THE SETUP OF A MOBILE MOBILITY PANEL FOR THE NETHERLANDS

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ABSTRACT

This paper describes the setup of the Dutch Mobile Mobility Panel project, in which GPS-enabled mobile phones (smartphones) are used as a passive multiple-week and multiple-year travel behaviour data collection tool. The data collection methodology used in the Dutch Mobile Mobility Panel comprised firstly the development of a smartphone application for iPhone and Android smartphones that automatically detects trips with its accompanying characteristics. Secondly, the trip data collected is enriched daily on a back-end server using data mining techniques to deduce suggestions for transport modes, places and trip purpose. In addition, additional data on weather conditions are added and errors in measurements are filtered out. Thirdly, an online follow up survey is conducted that enables participants to check and, if needed, revise trip characteristics or add or remove trips, and answer questions on specific travel conditions. Finally, participants fill in an online trip diary to report the trips for the first day of the field trial. This allows a comparison of the smartphone data collection with the conventional trip diary method. About 500 paid members of the LISS (Longitudinal Internet Studies for the Social sciences) panel are recruited to participate in the three-year mobility panel project, starting May-July 2013. The participants are a random sample of the Dutch population, and 20% smartphone owners (with iOS or Android operating systems) and 80% non-smartphone owners.

Keywords: panel survey, travel behaviour, smartphone application, pilot study

1. INTRODUCTION

In most countries, including the Netherlands, the understanding of people's travel behaviour is based on cross-sectional travel surveys where only one day is surveyed for each respondent in 'representative' periods when traffic flows are maximal (Ortuzar et al., 2010). This is not enough to gain a proper understanding of the dynamics in travel behaviour. More specific, cross-section data do not give any information to ascertain how choices will vary over time (i.e. policy response) if the system changes. Moreover, multi-day travel behaviour data (collection using GPS-devices) show a strong variation in travel behaviour (Stopher and Zhang, 2011). People are shown to visit new places even after several months of monitoring (Schönfelder and Axhausen, 2010).

This paper describes the set-up of the Dutch Mobile Mobility Panel project, in which GPS-enabled mobile phones (smartphones) are used as a passive travel behaviour data collection tool. The project is conducted by the Centre for Transport Studies at the University of Twente, in collaboration with the survey research institute CentERdata, ICT research institute Novay and the Dutch Ministry of Infrastructure and Environment. The Mobile Mobility Panel project has two main research questions. Firstly, we examine if GPS-enabled mobile phones can be an effective and efficient data collection method as an alternative to traditional trip diaries to monitor changes in long-run individual travel behaviour. Mobile phones are truly ubiquities having computation, sensing and communication capabilities and are carried by people throughout the day. It may become the most important solution to collect accurate and extensive travel behaviour data at low level of respondent burden in the near future. However, here is little experience yet with using mobile phones as data collection tools in the transport field. In the Mobile Mobility Panel project we develop an appropriate mobility monitoring platform to automatically record trips in detail (origin and destination locations, travel times) using algorithms to automatically detect (multi-modal) tours, trip purpose and transport mode, and a prompted recall procedure where participants check and if needed correct the automatically detected trip data. The second research question is to examine if GPS-enabled mobile phones be an effective data collection method to examine the variability of individual travel patters over time. A field experiment will be conducted aiming to collect multiple-week and multiple-year travel behaviour data from 500 Dutch panel members. The respondents are paid members of the LISS (Longitudinal Internet Studies for the Social sciences) panel administered by CentERdata (Tilburg University, The Netherlands), through its MESS project funded by the Netherlands Organization for Scientific Research (NWO). Respondents are asked to participate 2 to 4 four weeks in the period April to July during the years 2013, 2014 and 2015.

In this paper we describe the state of the practice of travel survey methods (Section 2), the methodology used in the Dutch Mobile Mobility Panel (Section 3), and the recruitment of participants (Section 4). At the moment of writing this paper (February 2013), the project is still in a development phase and fieldwork has not been conducted yet. Section 5 describes some preliminary results of a pilot project and section 6 presents preliminary conclusions. At the WCTR conference in July, 2013, first results of data collection (April-May) will be presented.

2. STATE OF THE PRACTICE OF TRAVEL SURVEY METHODS

In the past decades and to date, information on travel behaviour is mainly gathered through questionnaires. Stopher (2009) described how the research in travel behaviour evolved. In the 1950s and 1960s some major urban areas in the US home interviews were conducted to support urban transport planning. Interviewers were sent to a selected sample of households to conduct an interview about the travel of the previous day, collecting household characteristics additionally. In the 1970s the telephone and mail-back surveys emerged. National Travel Surveys still use this type of data acquisition, relying on self-registration. Already from the 1980s on telephone interviews were computer-assisted in terms that the interviewer can report the information during the interview.

In recent years technological developments catered for some methodological shifts. Households increasingly hold an unlisted telephone number and/or do only have (a) mobile phone(s), inducing sampling challenges. On the other hand, emerging technologies, such as internet surveys, GPS devices, and computer-based surveys, among others, increasingly offer new opportunities in data gathering. However, these technologies cannot completely substitute the traditional travel diaries yet. Although for example GPS devices may improve estimations of travel times and encloses routes to trip data (Murakami and Wagner, 1999), these technologies still need further development and need to prove their added value in accuracy and representativeness in relation to the traditional methods. For example, the penetration rate of internet connection in households is still not at the level of telephone connections, and can also affect the representativeness (e.g. underrepresentation of elderly and foreigners). As these types of data sources may prove to be valuable in addition to the traditional data sources, a paper survey still remains the main survey approach (Wolf et al., 2001). In the Netherlands however, data acquisition for the NTS is conducted more and more with mixed-mode approaches using digital forms.

To date, research in the field of travel behaviour still largely depends on data gathered through self-registration. Although this data acquisition strategy may enhance representativeness of the survey population, the data itself may contain inaccuracies, because it strongly relies on reported behaviour by the participant instead of observed behaviour. Moreover, this type of data does not allow for investigating causality in travel behaviour, because data is collected for a single day. Axhausen et al. (2002) already showed that multi-day panel surveys prove to be better in terms of studying the dynamics and causality in travel behaviour. Gathering travel behaviour data automatically and in a less intrusive way using GPS-enabled devices may prove to be a very valuable addition. Kracht (2004) showed the potential of using GPS and GSM over the traditional surveys in terms of the registration of trips and trip characteristics. For example, carrying a smartphone that records trips may provide a more accurate overview in terms of number of trips (i.e. underregistration of short trips can be reduced) and trip characteristics (i.e. trip distance, travel time and route can be included more accurately). However, the potential of using smartphones in travel behaviour research still needs to be investigated (Stopher, 2009).

In recent decades several studies have been conducted using GPS-based devices to gather travel behaviour data. Many researchers already chose or opt for this approach to increase data accuracy. In an effort to improve the expressiveness of travel behaviour changes in surveys among others, Bonsall (2008), Stopher et al. (2009) and Ortuzar et al. (2010) opted for the introduction of GPS-enabled devices in data acquisition. The first use of GPS-enabled devices in travel behaviour research focussed on using a GPS-logger in cars to gather VKT data of participants in the late 90s (Wolf, 2004). Later on the these new technologies were used to assist in travel behaviour surveys (e.g. (Kracht, 2004, Nielsen and Hovgesen, 2004)) and were introduced in longitudinal surveys (e.g. (Stopher et al., 2006, Schönfelder and Axhausen, 2010)). However, making people to carry the GPS-devices for a longer period of time proved to be difficult. Moreover, this method was mainly used for in-vehicle use and did not capture other modes.

Simultaneously, Asakura and Hato (2004) showed how to use the communication facilities of cellular phones for tracking individual travel behaviour. First studies were mainly focused on capturing the behaviour of crowds at a certain place and time (Wolf, 2004, Cooper et al., 2009). Later on the GSM was used to reconstruct the location traces of participants in behavioural research (e.g. (Krygsman et al., 2007)), however still relying on traditional questionnaires for the individual characteristics and underlying reasoning in travel decisions. Due to privacy issues this data source was not used extensively (Cooper et al., 2009). Moreover, in recent years developments in GPS and cell phones catered for a merge of GSM and GPS technologies, making the use of solely the communication technologies of cell phones obsolete. The use of smartphone, carrying among other a GPS-sensor, will probably rise in the coming years, enabling new data acquisition opportunities (Stopher, 2009, Nitsche et al., 2012). There already are numerous smartphone applications gathering personal travel data (e.g. UbiActive (Fan et al., 2012), Trip Analyzer (Li et al., 2011) and tripzoom (Bie et al., 2012)), however they are focussed on providing the smartphone user with feedback on their behaviour. Using smartphones as a tool to collect travel behaviour data for longitudinal analysis has to date not been conducted.

3. DATA COLLECTION METHODOLOGY

The data collection methodology can be broken down into four parts:

1. A smartphone application for iPhone and Android smartphones that detects trips with its accompanying characteristics.

2. A back-end server in which the collected trip data is enriched using data mining techniques to deduce transport modes, places and trip purpose. In addition, additional data on weather conditions are added and errors in measurements are filtered out.

3. An online follow up survey that enables people to check and, if needed, revise trip characteristics or add or remove trips, and answer questions on specific travel conditions.

4. An online trip diary to report the trips for the first day of the field trial. This allows a comparison of the smartphone data collection with the conventional trip diary method.

Smartphone application

Using the smartphone for measuring travel behaviour requires a dedicated smartphone sensing application. For the project an app, named MoveSmarter, was developed for iPhone and Android platforms. The MoveSmarter app is designed to gather data from several sensors in the smartphone to automatically detect significant displacement. The app uses a measurement strategy using GSM/UMTS cell, Wi-Fi and GPS sensors to detect whether or not the smartphone is moving and if so, it collects a location trace of the location measurements. If the smartphone remains stationary for some time, the app finalises the active collection and sends the data (i.e. location trace) to a server. Subsequently, in this back-end the location trace is cleansed with outlier detection and a trip is constructed from the location trace.

An important issue with using smartphones for data collection is finding the right balance between accuracy of measurement, battery management and respondent burden (figure 1). The accuracy of measurement hugely depends on how often sensor readings (like GPS locations) are collected. In the current travel survey field, GPS-loggers are used to track GPS positions very accurately (e.g., every 2 seconds a GPS signal). Monitoring trips for a whole day using the current generation of high-end or medium-end smartphones is not possible at this level of accuracy because of battery management. Balancing accuracy with battery life also has effects on the respondent burden. If on the one hand smartphone app is accurate but does not allow a full day of monitoring then respondents have a higher burden in the prompted recall procedure to correct and add trip characteristics of trips made but not measured by the smartphone. On the other hand, if the smartphone app is less accurate (e.g. every 10 minutes GPS signal is collected), then the quality of trip measurement is reduced, which also increases the respondent burden as short trips will not be detected and trip characteristics often need to be corrected in the prompted recall procedure.

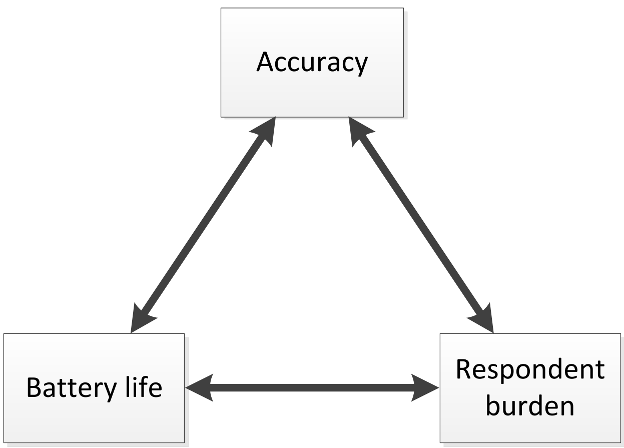

Figure 1 - Finding a balance between accuracy of measurement, battery life and respondent burden.

The MoveSmarter app uses algorithms to optimise power consumption. For example, if a user is not travelling – that is he is static within a GSM or Wi-Fi cell – the GPS is turned off to save energy. These algorithms are optimised to ensure 24 hours of passive travel behaviour monitoring is possible on a full battery load.

Back-end data server

At this server the raw data is stored and subsequently processed to estimate the following trip characteristics: (1) the raw data (time stamps and geo-location traces) are cleansed and analysed to create a trip with an exact origin and destination; (2) the trip modality is estimated based on the speed profile of the trip and; (3) the trip purpose is estimated based on the destination of the trip. The processed information is stored and sent back to the smartphone to appear in the trip overview in the MoveSmarter app. The app shows the following trip characteristics on the smartphone:

- date;
- departure time;
- modality;
- distance travelled; and
- travel time

and lists all trips chronologically for the specific participant to see.

Figure 2 - Screenshot of the (draft) MoveSmarter app

The collected GPS/GSM/Wi-Fi data are not necessarily error free. Being present for at least five minutes at a certain location currently marks the end of a trip. Errors may occur due to, e.g., long waiting for a traffic light or in a traffic jam, inaccurate location information from the sensors, or switch back and forth between GSM masts. This is periodically corrected at the server side, e.g., concatenating trips into end-to-end journeys or removing 'ghost trips'. Based on trips that are manually tagged before they are automatically labelled, a quality of trip classification is made and presented to the user as information on the smartphone app.

Online follow up survey

A web interface is developed for LISS panel members as a follow up survey. The web interface presents overview of trips monitored and allows participant to check and, if needed, to revise and complete the trips. Respondents are asked to revise their trips at least every three days. Furthermore, the participants were asked to denote particular circumstances that affected their mobility.

Trip overview

The trip overview is designed to show the trips to the participants and to allow them to modify the measurements and to reflect their actual trips. The trip characteristics, as sent back to the smartphone, were also sent to a database. Every single participant received access to his/her trip registrations via this database. The various characteristics measured by the app are presented, for the participant to modify if needed.

Figure 3 - Screen shot of the (draft) web interface presented to the participants

The web interface shows (1) a calendar with an overview of the days where the participant checked, completed and confirmed their trips, and (2) an overview of the trips for the selected day.

The calendar provides the participant with an overview of the days where he/she confirmed their trips. A green box indicates the participant confirmed to have filled in all trips for that day. A grey box indicates the participant didn't confirm yet. An orange box shows the unconfirmed days within the last three days.

The trip overview provides the participant with the overview of the processed trips gathered from the smartphone app for the seleted day. The trips were presented in the web interface, containing the following characteristics to be checked, completed and confirmed:

- Trip id
- Departure time
- Arrival time
- Origin
- Destination
- Mode of transport
- Purpose

The trip id is simply assigned to a trip based on the chronological order and cannot be altered by the participant. The time of departure and arrival are presented in terms of 'hh:mm' and represent the time of departure and arrival as registered by the smartphone app. Both can be altered by the participant if needed. The origin and destination of a trip are presented in column 4 and 5. Both the origin and destination contained the name of the street and the place. However, when altering or adding trips the participants could pinpoint their origin or destination by using the name of the activity or location as the exact address may not be known by the participants (e.g. supermarket, train station). The mode of transport and the purpose of the trip could be selected from predefined lists of modes and purposes. Finally some additional actions could be executed. Two consecutive trips could be combined into one trip, making the origin and departure time of the first trip and the destination and arrival time of the second the combined trip characteristics. Also, users can delete erronous trips. An additional row at the bottom of the overview was provided to register a trip not registered by the app. This added trip was then stored in chronological order with the other trips.

Circumstances affecting personal mobility

After correcting and/or completing the trips and trip characteristics on a particular day, the participants were asked to confirm that all trips for that day are now complete. Subsequently, the participants were asked to indicate the circumstances that may have influenced their mobility on that day. The following options were presented:

- Weather conditions (such as rain, snow, icy/slippery roads, etc)
- Disturbance or malfunctioning in the public transport system (such as dropped out trains or buses, severe delays, etc.)
- Particular traffic conditions (such as non-regular delays, accidents, etc.)
- Carrying (heavy) luggage (on parts of a trip)
- Travelling together with others (on parts of a trip)
- Illness of the participant
- Illness of a member of the participant's household

- Regular mode of transport is unavailable (e.g. the car broke down)
- Other circumstances
- No particular circumstances

Except when ticking the final box (i.e. no particular circumstances) the participants were asked how the particular circumstances had altered their mobility on that day. The participants could choose from:

- Choosing a different route
- Leaving earlier or later
- Choosing another mode of transportation
- Choosing a different destination
- Cancelling one or more trips

Filling the circumstances finalised the trip completion procedure for that particular day. The circumstances could only be denounced once. After completion the overview of the registered and corrected trips were presented again.

Traditional travel diary

One day of the field trial was assigned to compare the data quality of the traditional travel diaries with the data retrieved from the smartphone app. The first day of the pilot study period was designed to emulate a traditional travel diary and comparing to actual measurements using the smartphone. On the first day of the pilot period, the participants were presented an (online) travel diary, which was in line with trip overview in the web interface and was designed to resemble the traditional Dutch National Travel Survey as closely as possible. At the end of the first day of the pilot period, the participants were asked to fill in their trips of that day. Although the participants started using the MoveSmarter app, their trips during the first day were not presented in a list of trips in the app. In this way the participants are least biased by the overview of trips, presented in the app when reporting their trips.

In the travel diary the participants were asked to report:

- Time of departure and arrival
- Place of departure and arrival (origin and destination)
- Mode(s) of transport
- Trip purpose

In reporting the places of departure and arrival, the respondents were to report the street name, the postal code and place. In case of visiting place without knowing the exact address, the participants were asked to describe the place (e.g. parking garage, hospital, and train station). The participants were asked to denote at least one mode of transport from a predefined list of modalities. If necessary a second mode could be entered. The participants were asked to enter the most suitable trip purpose from a predefined list of purposes. Finally the participants were asked to denote the particular circumstances that may have affected their mobility for that day, as was the case in the web interface.

4. RECRUITMENT OF PARTICIPANTS

Participants in the Dutch Mobile Mobility Panel project are recruited from the LISS panel, administered by CentERdata at the Tilburg University campus. The LISS panel is the principal component of the European MESS project (more information can be found at: www.lissdata.nl), funded by NWO. The panel is set up and coordinated by CentERdata. The LISS panel is a representative sample of Dutch individuals who participate in monthly Internet surveys and consists of 5,000 households, comprising 8,000 individuals. The panel is based on a true probability sample of households drawn from the population register. Households that could not otherwise participate are provided with a computer and Internet connection. A longitudinal survey is fielded in the panel every year, covering a large variety of domains including work, education, income, housing, time use, political views, values and personality. Panel members are paid for each completed questionnaire. One member in the household provides the household data and updates this information at regular time intervals.

Participants will be smartphone owners and non-smartphone owners. Early 2012, about 22% of LISS panel members (1,150 people) currently own a smartphone running on several operating systems (Nokia OS, Blackberry OS, Apple IOS, Android, etc.). Roughly about half of these smartphones are iPhones or use Android as operating systems, for which the MoveSmarter app is developed. Smartphone ownership however increases fast and iPhone and Android-based mobile phones have a very high market share in phone sales.

About 500 LISS panel members will be recruited, of which 100 are smartphone owners with iOS or Android operating systems. 200 Android Smartphones (Samsung GIO) are distributed among non-smartphone owners. These smartphones are distributed, used and collected in two consecutive batches to achieve the intended number of 400 non-smartphone owning participants. Distributing smartphones among non-smartphone owners also allows an analysis of selectivity effects, i.e. a comparison of travel behaviour between smartphone and non-smartphone owners within population segments (e.g., age groups, income groups).

The Mobile Mobility Panel focuses on the population between 16 and 65 year old. The segment includes young adults and the working population which strong dynamics in travel behaviour and which are the most interesting group for research on the dynamics of travel behaviour. It is also the most relevant population segment from the perspective of transport policy; it is the future and currently most ‘automobile’ population segment. Furthermore, data from CentERdata show that smartphone ownership among LISS panel members is relatively high among panel members between 15 and 44 years old (more than two third of smartphones owners are located in this age group) and the lowest among elderly panel members (only 5% of smartphone owners are older than 65 years).

Privacy is an important issue in smartphone data collection. There are clearly privacy problems with making individual travel behaviour data available to the public; GPS tracks easily be used to trace the home location of the participant. The GPS data from the smartphones is sent to a server for further processing. The location traces are converted into trips with their accompanying trip characteristics. The participants are asked for "user consent" to notify their data is sent to a third party (Novay) first to be processed into trips. The participants of the LISS panel were already aware that their data is used for scientific purposes by the University of Twente. Collected data will be made public at a level of detail that does not violate individual privacy rights; the data will be anonymised and aggregated to allow integration with the LISS dataset that is published on the LISS data website.

5. FIELD TRIAL

The MoveSmarter app and online surveys were tested and evaluated in a pilot project with 50 LISS panel members in January 2013. LISS panel members agreeing to join the pilot received an account to be used to logon in the app and used their LISS account to logon in the web interface. No further prerequisites were set to recruit the participants for the pilot. Participants without a smartphone, or with an operating system other than a recent version of Android or iOS, received a smartphone to be used to install the MoveSmarter app and to be returned after the pilot. Once every three days the participant was reminder by email to check, revise, complete and confirm the trips and trip characteristics on the web interface. Panel members participated during a three week period.

The results of the pilot project showed that the respondent burden for correcting trips was too large. In the three week period, more than 2800 valid trips were detected and were presented to users in the follow up survey. For about half of the detected trips, users added or revised some trip characteristics, e.g. trip purpose, mode choice, destination address. The most important explanation for this high respondent burden was that in the pilot project there was no feedback from the user corrections to the back-end server. This implied that participants had to for example revise the label of the home and work location for each single home-to-work trip during the three week monitoring period when this was not correctly measured. At the moment of writing, these feedback mechanisms are implemented which are expected to reduce the respondent burden. A second pilot with another group of participants will be conducted in March 2013 to test the revisions made. Fieldwork will start in April to July 2013.

6. CONCLUSION

In most countries, including the Netherlands, the understanding of people's travel behaviour is based on cross-sectional travel surveys where only one day is surveyed for each respondent in 'representative' periods when traffic flows are maximal. This is not enough to gain a proper understanding of the dynamics in travel behaviour. This paper described the set-up of the Dutch Mobile Mobility Panel project, in which GPS-enabled mobile phones (smartphones) are used as a passive multiple-week and multiple-year travel behaviour data collection tool.

The data collection methodology used in the Dutch Mobile Mobility Panel comprised firstly the development of a smartphone application for iPhone and Android smartphones that automatically detects trips with its accompanying characteristics. Secondly, the trip data collected is enriched daily on a back-end server using data mining techniques to determine transport modes, places and trip purpose. In addition, additional data on weather conditions are added and errors in measurements are filtered out. Thirdly, an online follow up survey is conducted that enables participants to check and, if needed, revise trip characteristics or add or remove trips, and answer questions on specific travel conditions. Finally, participants fill in an online trip diary to report the trips for the first day of the field trial. This allows a comparison of the smartphone data collection with the conventional trip diary method.

About 500 members of the LISS panel are recruited to participate in the three-year mobility panel project, starting May-July 2013. The participants are a random sample of the Dutch population, and 20% smartphone owners (with a recent version of iOS or Android operating systems) and 80% non-smartphone owners. Distributing smartphones among non-smartphone owners also allows an analysis of selectivity effects, i.e. a comparison of travel behaviour between smartphone and non-smartphone owners within population segments (e.g., age groups, income groups). At the WCTR conference in July, 2013, the results of the first batch of data collection (April-May) will be presented.

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