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An open-source interactive travel diary for web-based trip reporting

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Abstract

Travel diaries are a state-of-the-art method to capture peoples' travel behavior. However, traditional approaches are burdensome for respondents resulting in fatigue and attrition, whereas new methods such as GPS-tracking are costly and fraught with issues of respondents' privacy of personal data. In this paper, we present an interactive, web-based travel diary, that improves the reporting process while minimizing efforts for survey designers. In a pilot study we show that the approach ensures to record detailed spatial trip information, but still guarantees respondents' data privacy. The open-source design allows a cost-efficient integration in any survey engine that supports HTML and JavaScript.

Keywords: interactive travel diary; travel behavior survey; data privacy; open-source

1. Introduction and Related Work

Travel diaries play an important role in travel behavior surveys. As respondents provide detailed information on their trips and trip characteristics, key mobility figures such as modal split, travel times, and traveled kilometers or others can be analyzed. Moreover, travel diaries are used as input data in travel demand models and thus play an important role in medium- and long-term transportation planning. One-day diaries, such as 'Mobility in Germany (MiD)' by infas et al. (2017) allow to study trends on an aggregated level. However, travel demand models particularly benefit from multi-day data by including information regarding individual day-to-day variation (Pendyala and Pas, 1997; Loechl et al., 2005). Research has shown that the currently used methods for multi-day travel diaries, such as paper and pencil interviewing (PAPI), computer-assisted personal interviewing (CAPI), and computer-assisted telephone interviewing (CATI), cause high effort for respondents to complete the interview resulting in fatigue and attrition (Chlond et al., 2013). Due to decreasing response rates, research is confronted with reaching different population groups with appropriate survey methods (Bonnel and Munizaga, 2018). Moreover, paper travel diaries also induce a high workload for survey designers in data preparation and plausibility checks (Bhat, 2015). As a result, new methods for travel diary collection have become the focus of research, e.g., GPS-tracking (Prelipcean and Yamamoto, 2018;

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Bhat, 2015), analysis of smart card data (Riegel, 2013; Spurr et al., 2015) and computer-aided approaches (Bayart and Bonnel, 2015; Hoogendoorn-Lanser et al., 2015).

GPS allows for the passive collection of travel data by logging locations automatically with a supporting device. This promotes a reduced respondent burden for participants. However, passive tracking methods have to be combined with an additional survey framework to also capture socio-demographic information (Cottrill et al., 2013). A comprehensive overview of existing tools and approaches to collect travel behavior is given in Prelipcean et al. (2018b). However, the authors state that nearly all tools in that field work similarly in a way that trip information is collected and additional trip information is provided by the users. Although great potential is seen in the collection of travel data with GPS, researchers recommend using GPS only as a complement of traditional survey concepts (Bricka et al., 2012; Nguyen et al., 2017; Stopher and Shen, 2011).

GPS is sensitive to recording errors due to battery limits of the logger (Bhat, 2015) or poor accuracy within specific situations, e.g., in trains (Bohte and Maat, 2009), and a varying accuracy of GPS records between multiple devices (Prelipcean and Yamamoto, 2018). Further, the quality of GPS data might suffer from errors in the algorithmic assignment of transport modes and trip purposes (Vij and Shankari, 2015) and the segmentation of collected trajectories into trips (Prelipcean and Yamamoto, 2018). Further, privacy issues arise with applications that need to be installed on respondents' devices (Prelipcean and Yamamoto, 2018). At least in Germany, the analysis of smart card data would also be inconceivable due to privacy aspects, whereas in countries with less sensitive data privacy regulations, smart card data has already been used successfully to obtain information on people's travel behavior.

Besides GPS-tracking, computer-assisted approaches based on the self-reporting of trips exist. Bayart and Bonnel (2015) present potentials of web-based surveys for household travel surveys by adapting the standard questionnaire used in France for household travel surveys to a web questionnaire. Hoogendoorn-Lanser et al. (2015) introduce a state-of-the-art travel diary that has been used for the Netherlands Mobility Panel. They integrated a visual day planner to support the respondents in not missing any trips. By using locations and related activities the recollection of trips within a day has been simplified. Since supervised surveys result in data with higher quality (Kagerbauer and Stark, 2018), suitable support of respondents is needed for such surveys. For example, viewing individual mobility on a map excites and motivates respondents (Bohte and Maat, 2009). Therefore, Greaves et al. (2015) present a map-assisted app as an opportunity to collect seven days of travel data. However, they used the map only to recall the travel information after the respondents had provided trip data in the interface before.

In general, spatial details in relation to visited locations allow in-depth analyses of travel behavior (Schönfelder and Axhausen, 2001). However, respondents need support to report their destinations, which is achieved by querying the addresses (Bayart and Bonnel, 2015). Since self-reported trips are often over-estimated regarding trip duration and trip distance (Nguyen et al., 2017), this method allows to collect more precise information. Examples of trip diaries that question specific address data exist in Hoogendoorn-Lanser et al. (2015) and infas et al. (2017). However, to guarantee the privacy of the respondents' personal data, questions on detailed start and destination addresses of trips have to be avoided in both GPS tracking and traditional travel diaries. By reducing the trip information on distance, start, and end time as it is done in some household travel surveys, e.g., Ecke et al. (2021), important information, such as the spatial distribution of trips, is lost. Therefore, a tool is needed that meets privacy concerns, creates little effort in collecting data from respondents, and at the same time captures spatial information as accurately as necessary. Also Kraft et al. (2020) highlight the need for a well-chosen combination of methods (GPS and traditional travel diary) to collect suitable data that enable comprehensive results regarding time-space analyses.

In this paper, we present an approach for an interactive travel diary, in which trips are reported in a web-based, open-source tool using an interactive map as a supporting instrument to collect information on start and destination locations. The exact spatial information is automatically abstracted to the level of travel analysis zones (TAZ) to maintain the privacy of respondents' personal data and preserve detailed information about the trips. Our development aims at providing maximum support for the respondent in the process of trip reporting while minimizing the survey designer's effort for data preparation and plausibility checks. According to Prelipcean and Yamamoto (2018) the biggest challenge is an open-source distribution of travel diary collection systems in order to decrease development costs as up-to-date current developments are typically not published. Hence, according to the automatic trip collection system MEILI (Prelipcean et al., 2018a) all codes of this project are made publicly available. Additionally, no software has to be downloaded.

The paper is organized as follows. First, we introduce the development of the interactive travel diary. Second, we describe its application in the survey engine 'Unipark' by Questback. Third, we evaluate the interactive travel diary by analyzing the results of recorded travel behavior obtained in a pilot study. Finally, implications for the interactive travel diary are given, followed by a conclusion.

2. Development of an Interactive Travel Diary

In this section, we present the design and technical implementation of our interactive travel diary as well as the reasoning behind the major design decisions. Its application and methodical implications are presented in the further course of the study. We will focus on the novel aspect of our approach, i.e., the interactive map for reporting the origin and destination of a trip. An example of this map is shown in Figure 1. The source code, as well as a running example, are available on GitHub (Kübler and Barthelmes, 2022).

Since the interactive travel diary is used to report geographical locations, the most fundamental requirement is a user-friendly visualization of a map of the survey area with intuitive controls for navigation. Our interactive map is designed to support the common click-and-drag map movement and scroll zoom on PC and the corresponding touch controls for mobile devices. This reduces the effort for participants who are already familiar with these controls. Additionally, a text-based search bar (see top right corner of Figure 1) to look up addresses on the map supports participants with lower visual-spatial orientation skills. Compared to paper surveys, the digital map is not limited to addresses. The search bar allows finding locations by the name of POIs (points of interest), as exact addresses may not always be known to the participant. Moreover, the search bar function makes the approach also suitable for conducting CATI-based travel diaries by supporting the interviewer in recording the location of origin and destination of trips. We implemented this map using the open-source JavaScript library Leaflet (Agafonkin, 2022). Leaflet provides the intuitive map movement as well as the search bar and allows to add multiple (map) layers. As bottom layer, we used a map provided by OpenStreetMap (OSM) (contributors, 2021), a free and open-source collection of geographical data. However, the selected maps are exchangeable with no effort.

The reporting of the origin and destination of a trip can be done by adding respective markers onto the map with a single left-click on a PC or tap on mobile devices. These map markers set the location of the start or destination of a trip. To comply with the regulations regarding the privacy of personal data, neither the marked coordinates nor a derived address is recorded by the tool. Instead, we added an additional layer that divides the area of the map into distinct TAZs. Consequently, the surrounding TAZ is stored and displayed on the map. These TAZs are disjoint polygons enclosing an area of the map that is coherent in a certain sense (e.g., a residential or industrial district). They are commonly used, e.g., in transportation planning. Highlighting the selected zone on the map contributes to inform the respondents regarding the address abstraction. To support this, the ID of the selected zone is displayed below the map, and a popup message appears on the map. However, since privacy requirements might vary in different survey areas, the tool can be modified to record exact coordinates if necessary.

The zone-polygons are provided in the open standard format GeoJSON (Butler et al., 2016). The visualization of the zones is customizable and also given in a JSON-like format. They are displayed as an overlay on top of the map. To prevent the zones from hiding the actual map and the information on it, they are drawn as transparent surfaces surrounded by a dashed border. Both the degree of transparency as well as the color are configurable. In our example, we used red and green for the origin and destination zone to match the color of the markers. Furthermore, all other non-selected zones are also displayed in blue color to give the participant an overview of selectable zones. Additionally, custom map layers tailored to the survey can be included between the map and the zone layer by specifying the web URL of a map server hosting the custom map tiles.

When reporting multiple subsequent trips, the participant has to select locations twice: once as destination and once as origin of the next trip. To reduce the workload (and thereby also reporting fatigue), we added a destination memory. If the participant selects a destination, the zone is locally stored in the browser and reused as origin for the next trip. This also contributes to increasing the consistency of the reported trips and reduces the survey designer's effort for plausibility checks.

The presented digital tool provides an extendable base to be customized by the survey designer. The interactive map is built with HTML and JavaScript, which are commonly used for browser-based surveys. Hence, it can be used with any online survey platform that supports custom HTML and JavaScript questions. Since JavaScript is a general-

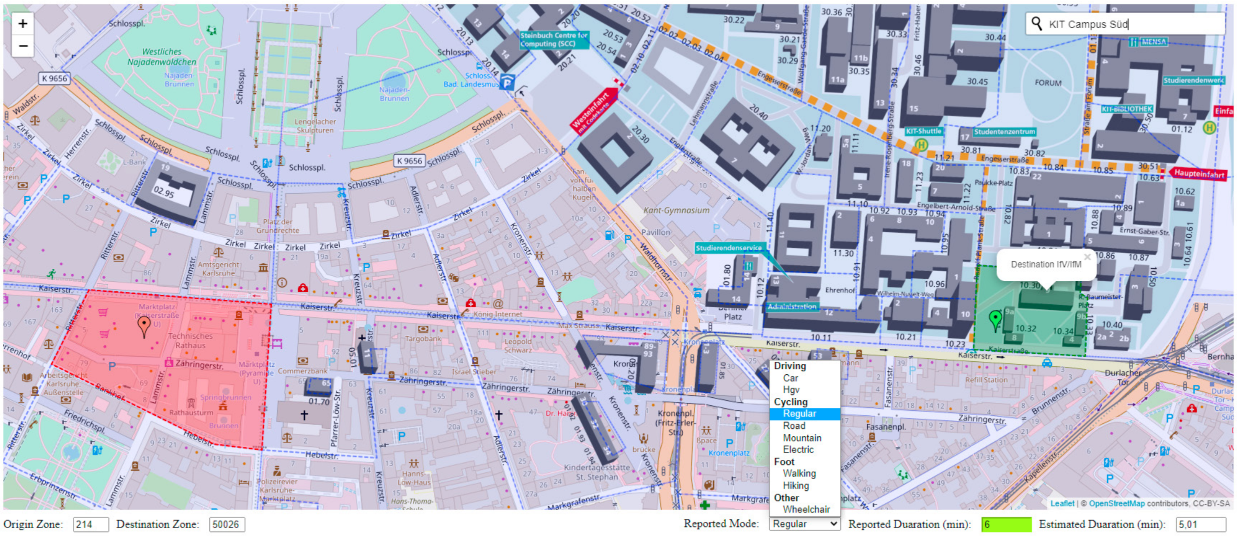


Fig. 1: The interactive map in an exemplary HTML embedding; origin location and zone in red; destination location and zone in green; non selected zones in blue

purpose programming language, the digital format further allows to include additional convenience features as well as automated processes, which reduce the survey designer's effort for the consecutive data preparation. Also, many JavaScript libraries are developed and published as open-source, which we aimed to achieve for our tool.

As an example of an extension, we implemented a prototype for automatic plausibility checks of the participant's reported travel time. Once origin and destination have been selected, we apply the web API of Openrouteservice (2022) to determine the estimated travel time between origin and destination. This can be compared to the reported travel time to investigate whether the reported value of travel time is plausible. The comparison can be made on the basis of any rule, e.g., absolute deviation, relative deviation, or dependent on the mode of transportation. This plausibility rule can be customized to the requirements of the study at hand. Also, alternative APIs or a static, pre-computed travel time matrix could be used for such plausibility checks. Figure 1 shows an exemplary visualization of this plausibility check below the map on the right.

In summary, our approach composes various open-source libraries and assets into an intuitive interactive map for reporting the origin and destination of trips in a travel diary format. This 'gamification' of trip reporting aims at increasing the motivation of participants to report trips and counteract reporting fatigue. Furthermore, the approach considers privacy concerns by abstracting from exact coordinates to TAZs.

3. Application

The interactive travel diary was applied in a pilot study to record the travel behavior of students at the Karlsruhe Institute of Technology (KIT) over the course of a week. For this purpose, we implemented the tool in the survey engine 'Unipark' by Questback. In addition to the travel diary, a questionnaire was developed with supplementary questions about socio-demographics as well as more detailed questions about the respondents' everyday mobility. However, the focus in this paper is on the travel diary itself.

The survey implementation should provide respondents with necessary information on reporting travel diaries. Accordingly, we first gave a sufficiently detailed introduction to the reporting process and provided tips for the respondents, how to best recall trips from memory, etc. This contains, among others, an example of how a travel log might look over the course of a day. Furthermore, they got a short introduction to the usage of the interactive map as well as to the abstraction of addresses to TAZs. They were also informed that only the zone IDs are saved by the survey engine. However, due to its intuitive character, the explanations could be kept brief. In our example, we added a more detailed map of the university campus, e.g., with the building numbers, as an additional layer to support an easier orientation for the responding students.

The order of the query and design of the consecutive survey pages should facilitate the reporting process and reduce its complexity. Hence, on a second page, the date for which the travel diary shall be reported was requested, as well as whether any trips were taken at all on that day. Only if a respondent answered the latter in the affirmative he or she was asked to report trips on the stated day. The query of the trips was done in a two-stage procedure on two different pages. In the first stage, participants were asked to indicate the locations of start and destination of the first trip on the interactive map. In the second stage, they were asked to report further information on the designated trip. These include start and end time, used modes of transportation as well as trip purpose. Based on information from the previous questionnaire part (such as occupation and ownership of mobility tools), only relevant options were selectable. Finally, the participants were asked if they did further trips within the reported day. If yes, they went through the two-stage process again until all trips of the day have been reported. Graphical impressions of the implementation in 'Unipark' are illustrated in Figure 2.

In our example, respondents were invited by e-mail to participate in the pilot study. As a reminder to report the trips of the ongoing day, an e-mail containing the link to the travel diary was sent out to the students at 8 p.m. every day. In total, 53 students participated in the pilot study. 61% were between 18 and 24 years old, while 34% were between 25 and 30 years old. Only two participants were older than 30 years. Regarding gender, about one-third of our sample was female, which is a representative quote within the study program. According to other socio-demographics, our sample showed similar characteristics. For most students, this pilot study was their first exposure to a travel diary. The study was carried out over the course of a fixed week from Monday to Sunday in November 2021. Only minor measures restricting mobility due to Covid-19 were active during the survey period.

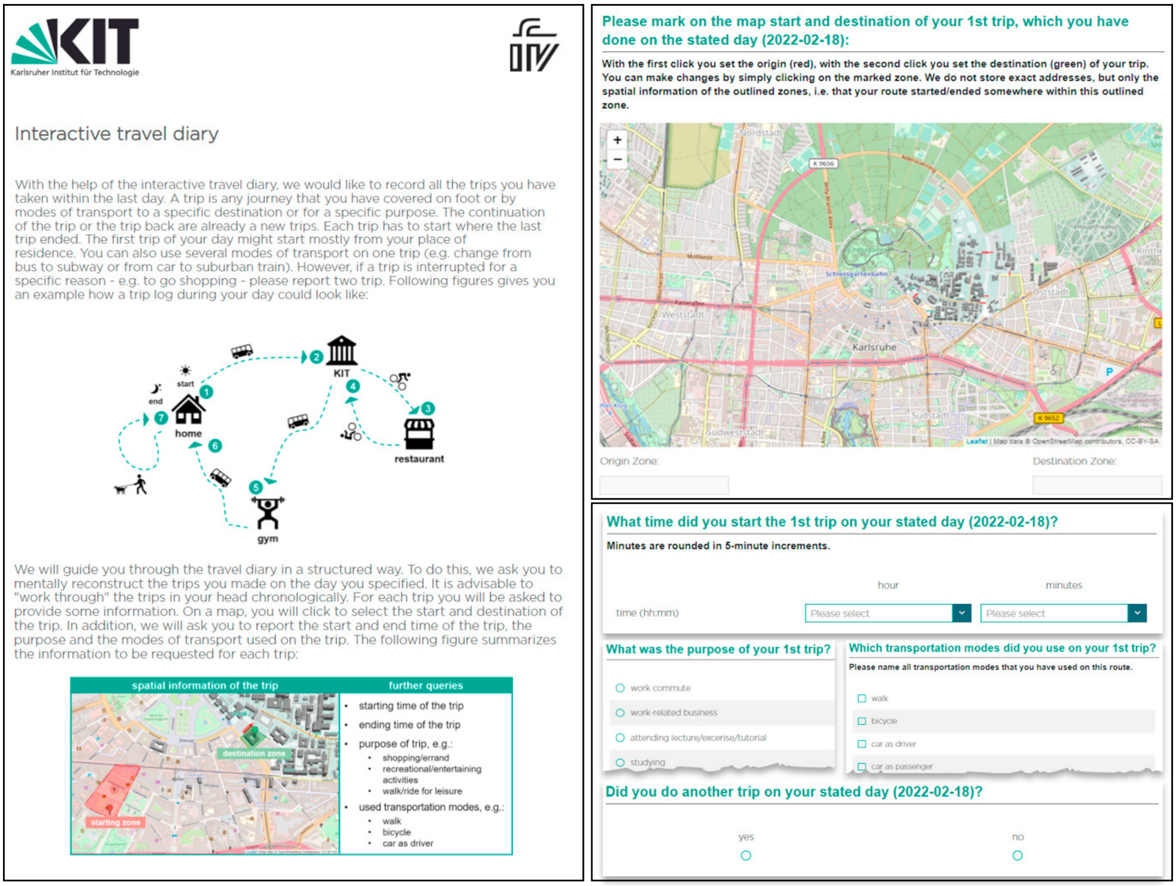


Fig. 2: Implementation of a travel diary in survey engine 'Unipark'

4. Evaluation

The results of the pilot study are used to assess the survey design of the interactive travel diary. Therefore, we give insights into the reported trip characteristics to analyze whether the design provides reliable trip information. To this purpose, we investigate whether and to what extent differences in trip characteristics are related to the design of the travel diary itself. Additionally, we investigate reporting effects and compare them with findings from literature. Finally, we give further insights into spatial analyses that can be performed with the presented approach.

4.1. Reported travel behavior

Data from the official household travel survey ”MiD - Mobility in Germany 2017” was used for comparison to evaluate the travel behavior recorded with the interactive travel diary. Although MiD contains a single-day and not a multi-day travel diary, comparability with socio-demographic characteristics of the sample and our pilot study was achieved by filtering the MiD to participants with the occupation “student” living in major German cities (variable: RegioStaR7). This also applies to our sample. Moreover, the age distribution of the selected sample of MiD is equal to ours, whereas differences occur towards the distribution of gender as the selected sample of MiD consists of a similar number of women as men. Since all the participants of our sample reported at least one trip per day, figures of the mobile population in the MiD were used as benchmarks. The comparison of key mobility figures is shown in Table 1. It should be noted that for the figures of our study, mobility time was assessed on the basis of the reported start and end times of a trip, while distance was calculated externally on the basis of mode-specific distances between the reported start and destination zone of each trip.

Table 1: Comparison of mobility-related characteristics between pilot study and MiD - Mobility in Germany 2017

	Pilot Study	MiD 2017
Overall statistics		
No. of participants	53	
Overall no. of trips reported	948	
Overall no. of persons and days reported	242	
Key mobility figures		
Trips per person and day	3.9	3.6
Distance per person and day [km]	38	44
Time per person and day [min]	97	105
Modal Split		
Walking	31%	27%
Bicycle	31%	23%
Private Transport	19%	25%
Public Transport	15%	24%
New Mobility Options	4%	–
Trip distance		
≤ 500m	13%	11%
500m - 1km	20%	13%
1km - 2km	18%	16%
2km - 5km	26%	28%
5km - 10km	9%	16%
10km - 20km	6%	6%
>20km	8%	10%

The average number of trips per person and day is higher in our sample than in the comparison group of the MiD. Performing a t-test on the overall number of 242 persons and days of reported mobility confirms this observation at a 95% significance level. The mean distance traveled per person and day and the time spent on mobility per person and day is 38 km and 97 min, respectively. These values are somewhat lower than reported in the MiD. However, a t-test could not detect any significant differences (95% level). When considering socio-demographic differences between both samples, it becomes clear that the sample of our pilot study has a higher proportion of male participants. According to the comparative sample of MiD 2017, but also to other literature such as Sánchez et al. (2014) young male people have, e.g., a lower trip rate but also a higher mileage traveled per day than young females. Consequently, representativity according to gender in our pilot study could result in greater differences between the key mobility figures than presented in Table 1. At the same time, the distance distribution of the reported trips shows that more short trips, especially trips shorter than 1 km, were reported in our survey than in the MiD. Fittingly, we observed a higher proportion of bicycle and walking trips than the MiD, as those modes were mainly used for shorter trips. As an example, we face a share of 76% of all walking trips that are shorter than 1 km. In MiD, this share is only 62%. Behrens and Estomihi (2009) found that especially walking trips are more often forgotten in trip-based travel diaries. Moreover, Bayart and Bonnel (2015) found web respondents to report fewer trips which can be traced back, in particular, to fewer walking trips. This does not seem to be the case in our pilot study.

Furthermore, we examined the distribution of trip purposes. The comparison between the pilot study and the MiD is shown in Figure 3. Basically, we see a high similarity between the distribution of trip purposes. Although Bayart and Bonnel (2015) identified an under-reporting of shopping trips as well as of less constrained trip purposes in web-based trip diaries, we see the opposite effect, with more shopping trips reported in our study than in the MiD (15% vs. 10%).

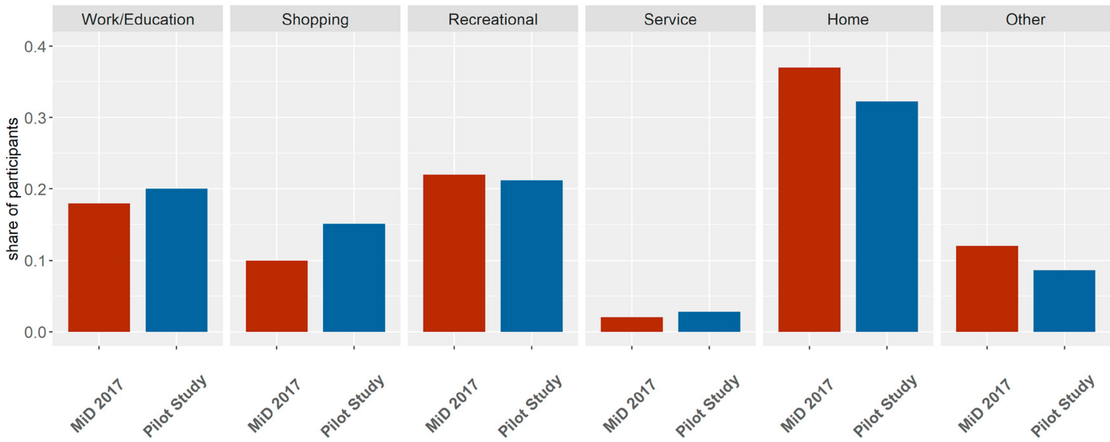


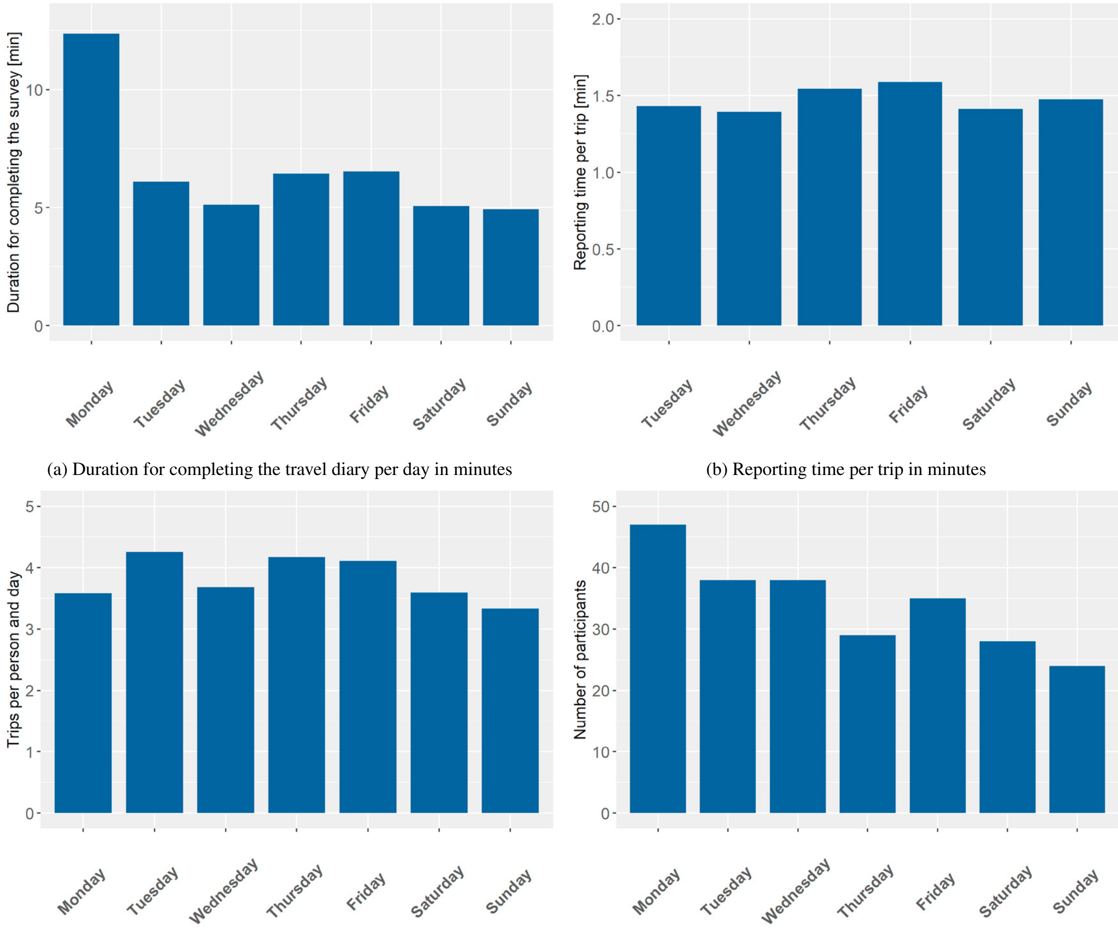
Fig. 3: Distribution of trip purposes; comparison between pilot study and MiD 2017

4.2. *Analysis of longitudinal reporting effects*

Reporting fatigue is typically manifested by a decreasing number of reported trips over the course of the reporting period (cf. Golob and Meurs (1986)). Attrition is manifested in individuals dropping out of participation in the travel diary. We examined both effects in our interactive approach.

First, we focused on the time it took participants to complete the travel diary per day (see Figure 4a). On average, a person who participated on all seven days of our survey invested a total of 46 min. On Monday, respondents received an additional questionnaire with questions about socio-demographics and details regarding their everyday mobility in addition to the travel diary. As a result, the largest proportion of reporting time was invested on Monday. On all other days, only the travel diary had to be completed, resulting in responding times between 5 and 6.5 minutes. This is significantly less than observable in other travel diaries, e.g., 10 minutes as identified by Bayart and Bonnel (2015). Figure 4b shows the average reporting time per trip as the quotient of the travel diary's reporting time and number of trips per person and day. This value does not vary a lot and averages at about 1.5 minutes per trip. We would have expected a decreasing reporting time per trip since learning effects usually occur.

To investigate reporting fatigue, the evolution of reported trips per person and day over the reporting week is shown in Figure 4c. We can observe an average number of trips per person and day of 4.0 on weekdays and 3.7 on weekends,



(a) Duration for completing the travel diary per day in minutes

(b) Reporting time per trip in minutes

(c) Reported trips per person and day over the course of the reporting period

(d) Number of respondents over the course of the reporting period

Fig. 4: Analysis of longitudinal reporting effects

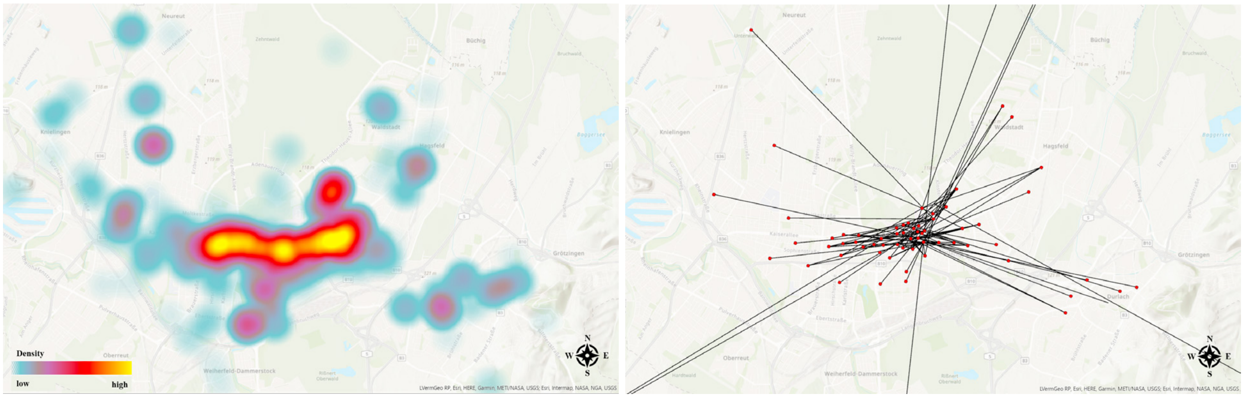
respectively. The fact that the number drops on weekends compared to weekdays is consistent with findings of travel behavior research. However, in contrast to existing literature (cf. Golob and Meurs (1986); Pas and Sundar (1995)), we do not observe a decrease in reported trips per person per day between the weekdays. Slight fluctuations do occur across single days, but these do not follow any structural change. As a result, we cannot identify any reporting fatigue over the course of the week in our interactive travel diary. However, it is noticeable that among the weekdays, the lowest number of trips per person and day was reported on Mondays, and thus the first day of the survey. As previously described, a significantly higher reporting time was required on this day due to additional questions.

To examine the effect of attrition in multi-day travel diaries as described by Chlond et al. (2013), we analyzed the number of participants over the course of the reporting period (see Figure 4d). Not all of the 53 participants completed the travel diary every day of the reporting period. Over the course of the week, the number of people who participated in the travel diary decreased. On the last day of the survey, only 24 participants were registered. Thus, even with our approach, the effect of attrition cannot be prevented. Overall, just about 44% of all participants completed the travel diary on at least 6 days. In times of decreasing willingness to participate in surveys, as noted by Singer and Ye (2013) among others, this value can be considered as moderate. Furthermore, we found that all participants in the pilot study were also mobile on the reported day. We, therefore, assume that non-mobile individuals did not report this but instead abstained from participating completely, which had a negative impact on the response rate.

4.3. Spatial analysis of reported travel behavior

The use of TAZs enables detailed spatial analysis. These give us a precise understanding of the spatial-temporal travel behavior of the participants, although we do not dispose exact addresses for start and destination locations. Since the structure of the collected spatial data of the trips is already implicitly geocoded and digitized, little effort is required for examination with geographic information systems. Likewise, little effort had to be put into the plausibility check of the reported trip chains since the correct order of start and destination zones was already ensured by our tool itself.

We studied the spatial structure of reported mobility at an aggregated level. Figure 5a shows a heat map depicting the density of travel demand generation, i.e., how often a trip started in which zone. Trips starting from the university ground were excluded for reasons of clarity. The mobility of students in Karlsruhe is focused along the main axis stretching from east to west. The pedestrian zone and numerous shopping facilities are located along this axis. Increased travel demand generation can be seen at the eastern end of the main axis. This area is known as a typical residential area for students due to its proximity to the university. Further north, there are also student dormitories, so increased travel demand generation was also expected here.



(a) Heat map of reported starting zones excluding zones at university ground

(b) Trip destinations starting from university ground

Fig. 5: Aggregated spatial structure of travel behavior

In addition to the places, where travel demand originates, the choice and spatial distribution of destinations also play a major role in the analysis of travel behavior, and hence the modeling of travel demand. Figure 5b shows an example of all trip destinations reported in the pilot study that started from the university ground. The red dots represent the focal points of the selected TAZs, the black lines represent the observed trips. A high proportion of the trips take place within the urban area of Karlsruhe. However, the evaluation also highlights the importance of demand-led relations to surrounding districts such as Karlsruhe-Durlach in the southeast. Furthermore, some relations, especially in the north of Karlsruhe, go beyond the city area. This example shows that the interactive travel diary can be used to quickly and clearly display the spatial distribution of travel demand. A temporally differentiated representation would also be possible. The information obtained can be used easily in travel demand models, e.g. to model destination choice on the same spatial database (TAZs) as the model itself, but also to calibrate other model parts.

5. Implications

Facing the presented results in the previous section, we further want to emphasize the methodical implications of the interactive travel diary in comparison to existing approaches for recording travel behavior in terms of travel diaries.

According to the reported travel behavior, we could show that in contrast to traditional survey approaches, our methodology of a web-based interactive travel diary seems to better support people in reporting short walking and bicycle trips. This finding is also in line with the results of Hoogendoorn-Lanser et al. (2015), who demonstrated that the visual representation of trips in travel diaries supports the reporting of short trips. Together with the fact that significantly more trips per person and day were surveyed in our study, we assume that our approach, therefore, particularly supports the reporting of short, unplanned shopping trips, e.g., the short trip to the bakery despite the online format. Moreover, since the share of reported trips home is lower than in the MiD, we assume that our visual approach also helps to reflect trip chains better. While in other approaches, e.g., the shopping stop on the way home, may not be reported, it is more likely to be reported in our approach. However, one has to consider that our survey was conducted during pandemic times. Although only minor Covid-19 measures were active and peoples' mobility was not restricted by law, people may have adapted their travel behavior.

One of the main goals of the web-based interactive travel diary is to reduce reporting fatigue and attrition, especially occurring in multi-day travel diaries. Identifying a below-average daily completion time for reporting trips shows that the approach forms a very time-efficient way to collect travel diaries. Moreover, facing stability in the completion time over the course of the reporting week and hence, the lack of learning effect, we conclude that our approach is fundamentally intuitive and very easy to apply for participants. In contrast to traditional approaches, we could not identify a decrease in the number of reported trips per person and day. Based on the findings of Bohte and Maat (2009), we hypothesize that the map-based approach motivates participants to complete the travel diary and that reporting trips is perceived as less of a burden. Thus, the approach is leading to an overall consistently good reporting quality. However, as we observed a slightly lower number of reported trips per person and day on the first day of the reporting period, we assume that on this day, in particular, fewer trips were reported than were actually made due to the longer version of the questionnaire on this day. In a future application, we would therefore suggest separating the travel diary from an additional questionnaire, and asking questions on socio-demographics, etc., probably one day prior to the starting period of the travel diary itself.

Furthermore, the pilot study showed that the effect of attrition could not be avoided using the interactive travel diary. However, it should be noted that the participation in the travel diary was not incentivized. If a suitable incentive is introduced, response rates may increase, and consequently, attrition may be mitigated (cf. Scheepers and Hoogendoorn-Lanser (2018)). Moreover, as we observed that non-mobile persons abstained from participating in the travel diary, we would adapt the e-mail invitation and reminder system by including another link that participants can click on if they were immobile on the reported day without having to provide further information. We assume to reduce respondent burden by this measure in order to avoid attrition.

The evaluation of aggregated spatial characteristics of the reported travel behavior showed that our tool is suitable to capture travel demand generation realistically. For transportation planning processes, the extension of our study to a representative sample of the entire population could result in the recording of mobility needs of different population groups. Further potential for the application of the interactive travel diary can be seen in the calibration and validation process of travel demand models, where TAZs are also used as the smallest spatial units.

In addition, the interactive travel diary guarantees the clarity of the graphical representation, particularly when the focus is on mobility to a single destination area or from a single origin area, respectively. Thus, the use of the tool would also be very suitable in the analysis of company-related mobility. The results obtained could then be used, for example, to capture the travel behavior of employees and, if necessary, to offer better mobility options to, from, or on the company site. Moreover, we could show that the interactive travel diary is suitable for analyzing one's spatial-temporal travel behavior in a disaggregated manner while simultaneously guaranteeing the privacy of a respondent's personal data. Consequently, the interactive travel diary demonstrates that data privacy is possible without relevant penalties for the precision of recorded data.

In general, one has to be aware that these conclusions are drawn from a sample based on students. This group is, on average, more educated and also younger than the rest of the population. Hence, the handling of the interactive travel diary may be easier for them than for other people resulting in a more optimistic outlook on the effects on attrition and fatigue. However, this population group, among others, is also not easy to address in traditional travel surveys. The results of our pilot study indicate that the interactive travel diary may be a suitable replacement for traditional survey approaches to stimulate the participation of typically under-represented population groups such as students. Nevertheless, being above-average technology savvy is a prerequisite.

6. Conclusion

In this paper, we presented an open-source interactive travel diary for web-based trip reporting. In a pilot study among 53 students, we were able to show that the approach is suitable for reliably recording travel behavior. Above that, we could even show that the presented tool seems to stimulate the reporting of more trips than typically in other approaches, which results in relevant implications for transportation planning. Moreover, the interactive travel diary can reduce further weaknesses traditional approaches are facing. The application can reduce reporting fatigue as the reporting process becomes more convenient for respondents (e.g., due to an increased time efficiency when reporting trips). Further, recording trips on the spatial level of TAZs within the interactive travel diary allows for in-depth spatial-temporal analyses of the respondents' travel behavior while respecting privacy issues of the respondents' personal data. Although the presented tool also may meet its limitations for some socio-demographic groups due to the cognitive effort required, the results from the pilot study showed promising effects for the travel diary collection of students, which is a group that is typically not easy to access in traditional approaches. It may be a good choice to obtain the travel behavior of an above-average educated and/or younger audience.

The interactive travel diary has positive impacts on the effort of the survey designer. Considering automated plausibility checks within the tool increases data quality, which reduces the survey designer's workload. Due to the extendable design, we ensured that the interactive travel diary can be easily customized to different subjects of investigation. In contrast to existing approaches of travel diaries, the open-source approach provides a cost-efficient way of recording travel behavior and facilitates the realization of a travel behavior survey even if a project's budget is low. With the implementation in an open standard format, the interactive travel diary can technically be integrated into every survey engine that supports the standards of HTML and JavaScript.

In further research, we will expand the survey to a larger and representative sample in order to support the observed effects of the pilot study. Hereby, we will also evaluate the potential of the interactive travel diary conducted as a CATI-based survey. Special focus will be given to the different responses between younger and older participants since especially young people are not easy to address for participation in travel diary surveys. We will investigate whether the younger, technology-savvy generation particularly might better respond to such interactive, web-based concepts. We will also analyze how the interactive travel diary contributes to a possible gender bias toward male participants in the sample selection due to its technology-based character. Moreover, a short follow-up questionnaire is planned to evaluate the usability of the tool and which problems were striking for the participants, e.g., possible problems using the map due to difficulties in finding locations. Further developments of the tool, such as the integration of more features for automated plausibility checks and a consideration of a graphical and tabular summary of all reported trips of a day as double-check mechanism for respondents' specifications, are planned.

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