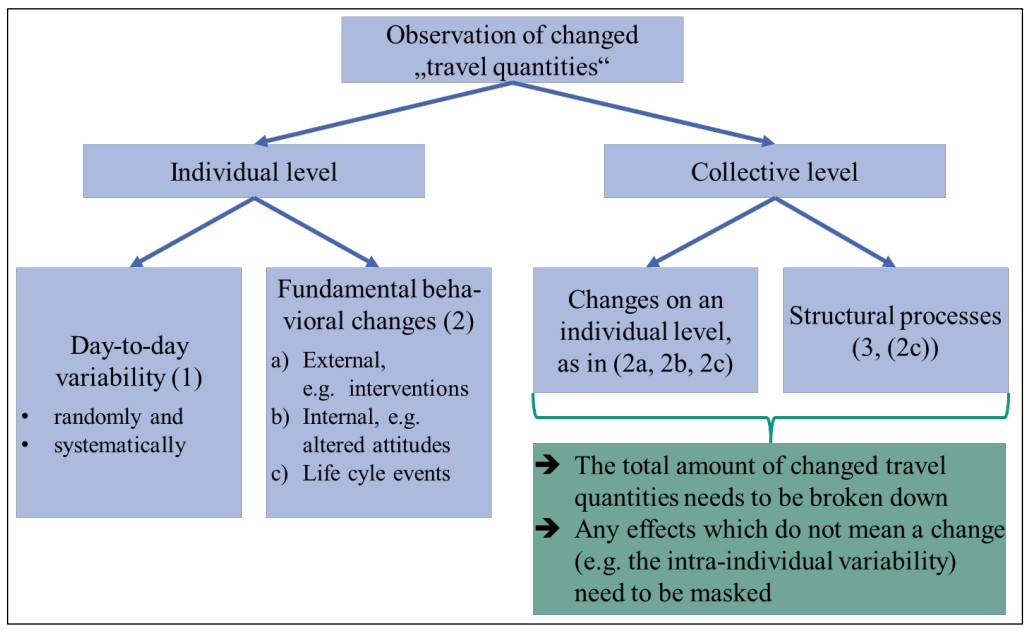


Figure 1. Break down of observed travel quantities into underlying causes.

First, we have to distinguish changes on an *individual level* and on a *collective level*: *intra-individually changed behaviors* and *changed travel quantities*, i.e. key figures for a total population or for defined subgroups in a population. We must be aware that changes in travel quantities will be caused not only by *intra-individually changed behaviors*

(2) but also by *structural processes* (3) on the collective, i.e. aggregated, level. Structural processes can be changes in society's socio-demographic structure such as differently car-socialized cohorts and a changing age structure. Splitting up the population into subgroups can help to identify whether changed travel quantities result from a changed population structure (e.g. higher share of retirees than before). Thus, the underlying reasons for changed quantities cannot solely be assigned to *intra-individual behavior changes* (2). Intra-individual changes can be caused *internally* (2b, e.g. an individual changes his attitudes and starts cycling without an external trigger), as well as *externally* (2a, e.g. by the provision of new infrastructure or new services, transport policies). In the absence of both internal and external changes, one might expect stable travel quantities; however there is more to it: individuals grow up, go to school, go to college, become older, have a job, change jobs, retire, activity places change etc. All these *life cycle events* (2c) will lead to behavioral changes on an individual level.

Another issue is the *intra-individual variability* (1): usually a lot of dynamics can be observed in the travel behavior of individuals from day to day. These can be systematic (we observe one behavior on the weekend and another on workdays) or random (tomorrow will be different from today). This intra-individual variability cannot be regarded as a changed behavior. Thus, fading out of the *intra-individual variability* remains a challenge when analyzing and measuring changes in behavior.

In the workshop, we discussed the relevance of different reasons, processes and interventions for individuals, subgroups or whole populations. In order to understand the reasons for behavior changes it is necessary to capture not only the behavior but also the potential reasons for a changed behavior (Madre et al., 2008). This is simple if changes take place on a structural or socio-demographic level only. It becomes more difficult if new policies, interventions, new services or new infrastructure are involved, which we do not record in our survey and of which we are thus unable to assign the effects on individuals (see e.g. Goodwin, 1989).

We need to find a way of distinguishing effects of structural changes and policy or intervention-related changes. Changes in (urban) transport policies may indeed lead to changed key figures. To verify the effects, however, a control group is needed (e.g. a similar population in the same city or in similar city) which is not affected by these interventions. Information on changed travel quantities on an aggregated level could be collected within the existing surveys rather than capturing it on an individual level.

Finally, it is of crucial importance to understand how attitudes lead to behavior changes (as in category 2b). This data is however often not available, as its collection is time- and money-consuming and the respondent burden increases.

3. Data and survey methodological approaches discussed and assessed

3.1. Abilities of behavior data to identify change

As many aspects influence the amount of travel and to better understand the processes of travel demand, we compared different types of surveys and data with a temporal component according to their respective abilities to observe, analyze and explain behavioral changes.

Figure 2 illustrates the different types of *behavior data* used to identify *change*: the above definitions were chosen to identify changes in behavior (*intra-individual* versus whole populations) and the amount of information that is necessary to identify, define and distinguish the changed behavior.

A temporal component is needed when analyzing behavioral change, because a measurement of behavior at one point in time is usually not sufficient. In principle, at least to get an idea about the amount of an expected structural change, it could be possible to compare the behavior of different population groups using the data of a large household travel survey done once. Using this kind of data, we can at least derive indications for the directions of a change if the population structure changes (e.g. an aging population with a higher share of retirees will lead to less work trips). For reasons of completeness, this aspect is also included in Figure 2.

A temporal component is also needed to distinguish *intra-individual variation* in behavior (D) from the *inter-individual variation* (A): So far, intra-individual variations have been quantified by analyzing longitudinal i.e. multi-day (continuous) behavior data (e.g., Axhausen et al., 2002; Hanson and Huff, 1988; Kunert, 1994; Pas and Koppelman, 1987).

Identifying typical behaviors (which can be treated like conventional data and will be explained in detail in section 3.5) explicitly allow us to fade out the randomness of the *intra-individual variation* and thus to identify the *real change*. However, despite this advantage, it is not possible to produce statistically sound figures using information on typical behavior only.

In view of the definitions given above we can thus conclude that repeated intra-individual survey (panel samples) provide more information to allow for the distinction between the *intra-individual changes* (C) and *changed travel quantities* (B). Here, the combination with a multi-day data collection can help to reduce the effects of the randomness of the *intra-individual variation* (D).

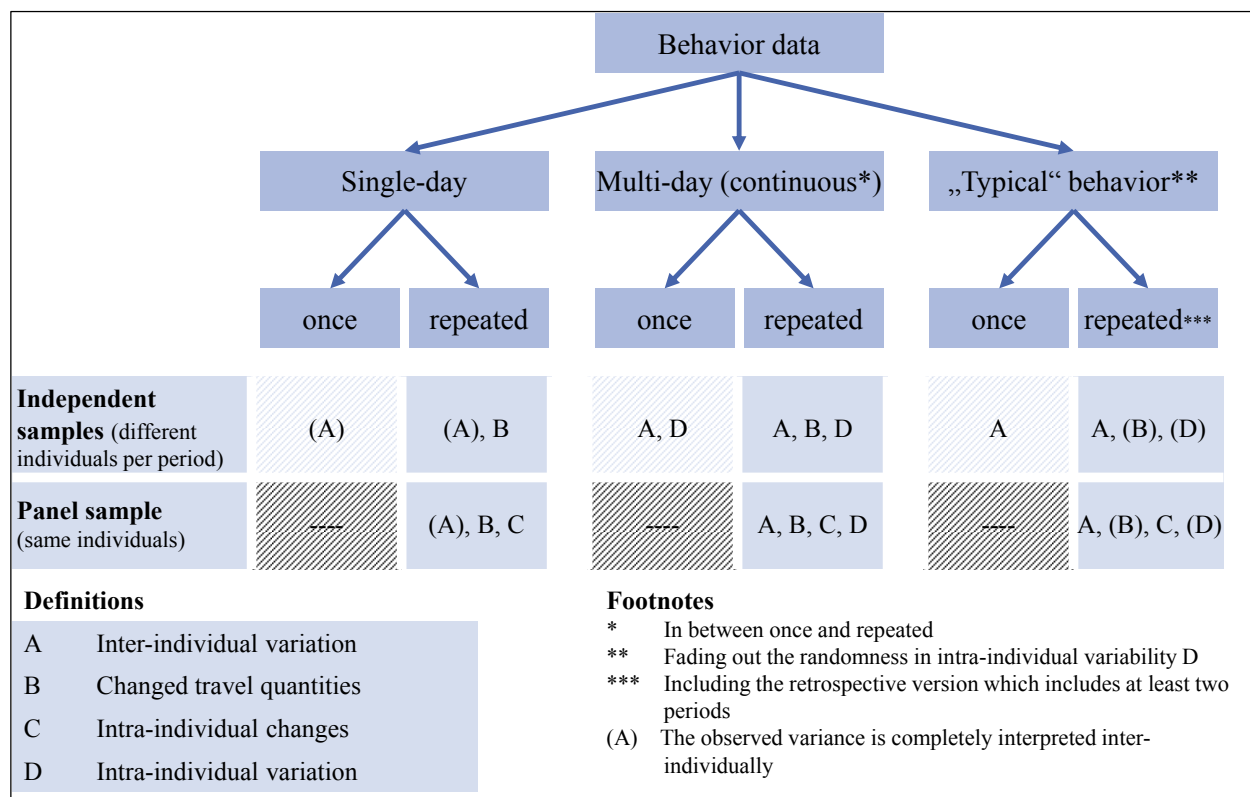


Figure 2. Categories of behavior data with their abilities to provide information about behavioral change.

After setting up these more general descriptions and definitions, existing types of data and corresponding survey designs with a temporal component were discussed and assessed against different aspects and criteria, such as:

- Identification, distinction and analysis of gross and net changes, possibility to identify compensation effects;
- Identification and measurement of typical behavior against the intra-individual variation of behavior;
- Privacy issues - need of personal data to be collected;
- Amount of information available per individual;
- Resulting respondent burden ;
- Measurability of attitudes and preferences within the same survey to explain observed behavior;
- Cost of data generation;
- Completeness of information gathered.

These issues are discussed in the following sections for panel surveys, repeated cross-sectional surveys, passive data and surveys on repeated behavior.

3.2. Panel-Surveys – both discrete and continuous

Panel surveys are, at least in theory, the best approach to provide data. They allow the identification and analysis of behavioral changes, as we measure the behavior for the same individuals or objects repeatedly over different time periods (Zumkeller et al., 2006). However, practical experience, e.g. in terms of feasibility (respondent burden) or the identification of behavioral changes against the variability of reported behavior shows their limits as well, see e.g. Kitamura and Bovy (1987) or Kuhnimhof et al. (2006). Based on the input paper of Kalter et al. (2017) the assets and drawbacks of panel data for analyses on behavioral change have been discussed.

By observing behavior of the same individuals at least two times (“before and after”), we can identify changes. Because of *intra-individual variability* (D) we need survey periods for more than one day to identify the “typical” behavior. Panel Surveys such as the German Mobility Panel (Zumkeller et al., 1997) observe individual travel behavior over the course of one week. This type of survey provides different data characteristics than cross-section surveys of one day only. However, the identification of typical behavioral patterns remains a challenge, even for the data over one week.

It is also necessary to collect the frameworks within a survey in order to bring the changes in behavior to a causal relation (new services, new infrastructure etc.). While we collect the individual characteristics, we usually have insufficient knowledge about the characteristics of the external environment. This means we can measure an *intra-individual change*, but we will very likely not be able to link the behavioral change to any external change. Therefore other information about the frameworks of behavior needs to be collected as well. Compared to independent samples (e.g. by cross-sectional surveys) panel surveys are then able to monitor the total dynamics of changes (the gross changes) and better understand compensation effects. In the case of independent samples, we can only identify net changes between any two points (or periods) in time.

Table 1. Transition matrix of individuals for cycling-intensities based on data of the German Mobility Panel (source: Streit et al., 2014).

		year n +1			Break down in year n
		Non- cyclists	Occasional cyclists	Frequent cyclists	
year n	Non cyclists	59%	7%	1%	67%
	Occasional cyclists	7%	10%	4%	21%
	Frequent cyclists	1%	3%	8%	12%
Break down in year n +1		67%	20%	13%	100%

Table 1 shows an example of the change in bicycle use behavior in the German Mobility Panel between two years. The net changes and the total amount of changed mode use behaviors can be identified by a comparison of the two marginal vectors (break down in year n and break down in year n+1). We see less individuals with no use of bicycles and slight increases in those who use bicycles. However, by counting the shares within the matrix off the main diagonal, reflects the far larger share of gross changes: more than 24 % of individuals change their cycling-intensities between any two years.

A general problem with panel surveys is panel attrition (i.e., only a portion of the original sample repeats the survey). The challenge is to ascertain if the dropouts are those that made or did not make any changes. These aspects need to be checked in detail. This is a matter for future research.

Respondent burden is also an issue: on the one hand, we would like to receive very detailed information from the participants, and several times, on the other hand this affects both the willingness-to-participate and panel attrition. Respondent burden should therefore be kept to a reasonable level. As a consequence, not too many additional questions and items should be included in the survey, however relevant they may seem. Moreover, incentives for participants and an appropriate panel maintenance is indispensable.

All measures and tools which ease the participant's burden should be assessed (e.g. passive tools like GPS-logs). Information should be taken from other sources as much as possible. This is certainly an issue for further research and especially relevant for panels against the background of panel attrition.

Long-term planning is essential for a panel survey, concerning all aspects such as organization, content, methodological tools, management and, last but not least, funding. Only very stable designs will be able to identify changes. Any alterations in the survey can easily result in methodological artefacts, which might by mistake be identified as behavior changes. This means any (unavoidable) design changes need to be checked carefully and only introduced for a whole sample after the proof of its inoffensiveness.

Generally, panel data can be used as repeated cross-section data. This is a very useful characteristic, as the amount of information per individual is large for reasons of the additional temporal dimension, making them a very effective means for research.

3.3. Repeated cross-sectional surveys

Wittwer et al. (2017) have presented different repeated cross-section surveys which are used for a combined age-period-cohort (APC) model; the challenges when preparing data for such an application were discussed as well.

Repeated surveys within a city, region or state at different points in times with completely independent samples are defined as repeated (or series) cross-section surveys. These approaches are usually applied for NHTS (National Household Travel Surveys) or at the city or regional level. These surveys are able to measure the change in travel quantities in general and, depending on sample sizes, split up the data into different person groups in terms of age, socio-economics and socio-demographics. The measurement of any changes (on a macroscopic level as key quantities) is comparably easy.

These cross-section survey approaches are widespread and well established. However, in order to limit the respondent burden, we usually only measure the behavior of one day (trip diaries of one day) plus a limited set of additional questions. For reasons of the limited amount of information per individual, privacy issues are of minor relevance.

Such repeated cross-section data are frequently interpreted as panel data in the sense of so called "pseudo-panels" and thus allow for identifying behavioral changes. This is based on the idea that certain "cohorts" can be followed in the temporal perspective and thus can be "re-identified", as similar individuals. The basic assumption is that the individuals in the same cohort become older with comparable biographies, socializations and experiences. This allows for identifying and defining "behavioral" changes in aggregates in terms of macroscopic travel quantities. It is however difficult to bring these changes into causal relation with policies and interventions for groups and individuals. We see that something happens, but the identification of the underlying reason is difficult (e.g. Kuhnimhof et al., 2013). Furthermore, the amount of information about changes in these pseudo-panels is restricted, as only the net changes between any two points in time (or periods) can be analyzed. All the compensation between any two periods and within any defined population subgroup will remain unclear. Any impacts on *intra-individual changes* (or the individual effectiveness of policy measures) within a group cannot be assessed. For statistical reasons (high *intra-individual variation*), we need large samples to identify whether (within a predefined group) a larger share of people is distinct in behavior from the previous year. Also, *intra-individual short term variability* (e.g. a changed behavior due to the weather or a modal change for any other reason) cannot be identified and analyzed.

We have to be aware that survey formats, sampling frames, survey designs etc. do change as well. Even when the same survey (e.g. covering the same geographical entity) is used, design and coding might change between any two years. A thorough data harmonization would thus be necessary.

In order to best identify changes in a long-term perspective we will need a series of cross-section surveys with a similar time interval between the survey periods. This approach is necessary to set up similar age cohorts with the same aging in between. More continuous forms of data collection are also needed to better reflect effects e.g. of the up-and-down-movement of economy or the variation between years in weather conditions and the resulting changes in behavior. This allows for the aggregation of data from different periods to enlarge the sample size for analyses. Data can be arranged in cohorts, typical period effects can be identified (e.g. the effects of special weather conditions in one year) and impacts of any special situations (e.g. a fuel shortage or disruption in public transportation due to a strike) can be measured in terms of the behavioral adaptations.

3.4. Passive data as continuously recorded data

The digitalization of many business processes, especially the new On-Demand-Mobility-services (ODM), generates by-product data, which has the characteristics researchers have dreamt of for many decades. Passive data can be a very mighty source, as they provide information that is usually both continuous and cost-efficient (i.e. the data are produced anyway). However, it is in the nature of passive data that, since they are produced for other purposes, they do not provide the information necessary for the researcher's focus.

Passive data has many advantages in terms of their generation, but some information is difficult to achieve. We have discussed their advantages, options and limitations in the workshop on the basis of the input papers of Nazem et al. (2017) and Wielinski et al. (2017).

Passive data is not conclusively defined. On the one hand, for passive data that is mostly collected for another purpose (e.g. determination of costs for subway rides), an application for research (e.g. identification and measurement behavioral change) can be seen as a secondary exploitation. This is done without the explicit approval e.g. of the smart card holders. Moreover, the data is often derived from technical devices like smart cards, car-sharing vehicles etc. The information about the characteristics of their users will be restricted at least by the legal framework of privacy issues. On the other hand, a smartphone-based collection of trips can also be characterized as passive data or at least as a "hybrid approach", as the active reporting of individuals is not needed or only necessary for certain aspects (e.g. specification of activity purposes). Beyond this, socio-demographic and further individual-related information is actively provided by the survey participants. Thus, this kind of data is only partly "passive" and require a lot of additional active involvement, therefore bearing the same disadvantages as active travel surveys (e.g., attrition, active participation, motivation, non-complete samples, biased samples).

Passive data mostly covers long time periods and are thus suitable for the measurement of behavioral changes. In the case of passive data, which is recorded anyway, there is no additional cost. The data is available and free of cost for researchers. At first glance, passive data is not biased by typical response errors, which occur in active travel surveys: it is factually revealed behavior. However, this data has other downsides. Sample sizes of passive data are mostly large and therefore representative for the object of research but limited to the object of research, e.g. smart card data only includes public transport trips within a metropolitan area. Passive data allows us to, at least theoretically, distinguish net change in travel demand from gross changes. We can measure compensations and quantify the *intra-individual* (respectively intra-smartcard) *variability*. We can aggregate passive data over different time periods and can therefore analyze (with the knowledge of any changes in the external framework) the behavior *before* and *after* (e.g. for the case of new infrastructure or disruptions). Any general changes can be measured as far as the respective data records are available. We then discussed if passive data could replace conventional data and surveys, taking into consideration any known challenges, obvious disadvantages and unsolved problems. Passive data is usually produced for a specific purpose. Hence, their adaptation and reconditioning for any other purpose is time-consuming (e.g. to generate "trips" out of GPS trajectories) and the results are ambiguous.

Privacy issues are of central importance. This limits not only the usability and application but also the collection of passive data. For example in Germany, cell phone providers need to change the identities of cell phones every day due to data protection legislation. Consequently, continuous records of the same cell phones cannot be retrieved. Another legal limitation is that the data can usually only be stored (and used) for a limited amount of time (e.g. in France).

Detailed socio-demographic or socio-economic information of the target population is usually not available. In many cases, only information about age and gender is available. Further information can partly be derived from the trajectories (e.g., working status). There are further reasons for data biases: first, single trajectories can be produced by the behavior of different individuals (e.g., two people use the same smart cards on different days). Second, one individual may produce different trajectories (e.g., an individual uses different smart cards on different days). Third, individuals may change their smart card as a result of damage or loss. In all these cases, a distinction and measurement of changes at the individual level is however restricted.

Passive data require massive efforts in data cleaning and distilling information. E.g., the identification and definition of trips out of a series of geo-coordinates is still difficult and time consuming since standardized software tools and algorithms are missing.

Researchers can neither control nor assess the data collection, so that researchers do not know how complete the data is. Any kind of weighing (who is represented) is difficult, as there is no way to know what share of the trip is recorded. This especially holds true if different options are available (e.g. paper tickets in addition to smart cards).

In summary, we are, in principle, able to identify and measure individual changes based on passive data but we have to be aware of their limitations. In the case of observed changes, information about potential causes such as changes in the tariff system or service supply need to be collected as well. Additional research is necessary.

3.5. Surveys that measure “typical” travel behavior

Surveys, which explicitly fade out the *intra-individual variability* by concentrating on “typical” and “usual” trip patterns, are an additional approach to identify changes at the individual level.

Based on the input paper by von Behren et al. (2017a) the advantages and disadvantages of a “travel skeleton” approach have been discussed. Retrospective surveys, which capture typical behavior before and after the change of external frameworks, are summarized under this approach as well. A survey to assess behavioral changes of employees after an office relocation was presented as an input paper (von Behren et al., 2017b).

The query of travel behavior information requires less time and effort with the skeleton approach compared to travel diaries, see e.g. Dianat et al. (2017). Consequently, more information can be gathered within a given survey interview time. We can therefore add some pursuing questions, e.g. about the frameworks or attitudes towards different modes of transportation in order to derive causal relationships as well. As mentioned, the exclusion of the *intra-individual variability* is a possibility to identify typical behavior. We can detect changes more easily as we concentrate on the relevant elements and determinants of travel. A further advantage of retrospective surveys consists of the provision of panel data.

However, querying typical travel behavior instead of single trips may result in biased survey results due to social desirability (e.g. in terms of the frequency of the use of certain modes) or an overestimation (typically seldom used modes, frequency of long distance trips) or underestimation (short trips in daily life).

Moreover, this approach does not allow for measuring exact travel quantities and statistically relevant key figures. The skeleton approach will not be able to provide figures suitable for political and planning decisions and must therefore be regarded as specific in terms of the applicability and usability of the produced information.

Any repetition of the survey in order to measure behavioral changes (or a series of repeated skeleton surveys as a panel) would meet the same disadvantages as other panel surveys (e.g. by panel-attrition and panel-conditioning), or even more so, asking for typical behavior again and again would likely cause more of these than conventional panel survey approaches.

4. Conclusion and recommendations

To conclude the discussions during the workshop, our recommendations for surveys in general and for future research can be summarized as follows:

- We recommend to conduct cross-sectional travel surveys with large samples, not only seldom or sporadic but to use more continuous forms of data collection approaches. That way, the influence of externalities on travel quantities can be better understood, e.g. weather conditions or the economic situation. This will help to overcome the pitfalls resulting from merely sporadic surveys and better understand why changes occur.
- Never change a survey design if you want to measure a behavioral change: even small methodological design changes can result in changed travel quantities and therefore will either blur a changed behavior or fake a behavioral change. However, as design adaptations may be unavoidable in light of changing technological, societal and attitudinal frameworks, these must be thoroughly monitored through a slow introduction and comparisons with the unchanged design (Weiss et al., 2017).
- We know that certain population groups have a higher propensity to change their behavior over time than other population groups. Research about appropriate sampling designs can help to capture data within the limits of a restricted budget. However, this requires some more effort in the use of the resulting data, which cannot be used conventionally.

- We recommend to reduce the respondent burden by using available technology as much as possible, potentially accepting some errors. E.g. if GPS data are available and information about the characteristics of destinations are available, both layers of information can be linked. However the size of the resulting error should be quantified (an issue for research), algorithms for the identification of activities (is a regular visit to a shopping mall for leisure, shopping or for work?) need improvement and could be standardized.
- As the number of survey questions is restricted, the combination of core surveys and satellite surveys is a suitable approach to gather additional information. However, this creates new challenges: traditionally complete surveys in terms of data sets become incomplete.
- Further research and best practice examples on the enrichment of existing surveys with additional information and combining different approaches (e.g. panel surveys and passive data) is needed. A continuous longitudinal survey to measure behavioral changes both on the individual and on the collective level would be an ideal tool for investigating behavior change, but such a dataset is not available. Instead, it is conceivable to derive “virtual longitudinal” behaviors using data fusion approaches. Here, appropriate simulation tools need to be developed to better understand how societal, demographic, economic and spatial processes sum up to travel quantities and how much quantity change is caused by a changed behavior. Also, the design and development of approaches to collect behavior in a more or less general way (“typical behavior”) and thus to identify *intra-individual changes* are conceivable. Therefore, we need to learn how to make use of the mutual synergies of traditional travel surveys and passive data with different characteristics.

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