Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 11 (2015) 263 – 279

Transportation Research Procedia

www.elsevier.com/locate/procedia

10th International Conference on Transport Survey Methods

Field evaluation of the smartphone-based travel behaviour data collection app "SmartMo"

Martin Berger [a]*, Mario Platzer [a]

verkehrplus GmbH, Elisabethinergasse 27a, 8010 Graz, Austria

Abstract

This paper outlines an innovative approach to the evaluation of a self-administered smartphone-based survey for the collection of travel behaviour data. For this approach, a traditional travel survey is modified to match mobile devices. The smartphone application "SmartMo" is designed in a multi-stage iterative development process. It is then implemented and evaluated through a number of field tests involving 97 participants. Results of the field evaluation will be discussed including the technical performance (e.g. secure data transfer and data management, energy consumption, map-matching), usability (e.g. comprehensibility, handling, joy of use) as well as user acceptance (e.g. willingness to participate, data protection and privacy). A brief overview of the SmartMo data collection system will also be provided.

Peer-review under responsibility of International Steering Committee for Transport Survey Conferences ISCTSC

Keywords: self-administered smartphone-based travel survey; data collection; privacy by design; trip non-response, battery consumption, field test

* Corresponding author. Tel.: +43 69918870744.
E-mail address: martin.berger@verkehrplus.at

Peer-review under responsibility of International Steering Committee for Transport Survey Conferences ISCTSC
doi:10.1016/j.trpro.2015.12.023

1. Background

Multifaceted demands on travel surveys have emerged over the last years. Challenges are primarily due to transport policy objectives, societal changes and the emergence and employment of increasingly complex transport planning methods.

Valid and detailed individual travel behaviour data is urgently required for research and evidence-based decision-making by policy-makers. Further challenges emerge when the goal is to provide high quality individual travel behaviour data and improve user acceptance of travel behaviour surveys.

1.1. Requirements

Traditional and numerous current travel surveys use paper based travel diaries, in which all realized trips have to be reported by the respondents mostly over the course of one day. Many relevant studies (Stopher et al. 2007, Wolf et al. 2003, Bricka 2008) affirm the already long-held suspicion that travel diaries are quite error-prone. On the one hand many trips are not consciously perceived, since the travel behaviour is very complex and often habitual. On the other hand, retrospective information is subject to memory recall constraints and the individual ability of subjective estimation. Traditional travel surveys in the form of a travel diary can no longer keep pace with actual social and technological developments. Central problems and challenges include,

- the increasing necessity of valid and more detailed travel behaviour data, such as a full coverage of short distance trips (e.g. walking and cycling trips for intermodal travel), the exact route and the use of "new" modes of transportation (e.g. Car- and Ridesharing, electric cars),
- the declining motivation and acceptance among participants to take part in surveys due to an overall increase of surveys and direct marketing as well as increased privacy concerns and data protection demands.

1.2. Chances

At the same time, the technical possibilities available for travel surveys have changed rapidly. The proliferation of innovative information and communication technologies, GPS positioning systems and GIS systems offers numerous opportunities to optimize the procedures for collecting mobility data. Advantages of a mobile, smartphone-based survey include:

- Smartphones - equipped with numerous sensors – are ubiquitous, they can be used anywhere and anytime.
- Robust, portable and affordable GPS tracking instruments record data automatically without much effort for the users. Data (e.g. trip distance and duration) is unaffected by self-reported errors (e.g. short trips by foot) and therefore GPS are high precision instruments.
- Integration of GPS systems with GSM and WLAN modules in smartphones taking advantage of numerous beneficial smartphone characteristics: user-friendly touch screen and key pad, low weight and high battery performance.
- Standardized and flexible software development environments enable the implementation of complex and adaptive questionnaires on smartphones.
- Increasing usage of GIS devices, e.g. digital maps including public transport networks, footpaths (e.g. OpenStreetMap,) and tools for data integration (e.g. GIP: graph integration platform).
- Development of powerful map-matching algorithms for matching tracks and map data.
- Progress in statistical and visualization tools (Google Maps, Google Earth, RGL: 3D real-time visualization device system for R) for 3D visualizations of trip and activity data.

1.3. Development path of mobile travel surveys

Self-administered mobile travel behaviour survey methods which rely on different devices like mobile telephones with GSM (e.g. TTS TeleTravel System from Wermuth et al. 2003) and PDAs with GPS (e.g. PARROTS from Bellemans et al. 2008) and which were identified as alternatives to traditional travel behaviour surveys, have been adopted by a rapid progress in the field of information and communication technologies (ICT).

Smartphones with GPS/GSM/WLAN, which are now integral to everyday life and which offer possibilities to measure individual travel behaviour, are more convenient for the participant and help produce higher data quality (Barbeau et al. 2008, Chen et al. 2012, Cottrill et al. 2013).

Progressively, sensors of smartphones are used to reduce the burden on the user by automatically sensing contextual information (Chen & Fan 2012). Whereas several approaches exist for the automatic detection of transport modes (Thiagarajan et al. 2010; Zheng et al. 2010; Reddy et al. 2010), it is difficult to identify trip purpose or activities from GPS data alone (Schüssler & Axhausen 2008). In the latter, Kawasaki und Axhausen (2009) infer shopping activities and Xiao et al. (2012) attempt to indicate stops by using specifically developed algorithms.

For technical validation (e.g. algorithms to eliminate outliers and map-matching) and user-based validation (e.g. user-friendly backend-system, prompted recalls) of the collected data, post-processing procedures will be used. Effective map-matching algorithms (Marchal et al. 2005) and digital maps of multimodal transport networks (e.g. OpenStreetMap) facilitate integrated data management. For example, prompted recalls motivate the user to monitor, correct and complete data during the mobility survey or ex post (Auld et al. 2010; Li & Shalaby 2008; Stopher et al. 2004; Bohte et al. 2009; Zegras et al. 2012). On the one hand, these studies could demonstrate the advantages of technology-based data collection tools, on the other hand, additional monitoring requirements frequently overburden the test user.

2. Objectives and Research Questions

The core objective of this study was to develop a user-friendly smartphone-based survey application for collecting travel behaviour data and to design an effective data collection procedure for travel surveys. The introduced system SmartMo had to be comprehensively put to the test in the field.

Based on in-depth field evaluations, this paper discusses specific aspects of the user experience, as well as opportunities and limitations of a self-administered smartphone-based travel survey. The key criteria for developing and implementing a self-administered, smartphone-based data collection tool include: (i) privacy by design, (ii) strategies to increase data quality, (iii) challenges to reduce battery consumption while tracking routes and (iv) evaluation of user experience (e.g. usability, joy of use, respondent burden) in empirical field research.

3. Overview of "SmartMo"

3.1. Total System

In addition to household and personal characteristics, trip information has to be manually reported or measured automatically by the active tracking system on the smartphone. The system SmartMo combines smartphone and desktop computers for collecting data. The content of the survey is derived from the KOMOD study (see Fellendorf et al. 2011), which defines standards for travel surveys in Austria and is defined as trip-based. All raw data will be transmitted to an external server. Energy intensive post-processing, like the map matching, distance measurement and validation of the trips, also run on the server (see Figure 1). Map matching algorithms merge the measured geolocation of the tracks on a digital map or through a reference transport network such as OpenStreetMap. Integrated plausibility checks for the monitoring and analysis of the collected trips (e.g. identical starting and end point, plausible trip chains, identify and eliminate outliers) promote the collection of high quality data.

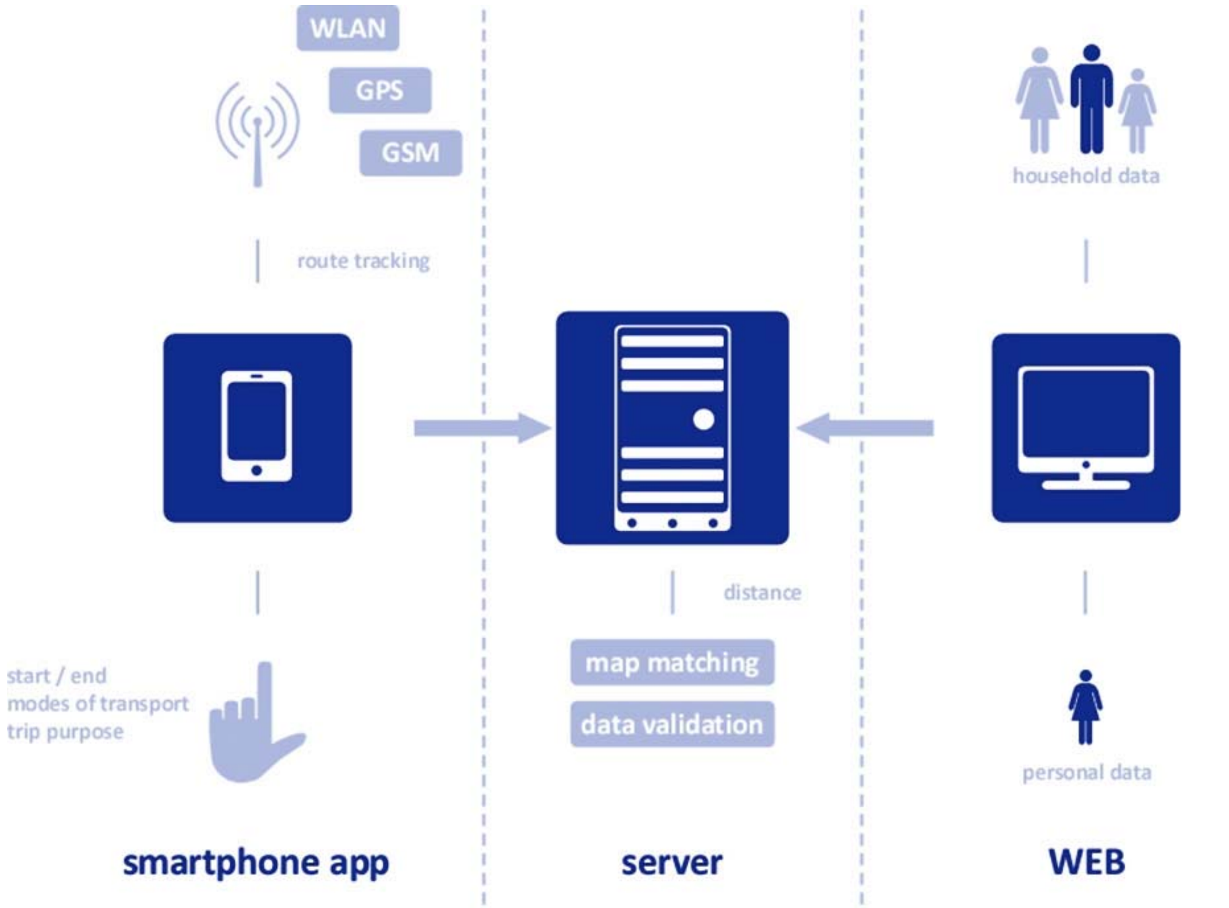

Figure 1. Total system of SmartMo

3.2. Smartphone application "SmartMo"

The SmartMo app is a mobile survey tool developed for collecting travel behaviour data based on standard smartphone operating systems iPhone and Android[1]. Figure 2 illustrates the GUI of the iOS version.

[1] iTunes: https://itunes.apple.com/at/app/smartmo/id480121835?mt=8
Google Play: https://play.google.com/store/apps/details?id=com.easymobiz.smartmo&hl=de

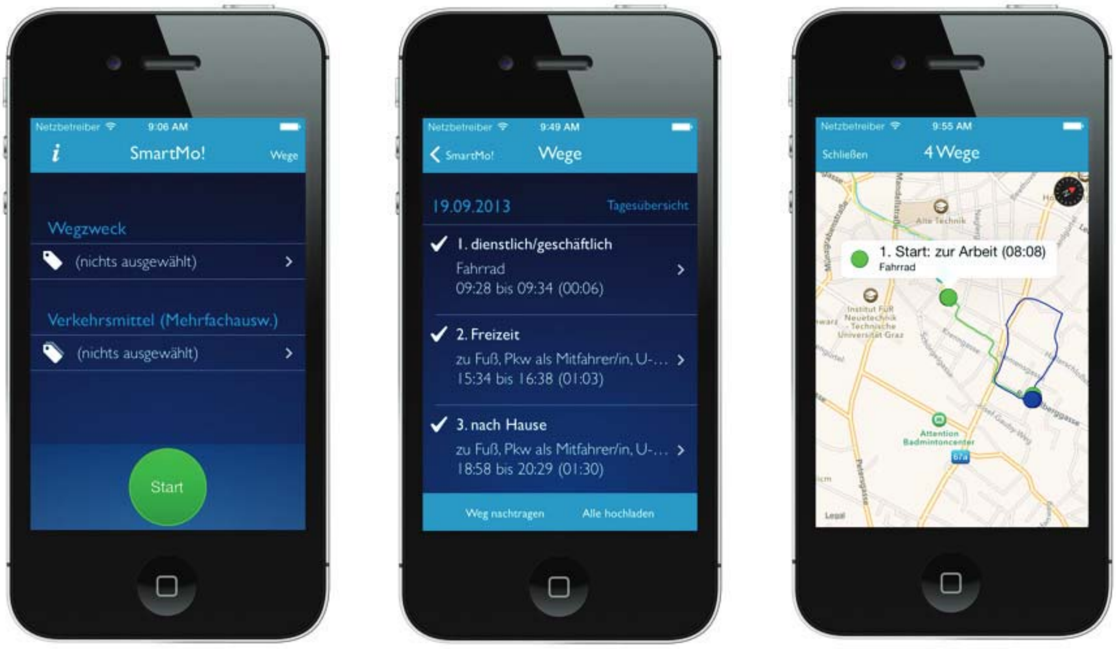

Figure 2. SmartMo GUI: (a) start screen; (b) report of trips; (c) visualization of tracks

It is possible to keep the app running in the background and to switch to another application. The main features of the app SmartMo are:

a. hybrid, automatic locating system (A-GPS, GSM, WLAN) for route tracking,
b. asynchronous data input of trip characteristics (e.g. trip purpose, mode of transport) allow users, particular those under time pressure, to postpone entering of trip information until later,
c. editing functions (e.g. for completely missing data and to edit incorrect travel data) to improve data quality,
d. implemented privacy strategies (e.g. active tracking, cutting the start and end point of a trip) to guarantee data autonomy and data security and
e. energy saving settings to enable an efficient smartphone use.

a. <u>Localization</u>

The smartphone app uses three sensors for localization: A-GPS, GSM and WLAN. This hybrid localization system manages to complement each component in an optimal way. Weakness of GPS positioning detection (e.g. no or weak connection to satellites, signal reflections and shadows) are partially compensated by GSM and WLAN. While GPS enables the highest localization accuracy, WLAN provides data for enclosed spaces. The hybrid system also makes the identification of outliers much easier.

b. Data collection

Trip data was manually reported and automatically measured immediately before (pre-trip), during (on-trip) and after (post-trip) the movement. Figure 3 shows the sequential process of the trip data collection. Before starting an activity, the user has the option to manually enter the trip purpose and transport mode via touch screen (see Figure 2a). At the beginning and at the end of the movement, the button "start" and "end" had to be pushed. During this period the route would be tracked automatically via A-GPS, GSM or WLAN. After completing a trip, erroneous data could be corrected or missing data complemented. Finally the user could upload the data to the server. It is also known that participants can reduce data quality by deleting data or by changing correct data. Generally the positive effects (e.g. data sovereignty, correct identification of trip purpose and complete missing data) should overcome the negative effects.

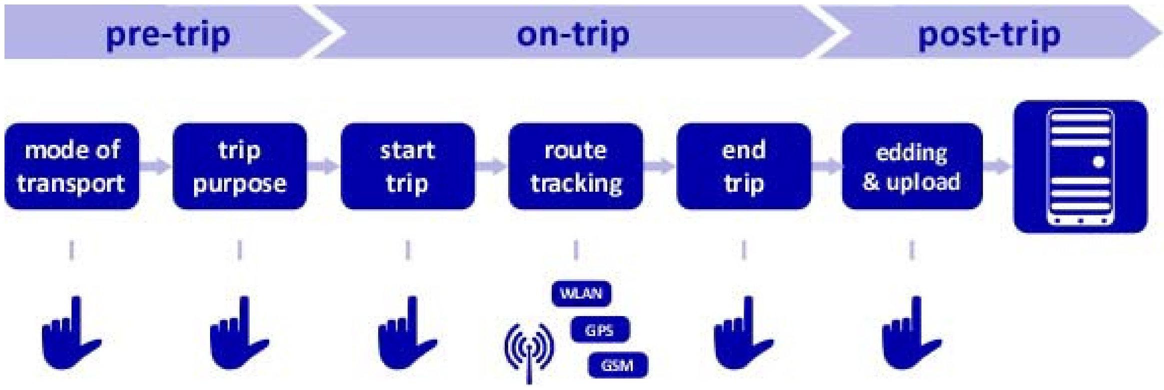

Figure 3: Process of collecting trip data

c. Data quality

To improve data quality, different strategies can be pursued. For a clear overview, all recorded tracks including the trip parameters are listed in a diary on the smartphone (see Figure 2b).The iOs enables to display all tracks realized during a day in a map (see Figure 2c). Users can subsequently correct and complete trip parameters. During the field, test users will be reminded daily by SMS to add forgotten trips and to upload all trips to the server.

Automatically measured GPS-tracks and objectively calculated trip distance and trip duration help avoid inaccuracies due to individual and subjective assessments. Additional map matching algorithms and filter criteria for identifying and eliminating outliers are implemented externally on a server.

d. Data privacy and protection

Figure 4 illustrates the implemented data protection and privacy strategies. Right at the initial stage of downloading the app, users receive an introduction to the privacy regulations. To get access for downloading, an approval is required. During the initial development process much attention was paid to user's data sovereignty. Since the system is based on active tracking, the user can choose which trips will be recorded and which ones shall not be documented. The user also has the option to delete routes and upload them to the server. In addition, the app provides an editing function to cut starting and end points from the tracks. This way, it is impossible to infer the person solely from the recorded paths.

Only authorized participants recruited by the survey team receive a registration code. This code is required to upload the tracks on the server. Personal and household data is collected independently of the trip data and an aggregation of all data is only possible with an anonymous key variable. Secure data transfer and storage are guaranteed through automatic encryption. Since the data will not be disclosed to third parties and only published as aggregate results, it is not possible to identify a person this way.

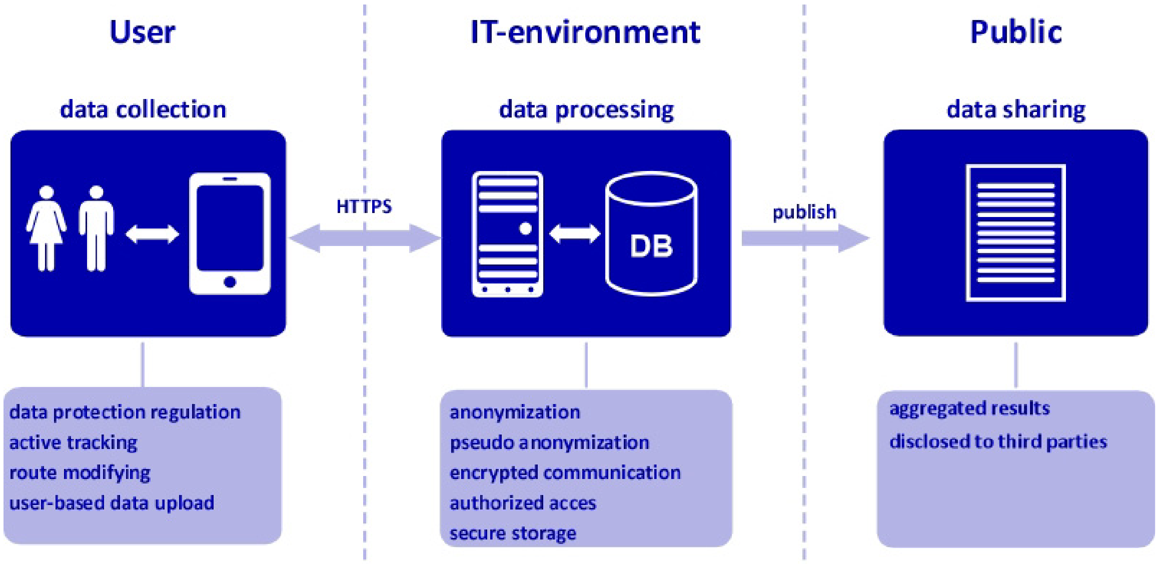

Figure 4: SmartMo data protection and privacy concept

e. Energy saving

The battery life of a smartphone depends on the individual usage and the energy required to run the SmartMo app. When developing energy saving strategies, both aspects were taken into account.

In order to reduce energy consumption during the field tests, users received a SMS daily with energy saving tips. In particular, the users were informed about energy efficient smartphone settings and they were reminded to charge their smartphone at night. Such specific information which was intended to raise awareness regarding energy saving measures would counteract energy-intensive habits.

From a technical point of view, one underlying development criteria was to achieve a balance between data accuracy and tracking frequency. A special prototype setting enables the verification of the tracking frequency. In several tests the correlation between energy consumption, tracking frequency and data accuracy was investigated. For future developments, the tracking frequency should be chosen depending on the means of transport.

Furthermore, a low energy app could be developed because high energy processes, such as map matching and the calculation of the distance of a trip, run on the external server.

4. Field test

The technical and practical functionality of the travel data collection system SmartMo as well as the conduct of the survey design were tested under real world conditions. The objectives of the field test were to increase knowledge of user acceptance (e.g. participation, motivation and privacy concerns), usability (e.g. data entry effort, user-friendliness, handling and pleasure of use) and reliability of the technical system (e.g. data transfer and storage and security). The field test - only the collection of trip data – had started in October 2013 and finished mid-November.

4.1. Workflow of the field test

Figure 5 illustrates the workflow of the field test, whereas different media channels for communication and means of data collection were used:

1. The recruitment process raised awareness of the field test. People were informed via flyers, social networking sites (e.g. Facebook) and e-mail distribution lists of universities. To increase willingness to participate, an incentive of 20 € cash payment was provided at the beginning of the field test. It was anticipated that this pre-payment would increase participants' levels of trust and establish an obligation to avoid early termination of the survey process. Due to this self-recruitment approach it is not possible to draw a random sample of the population, which would normally guarantee a representative sample.
   The activation process aimed to inform the participants in more detail and to motivate them to take the first steps participating. Introductions and demonstrations (e.g. video tutorial, flyer with the user manual, FAQs) on how to use the app and how the field test will be conducted were administered on the project homepage. Interested individuals received a link to an online master data portal with an invitation to enter their personal data. They then obtained a personal registration code via e-mail. The registration code also enabled the researcher team to define how they can participate in the mobility survey.

2. The data collection process consisted of gathering personal, household and trip information. The data collection system SmartMo combines a smartphone app to collect trip based information (e.g. trip purpose, mode of transport, route) and online-based household and personal questionnaires. While only one member of the household has to reply to household questionnaires, personal and trip data have to be filled out by each person. For this field test, the sampling unit was an individual but additional individuals could participate if they chose to and owned a smartphone. The fact that not every member of a household owned a smartphone was irrelevant. The participants had to track all their trips during a pre-set multi-day period on typical weekdays (Tues., Wed. and Thurs.). For more details about collecting trip data see capture 4.2 section b.

3. Communication and support were provided throughout the entire duration of the field test. At the beginning of the field test, participants received a reminder SMS how to download and use the app as well as to register with their personal code. They also received detailed information on the test period (e.g. on which days to collect trip data) and a link for the online personal and household survey.
   During the field test, the participants received support via a telephone helpline and through an automatically generated SMS sent out several times a day (morning, noon and evening). This short information contained energy saving and charging tips, and reminded the participants to complete and upload all their completed trips.
   At the end of the test period, the participants received a 'thank you e-mail,' with the reminder to monitor and upload all their trips and to answer the household and personal questionnaire.

4. In the evaluation process the user experience was measured via an online-based questionnaire.

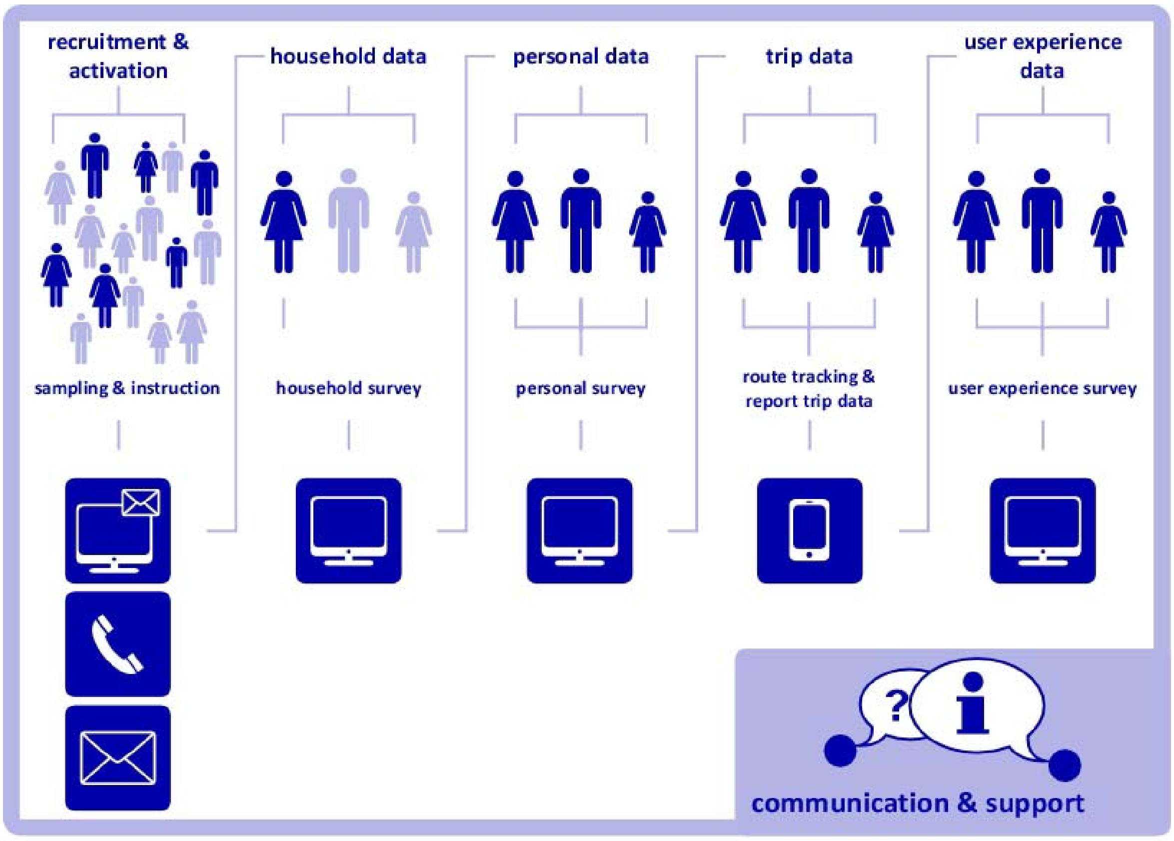

Figure 5: Workflow of the field test (modified from Cottrill 2013)

4.2. Description of the sample

The field test did not provide a statistically significant and valid sample, but the overall experience provided a number of useful findings for the ongoing development of the system. One objective was to achieve a high amount of so-called "lead-users". For this group it is typical to own their own smartphone and to be very skilled at using it. About 90% of the participants had owned their smartphone for over a year. Details regarding gender, age, affinity to technology and smartphone type are summarized in

Table 1.

The sample consisted of 97 self-recruited participants. In general, most participants were of young age. Both sexes were represented equally in the sample. Approximately two thirds of the participants used an Android smartphone - mostly Samsung smartphones - and one third an iPhone. The psychological background and affinity for technology were assessed through multiple survey questions in order to increase the reliability of the measurement. All questions were answered on Likert-type rating scales with five categories, whereas a value near one signalizes “high” and a value near five “low” affinity for technology. About 66% of the participants were interested in modern communication technology (e.g. internet and smartphones), used them more frequently than the average population and regard such technologies very positively. Only a small percentage had a low affinity to said technology.

Table 1. Specification of the sample

Aspects	Absolut (relative) Frequency
Gender	
- male	49 (50%)
- female	48 (50%)
Age	
- <= 20 years	9 (9%)
- 21 – 25 years	49 (51%)
- 26 – 30 years	23 (24%)
- >= 31 years	16 (16%)
Affinity for technology	
- high (<= 2.17)	64 (66%)
- neutral (2.18 – 3.83)	29 (30%)
- low (>= 3.84)	4 (4%)
Smartphone operating system	
- iPhone	31 (32%)
- Android	66 (68%)
Smartphone type	
- Samsung	32 (33%)
- iPhone	31 (32%)
- HTC	15 (16%)
- Sony Ericsson	12 (12%)
- Others	7 (7%)
Total	97 (100%)

5. Main results

5.1. Restrictions and user effort

For practicality and convenience reasons it is important that the app SmartMo can be used without restricting everyday life. The results show that for 79% of all users, SmartMo did not adversely affect their routine or everyday behaviour; only 5% felt restricted (see Table 2). About 39% of the participants have their smartphones on them at all times. About 25% do not carry a smartphone more than once a week. A few reasons given for not carrying a smartphone include forgetting to take the device, exercising or short shopping trips.

It is commonly known that with increasing complexity and effort required for data entry, the willingness to participate in mobility surveys decreases. Users evaluate the effort for recording their trips differently and depending on context. This activity includes starting and completing the automatic route tracking, as well as the manual entry of the trip parameters (e.g. mode of transport, trip purpose) and the data upload. For the majority of participants, that is 57%, the entering of trip data is not or a little exhausting, whereas about 25% of the overall participants reportedly consider the entering of data to be exhausting (see Table 2).

In this regard, it is important to consider how much time a user needs to record all trips during one day. A major advantage of the mobile data collection app SmartMo is the fast recording of trip data. 70% of the participants perceive the overall duration needed for trip detection to be very short (20%) or short (50%), while only 7% of users spent considerable amounts of time to document their trips. For nearly 80% of the participants, detection and reporting of all trips during a day takes about less than 10 minutes. In comparison to mobility diaries, which are commonly used in mobility surveys, the mobile data collection tool SmartMo has great advantages due to the low effort required for the input of trip data.

Table 2. Restriction and user effort

Statements	relative Frequency				
	Totally agree	Agree	Neither agree nor disagree	Disagree	Totally disagree
Reporting and recording trip data as well as data upload during a day was very exhausting.	3%	22%	18%	37%	20%
In daily life I was restricted by the usage of the SmartMo app.	1%	4%	16%	40%	39%
It takes a lot of time to record the trips.	0%	7%	23%	50%	20%
Total	97 (100%)				

5.2. Usability

Essentially, the SmartMo app is very user-friendly. Using a comprehensible grading system ranging from "1", for very good, to "5", for insufficient, it could be illustrated, that about 81% of the participant evaluate SmartMo to be very good and good, 16% satisfactory, only 3% sufficient and no one insufficient. The usability in comparison between iPhone and Android smartphones do not differ considerably. An additional two thirds of all participants like the optical design of SmartMo and only one third dislike it. In order to examine the construct usability, different aspects had to be taken into account. The results of the field tests show that the SmartMo app,

- is easy to use (96 %),
- requires little time for efficient use (96 %),
- offers a sufficient help function (60 %),
- enables easy clicking of buttons (98 %),
- requires no redundant inputs (83 %),
- uses clear terminology (93 %) and intuitive icons (70 %).

Moreover, 54% of the participants enjoyed using the SmartMo app and more than half became more conscious of their daily travel behaviour (see Table 3).

Table 3. Joy of Use

Statements	relative Frequency				
	Totally agree	Agree	Neither agree nor disagree	Disagree	Totally disagree
I enjoy using the SmartMo app.	22%	32%	32%	12%	2%
By collecting my trips I become aware of my travel behaviour.	12%	39%	12%	19%	18%
Total	97 (100%)				

5.3. Data validation

During the entire test period of three days, the 97 participants realized 1.201 trips. These trips were completed and validated. On average, one person realized about 4 trips during the course of a day. Four trips per person per day score below the results of other GPS studies (Stopher et al. 2010, Auld et al. 2009, Bohte & Maat 2009, Schuessler & Axhausen 2015, Bricka & Bhat 2006). Despite having the possibility of completing missing trips, participants seem to forget reporting all their realized trips. On average, participants spent 22 minutes for the tracking of all trips during a day.

Missing trips

An objective comparison of the sequences of the trips showed that for 56% of all 1.201 trips, the end point of a finished trip and the starting point of a new trip match. It can be concluded that the participant does not forget to record trips. 14% of all trips are not connected and for 30%, data cannot be used to draw any conclusions.

Additionally, the participants were asked how many trips they did not track during the three days. Considering that this estimation is entirely based on memory recall, 37% of all participants said that they tracked all trips. 28% forgot one trip, 16% two trips, 8% three trips and 11% more than three trips over the period of three days (see Table 4). The results show that participants forgot significantly fewer trips on the third day. Thus, Bricka und Bhat's (2006) conclusions which suggest that with progress of researched days participants increasingly fail to record their trips as frequently, could not be confirmed in this case. Potentially, this effect occurs exclusively with longer test periods.

To prevent participants from forgetting about recording trips, reminders via SMS messages were sent in the morning, noon and evening, knowing that this strategy may be inconvenient for the participants. In order to quantify these effects, a target-control group design was implemented, whereby both groups (SMS-group vs. non SMS-group) were nearly of the same group size and socio-democratic distribution. The results illustrate that SMS, as a reminder for recording trips, is rather ineffective. Additionally, almost half of the participants who were part of the SMS-group were annoyed by the reminder (see Table 4). Only a quarter of the participants perceived the SMS reminder to be helpful for remembering to record their trips.

Table 4. Missing trips

Question / Statement	Answers				
How many trips did you forget over the 3 days?	none	1 trip	2 trips	3 trips	> 3 trips
	37%	28%	16%	8%	11%
The text message reminder was…	not annoying	little annoying	neither	annoying	very annoying
	10%	15%	27%	38%	10%
Total	97 (100%)				

Modifying of trip data

Available editing features enable the user to modify trip information. In other words, the user has the chance to correct false data and complete missing data, delete data and cut the end sections of the track so that the precise location of the starting and arrival point cannot be identified. The measurement of user activity provides necessary insights into the importance of these technically implemented strategies. 92% of the participants completed missing trips, 33% corrected false data, 20% modified their tracks by cutting the start and end sections of the tracks and 10% deleted trips (see Table 5). The main reasons for modifying data are to correct (80%) and to complete missing information (30%). About 10% address privacy concerns. For about 75% of the participants the editing features were very important or important; while only 4% evaluated these features as unimportant or very unimportant. The deleting, correctting and completing of features are clear and comprehensible for most participants. However, the cutting device feature is more difficult to understand (see Table 5).

Table 5. Editing features

Questions	Do you use the following editing features?		The following editing features were comprehensible.				
	yes	no	Totally agree	Agree	Neither agree nor disagree	Disagree	Totally disagree
Complete data	92%	8%	32%	31%	17%	7%	1%
Correct data	33%	67%	50%	29%	11%	8%	2%
Delete data	10%	90%	58%	27%	13%	2%	0%
Cut start and end section of the trip	20%	80%	31%	24%	26%	14%	5%
Total	97 (100 %)						

5.4. Energy consumption and charging behaviour

Reaching critical energy state

In the field test, it could be shown that using the SmartMo app lowers the battery of the smartphones by about 12% of total capacity per hour (see Figure 6). While smartphones with android operating system absorb 9% of total energy per hour, the iPhone, with an average of about 13% per hour, maintains the highest energy consumption. This may require the user to recharge the device more often than they usually would. However, this result does not take into consideration varying smartphone usage among the participants.

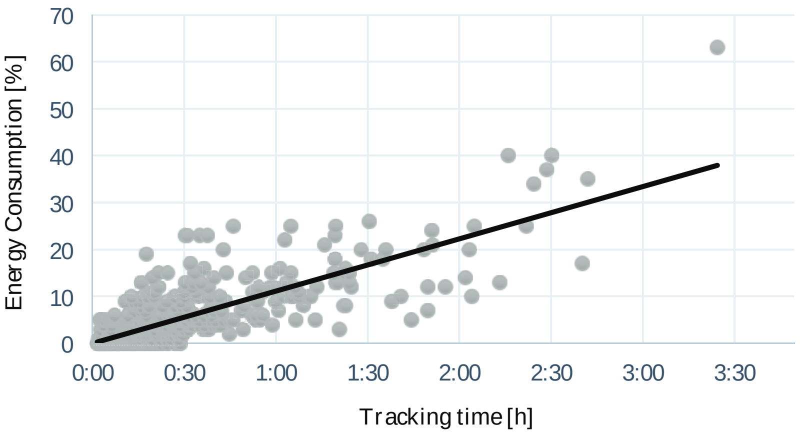

Figure 6: Energy consumption (n=1.201 trips)

During the test period of three days, only 9% of the participants reported that they had problems with the battery life of their smartphones. The most common reasons for low battery status occurred because of other smartphone features and participants forgetting to charge their phones.

The SmartMo app delivers data of the energy consumption, especially the energy status at the beginning and the finishing of a trip. In only 3% of all recorded 1.201 trips a critical battery status about lower than 15% has been reached.

Charging behaviour

7% of all participants charge their smartphone several times a day, 60% once per day, 29% every second day and 4% less than every second day. Results regarding the battery status at which the participants charge their smartphones illustrate that 29% charge their smartphone if the battery is totally empty and 56% at a battery level of 25%. Only 4% use every possibility to charge the battery (see Table 6).

To investigate whether the participants charge their smartphone at night or during day, the participants were classified into "day charger", "night charger" and "mixed charger" groups, respectively. While a day charger uses every opportunity during the day to boost their smartphone, a night charger connects the smartphone and the recharger during sleep. Table 6 shows that the sample consists of approximately 12% day charger, 65% night charger and 23% mixed chargers. Additional the measured energy consumption via app shows, that 3% of all 1.201 trips are charged on trip.

Table 6. Charging behaviour

Question/ Statement	Answer				
Usually I charge my smartphone when the battery power is…	0% - empty	25%	50%	75%	depending on the occasion
	29%	56%	9%	2%	4%
How often do you charge your smartphone?	< two days	every two days	once per day	several times daily	-
	4%	29%	60%	7%	-
Total			97 (100%)		

5.5. Data privacy and protection

The results of the field test confirm that especially for online-based surveys, data privacy and protection play a critical role. Only for very few participants (8%), data privacy and data protection are less or not important. Accordingly, it is important for 92% of participants to obtain detailed information about the use of their data (see Table 7).

Consequently, it could be concluded that persons in the sample are generally very concerned about data privacy and protection issues. Therefore, issues of data protection have already been taken into account during the development phase. The system SmartMo offers a comprehensive privacy and data protection concept which guarantees data sovereignty for the user. Below, results are shown on how participants evaluate the implemented technical strategies (e.g. active tracking, self-determined editing and uploading of the trips) as well as the survey design (e.g. anonymous registration code, agreement to data protection regulations):

- Data protection regulations: Before downloading the app, the participants had to read and agree to the general data protection regulations. Results show that this regulation must be written in a clear and comprehensible manner, since every second person considers this to be essential for downloading an app (see Table 7).
- Anonymous registration code: Findings indicate that collecting anonymous data significantly minimizes privacy concerns of the users. For 63% of all participants, future use of the anonymised data becomes insignificant.
- Upload trip data: For 58% of the participants it is important to control the data upload. Only for a quarter of the participants it does not matter how the data will be transmitted to the server (see Table 7). The user had the option to upload single trips or a combined total, whereas 40% chose the latter.
- Active tracking: SmartMo pursues the approach of an open, self-determined data collecting system, which means that it is the user who defines what kind of data and to what extent it will be collected. The system should not collect data automatically without the knowledge and acceptance of the user. For about 89% of the participants it is very important to retain data sovereignty (see Table 7). Data sovereignty in this context means

that the user has complete control over what kind of data is collected and transmitted to the server. This user requirement can be satisfied through active tracking.

Table 7. Importance of data protection regulations and anonymised data

Statements	relative Frequency				
	Totally agree	Agree	Neither agree nor disagree	Disagree	Totally disagree
It's important for me to know how others handle my personal data.	51%	41%	5%	3%	0%
It's important for me to know which personal data is collected or sent and what happens with it.	45%	44%	7%	4%	0%
It's important for me that I can control which trips will be uploaded.	34%	24%	17%	22%	3%
I'm choosing apps in response to the privacy policy.	11%	45%	13%	24%	7%
I don't care about what happens with the collected trips if it's anonymous.	22%	41%	11%	19%	7%
Total			97 (100%)		

6. Conclusion

This paper provides an overview of the smartphone-based data collection system SmartMo and presents field test results. Considering the increasingly high popularity and overall advantages of smartphones, a mobile travel data collection tool was developed through a multi-stage process that increases data quality while it also reduces the participation efforts for the survey participant.

The SmartMo system was tested under real word conditions with 97 participants in Austria over a multi-day period. The evaluation survey of the field test addresses questions like data accuracy, acceptance and usability of target persons, privacy issues or energy consumption.

Strength and Limitations

The main results of the field test show that,

- the SmartMo app is intuitive and easy to use, easily comprehensible and does not exhaust the user. More than half of the participants enjoy using the SmartMo app.
- the quality of the data could be increased through automatic and objective trip tracking. Daily reminder services, like automatic generated text messages, have less or no effects on the prevention of missing trips.A passive tracking system could likely solve the problem of underreporting.
- most implemented strategies for privacy protection and data sovereignty are important for the test users; it seems that for increasing user acceptance it is crucial that the tool enables active tracking,
- very few users had problems with the energy consumption of smartphones; this is probably due to the fact that many users have followed the tips for optimizing (e.g. charging overnight) and energy saving (e.g. turning off keypad tones).

Taking the composition of the sample into account, these results could not be generalized and could only be interpreted within the context of the survey sample. The sample is not representative and only people with smartphones could participate in the field test. From the positive user experience of mostly younger people, good usability for other social groups without a preference for a smartphone cannot be inferred automatically.

Smartphones are now mostly in use by younger people. Older persons, particularly seniors rarely use smartphones. This gap is more obvious for women than for men. Furthermore, it has to be taken into account that usually owners of smartphones do not use all functions of the device and there is no sign for equal use either. Because of this coverage error, caused by the common way smartphones are used, it is not possible yet to carry out representative travel surveys. However, for the future it can be anticipated that smartphones will have reached nearly the whole population and therefore the coverage gap will decrease.

Implications

SmartMo is a highly user-friendly data collection system. Nonetheless, a combination with Gamification elements (e.g. gather points and awards, see ecological footprint) could increase user acceptance.

SmartMo collects high quality data (e.g. positioning accuracy). The dilemma between, on the one hand, a minimized data entry effort for the user, and on the other hand, a high data quality, can be partially solved by the automatic sensing of trip information. For example, there is still potential for the improvement of route tracking for trips by train and in particular by metro. More powerful map-matching technologies that integrate the network and timetable data of public transport, the integration of more complex algorithms for error analysis and a backend-system that enables self-monitoring through the user, could also improve data quality.

It can also be assumed that individuals who decline to participate in travel surveys (unit non-response), are strongly influenced by privacy and data protection concerns. This particular problem is typical for apps which localize the exact position of a user. To avoid this negative sampling effect, different strategies to guarantee privacy and data protection (e.g. manipulation of the tracks, anonymous registration code) are implemented in the entire SmartMo system. Nevertheless, particular and further attention to this approach remains a task for the future.

In the field, test problems with battery life occurred only sporadically. In addition to the energy saving strategies (e.g. reminder via SMS, identifying the optimal tracking rate) implemented so far, for upcoming versions it should be possible to stop tracking if the person does not move. Actual trends assume a further improvement of the energy performance of smartphones, so that the negative impact of larger displays, faster processors and higher data transfer rates could be counteracted.

Future Research

Many studies which focus on self-administered smartphone-based travel surveys are currently in various development and testing stages. However, in contrast to GPS studies which are implemented globally, fundamental insights obtainable from large-scale data are sorely lacking. In particular, issues of scalability and quality criteria of empirical social scientific research like coverage, sampling or non-response remain to be answered in the future. Comparisons of smartphone-based surveys with traditional travel surveys provide detailed insights of data quality and constitute excellent opportunities for future research.

Future trends signalize that smartphones will be equipped with more sensors (e.g. gyroscope, altimeter, hygrometer, thermometer and heart rate monitor) capable of sensing in more detail what is taking effect in the environment of the device. In this regard, investigation of automatic transportation mode and activity detection should be intensified with the aim to reduce usage effort while increasing data accuracy. It can be anticipated that this approach will address currently unanswered questions concerning issues of privacy by design.

Acknowledgements

This paper is based on results of the research project SmartMo. The project was funded by the BMVIT (Austrian Ministry for Transport, Innovation and Technology) and administrated by the FFG. Without financial and organisational support, a study to this extent would not have been possible.

References

Auld, J., Williams, C., Mohammadian, A. K., Nelson, P., 2009. An automated GPS-based prompted recall survey with learning algorithms. Transportation Letters.' The International Journal of Transportation Research, 1(1), 59-79.

Auld, J., Frignani, M., Williams, C., Mohhammadian, A., 2010. Results of the Utracs Internet-based Prompted Recall GPS Activity-travel Survey for the Chicago Region. Lisbon, Portugal, July 11-15.

Barbeau, S., Georggi, N., Winters, P., Labrador, M., Pérez, R., 2008. TRAC-IT: A smart user interface for a real-time location-aware multimodal survey tool. Paper Presented at the 15th World Congress on Intelligent Transportation Systems, New York, USA, 16-20th November 2008.

Bellemans, T., Kochan, B., Janssens, D., Wets, G., Timmermans, H., 2008. Field evaluation of personal digital assistant enabled by global positioning system: impact on quality of activity and diary data. Transportation Research Record, 2049, pp. 136-143.

Bohte, W., and K. Maat, 2009. Deriving and Validating Trip Purposes and Travel Modes for Multi-Day GPS-Based Travel Surveys: A Large-Scale Application in the Netherlands. Transportation Research Part C, Vol. 17, No. 3, pp. 285–297.

Bricka, S., Bhat, C.R., 2006. Comparative Analyses of GPS-Based and Travel Surveys-Based Data. Paper #06-0459. TRB.

Bricka, S., 2008. Non-Response Challenges in GPS-Based Surveys. Resource Paper Prepared for the May 2008 International Steering Commitee on Travel Survey Conference Workshop on Non-Responses Challenges in GPS-based Surveys.

Chen, Q., Y. Fan, 2012. Smartphone-Based Travel Experience Sampling and Behavior Intervention. Paper Presented at the 91th TRB Annual Meeting, Washington, D.C.

Cottrill, C.D., Pereira, F.C., Zhao, F, Dias, I. Lim, H.B., Ben-Akiva, M., Zegras, C., 2013. The Future Mobility Survey: Experience in developing a smartphone-based travel survey in Singapore. Transport Research Record, vol 2354, S.59-67.

Kawasaki, T., Axhausen, K., 2009. Choice set generation from GPS data set for grocery shopping location choice modelling in canton Zurich: Comparison with the Swiss Microcensus 2005. Arbeitsberichte Verkehrs- und Raumplanung: Working Paper 595.

Fellendorf, M., Herry, M., Karmasin, H., Klementschitz, R., Kohla, B., Meschik, M., Rehrl,K., Reiter, T., Sammer, G., Schneider, C., Sedlacek, N., Tomschy, R., Wolf, E., 2011. KOMOD - Konzeptstudie Mobilitätsdaten Österreichs: Handbuch für Mobilitätserhebungen. Im Auftrag des BMVIT, Programmlinie ways2go.

Li, Z., Shalaby, A., 2008. Web-based GIS System for Prompted Recall of GPS-Assisted Personal Travel Surveys: System Development and Experimental Study, Transportation Research Board 87th Annual Meeting Compendium of Papers DVD, Transportation Research Board, Washington, D.C.

Marchal, F., Hackney, J.,Axhausen K. W., 2005. Efficient Map Matching of Large Global Positioning System Data Sets: Tests on Speed-Monitoring Experiment in Zürich. Transportation Research Record, 1935, pp. 93–100.

Reddy, S., Mun, M., Burke, J., Estrin, D., Hansen, M., Srivastava, M., 2010. Using mobile phones to determine transportation modes, ACM Trans-actions on Sensor Networks, vol. 6, pp. 1–27.

Stopher, P., Collins, A., Bullock, P., 2004. GPS Survey and the Internet. Paper presented at the 27th Australasian Transport Research Forum (ATRF), Adelaide.

Stopher P., FitzGerald C., Xu M., 2007. Assessing the accuracy of the Sydney Household Travel Survey with GPS. Springer Science+Business Media, published online: 23 June 2007.

Stopher, P., Prasad, Ch., Zhang, J., 2010. Comparing GPS and prompted recall data records. Working Paper ITLS-WP-10-24.

Schüssler, N., Axhausen, K., 2008. Identifying Trips and Activities and Their Characteristics from GPS Raw Data Further Information. Paper presented at the 8th International Conference on Survey Methods in Transport: Harmonisation and Data Comparability, Annecy.

Schuessler, N., Axhausen, K. W., 2015. Processing Raw Data from Global Positioning Systems Without Additional Information. In: Transportation Research Record: Journal of the Transportation Research Board, No. 2105, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 28–36.

Thiagarajan, A., Biagioni, J., Gerlich, T., Eriksson, J., 2010. Cooperative transit tracking unsing smartphones, in Proceeding of the 8th ACM Conference on Embedded Networked Sensor System (SenSys `10), USA.

Wermuth, M., Sommer, C., & Kreitz, M., 2003. Impact of new technologies in travel surveys, in: P. Stopher, P. Jones (Eds), Transport Survey Quality and Innovation, pp, 455-482, Oxford UK.

Wolf, J., Loechl, M., Thompson M., Arce, C., 2003. Trip rate analysis in GPS-enhanced personal travel surveys. In: Stopher, P., Jones, P. (eds.): Transport Survey Quality and Innovation, pp. 483–498. Elsevier Science, Oxford.

Wolf, J., Lee, W., 2008. Synthesis of and statistics for recent GPS-enhanced travel surveys. Paper presented at the 8th International Conference on Survey Methods in Transport, Annecy, France, 25-31th May 2008.

Xiao, Y., Low, D., Bandara, T., Pathak, P., Lim, H. B., Goyal, D., Santos, J., Cottrill, C., Pereira, F., Zegras, C., Ben-Akiva, M., 2012. Transportation activity analysis using smartphones Proc. of the 9th IEEE Consumer Communications and Networking Conference (CCNC 201, Jan 2012).

Zheng, Y., Chen, Y., Li, Q., Xie, X., Ma, W.-Y., 2010. Understanding transportation modes based on GPS data for web applications, ACM Transactions on the Web, vol. 4, no. 1, pp. 1–36, Jan 2010.

Zegras, C., Cottrill, C., Pereira, F.C., Zhao, F., Dias, I.F., Xiang, Y., Lim, H.B., Ben-Akiva,M., 2012. The Future Mobility Survey: Experiences in and examples from developing a smartphone-based travel survey in Singapore. Accepted for presentation at the International Symposium of Space-time Behavior and Smart Travel & the 7th Workshop on Spatial Behavior Research and Planning; organized by: Peking University, Beijing Transportation Research Center and Tsinghua University, 8 December.