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IN THE FIELD EVALUATION OF THE IMPACT OF A GPS-ENABLED PERSONAL DIGITAL ASSISTANT ON ACTIVITY-TRAVEL DIARY DATA QUALITY

Dr. ir. Tom Bellemans
Ir. Bruno Kochan
Dr. Davy Janssens
Prof. dr. Geert Wets (*)
Prof. dr. Harry Timmermans

dr. ir. T. Bellemans, ir. B. Kochan, dr. D. Janssens and Prof. dr. G. Wets are members of the Transportation Research Institute (IMOB), Faculty of Applied Economics, Hasselt University
Wetenschapspark 5 Box 6
B-3590 Diepenbeek
Belgium
Fax. + 32(0)11 26 91 99

E-mail: Tom.Bellemans@UHasselt.be
Tel: +32(0)11 26 91 27
E-mail: Bruno.Kochan@UHasselt.be
Tel: +32(0)11 26 91 22
E-mail: Davy.Janssens@UHasselt.be
Tel: +32(0)11 26 91 28
E-mail: Geert.Wets@UHasselt.be (*) Corresponding author
Tel: +32(0)11 26 91 58

Prof. dr. H.J.P. Timmermans is Professor of Urban Planning at the Eindhoven University of Technology and director of EIRASS
P.O. Box 513
Vertigo 8th floor
5600 MB Eindhoven
The Netherlands
Fax. +31(0)40 243 58 95

E-Mail: H.J.P.Timmermans@bwk.tue.nl
Tel: +31(0)40 247 39 60

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Abstract. A custom tool, PARROTS (PDA system for Activity Registration and Recording of Travel Scheduling) was developed to collect both activity data and GPS data. This tool is currently deployed in a survey that is carried out on 2,500 households in Flanders (Belgium). This paper discusses the findings on the effects of a GPS-enabled PDA data collection tool featuring default answers, pre-defined drop-down lists and many other graphical design elements on data quality. Two types of data are collected using PARROTS: activity-travel diaries inputted by the respondents and location data logged by a GPS receiver. To judge the effect of the PARROTS tool on the quality of activity-travel diaries, a paper-and-pencil diary was designed and deployed as well and various analyses were performed on both the paper-and-pencil and PDA data. For the collected GPS data the data quality was investigated in terms of availability of location information in the logs. In addition to investigating data quality, the impact of using PDA-technology on user response rates is examined and compared to response rates for the paper-and-pencil format. Based on the above analyses, the performance of PARROTS as an activity-based survey data collection tool is assessed.

INTRODUCTION

Traditionally, travel surveys data have been collected by paper and pencil or over the phone. The coming of activity-based analysis, which prompted the need for considerably more detailed data on travel behaviour, identified the advantages of collecting activity or time use diary data (e.g. (*1*), see (*2*) for an overview). At the same time, however, the use of diary data virtually precluded the use of telephone interviews and in addition substantially increased respondent burden and error proneness, e.g. (*3*), (*4*). To avoid such error or at least reduce it, computer assisted diary instruments were developed. The first of these was MAGIC (*5*), a DOS-based computer program, which allowed people to schedule and reschedule their activities, logged this process and also had some limited functionality for identifying errors. It was the predecessor of several windows-based programs, with improved user interfaces, such as CHASE (*6*), iCHASE (*7*), CHASE_GIS (*8*), REACT (*9*) and VIRGIL (*10*) to name a few. Progress in this field reflects a shift from laptops to internet and from verbal to a combination of verbal and map-based interfaces, even allowing for virtual reality e.g. (*11*). The superiority of these tools in terms of reliability is well reported in the literature.

More recently, considerable attention among academics and professionals alike has been paid to the use of GPS, first as stand-alone technology, later embedded in cellular phones. The potential advantage of such technology has been well reported in the literature e.g., (*12*), (*13*), (*14*), (*15*). However, even in the best case, GPS technology only allows one to trace the movement (routes) of travellers. It should be realized that route choice information is not the only and not necessarily the most important piece of data for activity-based analyses and models. Activity-based models predict which activity is conducted where, when, for how long, the transport mode involved, and with and perhaps for whom the activity is conducted. Many of these choice facets are not captured by GPS technology. At best, one can try data fusion approaches to extract such additional data.

Nevertheless, the application of such tools has been confined largely to academic research. Large scale data collections conducted by consultants and national bureaus of statistics continued to use paper-and-pencil and phone-based surveys. Data cleaning and error correction involved a considerable amount of effort, although there have been attempts to develop user-friendly software for detection and semi-automatic correction of errors, e.g. Sylvia (*16*).

To avoid relying solely on such data fusion approaches, in the context of the Strategic Basic Research Project – An Activity-Based Approach for Surveying and Modelling Travel Behaviour, sponsored by the Flemish Government, an activity-travel diary survey tool, called PARROTS (PDA (Personal Digital Assistant) system for Activity Registration and Recording of Travel Scheduling) was developed (*17*). PARROTS runs on a PDA and uses the Global Positioning System (GPS) to automatically record location data. The PDA was programmed such that besides automatically registering its location, respondents can provide information about their activity-travel behaviour as well. Previous experiences with computer-assisted data collection tools (MAGIC; VIRGIL) and knowledge-based semi-automated correction software (SYLVIA) were incorporated in the PARROTS design to a maximum extent. An important advantage of PDA-based collection of diaries is the possibility to guide the input process in order to assist the respondent and to avoid inconsistencies and other types of anomalies. Given the portability of a PDA compared to laptops and other electronic data collection tools, PARROTS is well-suited for in the field activity and travel registration. As PARROTS is designed to be run on a PDA that has (embedded) GPS, it enables automatic registration of the spatial dimension, or the location component of the activities, which proves to be difficult to collect using the traditional paper-and-pencil survey methodology.

In this paper, some results of the use of PARROTS in a survey of 2,500 households in Flanders (Belgium) are presented. This means that this study is probably one of the largest using GPS and one of the few that we are aware of that uses GPS-enabled PDA's. In particular, the effects of a GPS-enabled PDA data collection tool featuring default answers, pre-defined drop-down lists and many other graphical design elements on data quality are assessed. The data quality of both the data inputted by the respondents and the location data logged by GPS is investigated. In addition to investigating data quality, the impact of using PDA-technology on user response rates is examined and compared to response rates of the paper-and-pencil format. Based on these differences, the performance of PARROTS as an activity-based survey data collection tool is assessed.

THE INSTRUMENTS

This section primarily deals with a discussion of the functionalities of the PARROTS tool, followed by a brief description of the paper-and-pencil tool.

PARROTS: An Activity-Travel Diary Survey Tool on a GPS-enabled PDA

The goal of PARROTS is to implement an activity-travel diary on a PDA with an integrated GPS logger to automatically capture location information. The collected data consists of data that will be used to build a dynamic activity-based model called Feathers. Part of the collected data consists of the data regarding replanning and execution of activities and trips that is manually input by the respondents. The other part of the data consists of location data that is automatically collected using GPS. Both planned and executed activities and trips are registered with the possibility to alter the attributes of the planned activities. This way, information is collected regarding the decision and scheduling processes, which results in an evolution from an intention to execute some activities and trips to an executed activity-travel diary. A similar philosophy was adopted in (*18*).

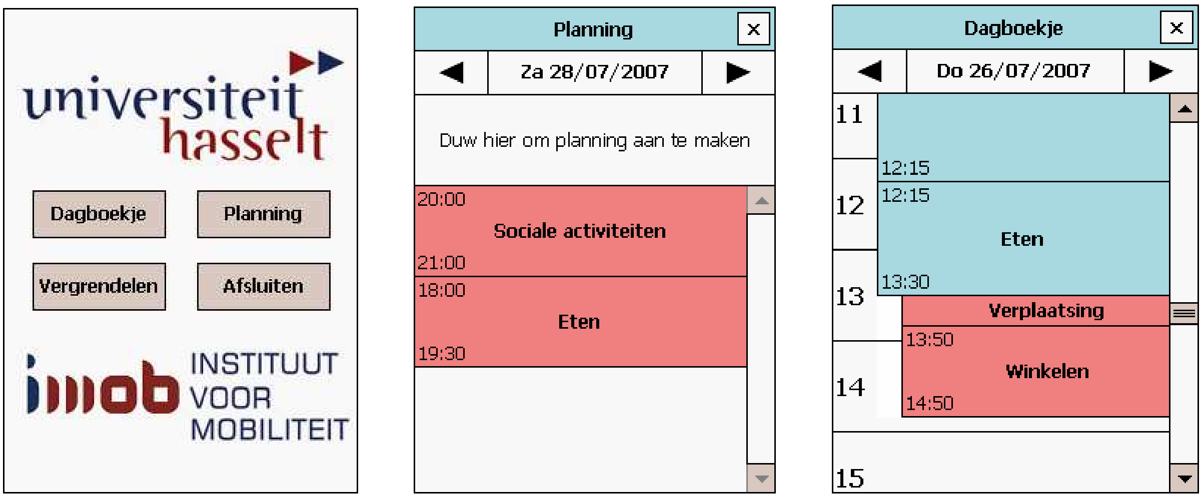

FIGURE 1 PARROTS main GUI (Left), planning GUI (Middle) and diary GUI (Right). In order to facilitate the distinction between planned and executed activities, planned activities are depicted in red and are wider than executed activities, which are depicted in blue.

If the PDA is switched on, PARROTS starts automatically and the main GUI is shown (Figure 1, Left). Whenever PARROTS is active, the GPS logger is operational logging the GPS location strings at a configurable rate. Hence the respondent can automatically record route and location information using GPS by keeping the PDA switched on. The 'Vergrendelen' button provides a screen lock functionality such that the PDA can safely be stowed during the trip. The PDA is switched off using the 'Afsluiten' button.

The buttons 'Planning' (Planning) and 'Dagboekje' (Diary) are used to launch the graphical user interfaces (GUI) to input planned and executed activities and trips respectively. In the planning GUI, the registered activities and trips are grouped by day and are listed in the same order they were entered (Figure 1, Middle). In the diary GUI, the executed activities and trips are displayed in a layout that resembles an agenda (Figure 1, Right). The difference in both GUI's stems from the fact that providing an agenda layout for planned activities is reported in literature to bias the collected data due to visual feedback of the interface (*19*).

Whenever an activity or trip is registered in PARROTS, a number of attributes for this activity or trip are collected using a customized GUI. The most important activity and trip attributes PARROTS collects are: activity type, date, start and end time, location, mode of transportation, travel time and travel party. Note that although PARROTS collects location data using GPS, the location of activities is still queried. The match between location information provided by the respondent and the location logged by GPS can be verified during postprocessing in order to validate the data. Replanning information is collected by allowing the respondent to update all attributes and by querying for the reasons of the registered changes.

PARROTS features several data consistency checks, the most important of which are: checks that all required data is available and feasible, checks on overlaps and/or gaps on the time axis and checks for discontinuities in location. If any of the checks fails, the user is taken to the relevant GUI and an informative error message is shown. These checks are only enforced for activities and trips that are labelled as executed.

Paper-and-pencil Survey

Besides PARROTS, a traditional paper-and-pencil survey was designed. Similar to PARROTS, both the planned and executed activities and trips are registered in a separate booklet. To obtain a link between planned and executed activities, respondents were asked whether the executed activity was planned and if it was, the sequence number of the corresponding activity in the planning booklet was asked.

Obviously, one cannot register detailed information about replanning behaviour of a respondent as this would involve many manual checks on both booklets leading to unacceptable respondent burden. Hence, no replanning information was gathered in the paper-and-pencil survey and only the reason for differences in duration of planned and executed activities was queried.

DATA COLLECTION

Activity-based models predict which activity is conducted where, when, for how long, the transport mode involved, and with whom the activity is conducted. In order to collect the required data for building an activity-based model for Flanders, a large scale survey is being conducted on 2,500 households. The PARROTS and the paper-and-pencil survey tools are both being used on half of the surveyed households. As the survey is currently ongoing, the results presented in this paper are based on 816 surveys, 440 using paper-and-pencil and 376 using PARROTS, collected so far.

Although there is no cost for data imputation using PARROTS, it needs to be noted that the GPS-enabled PDA's need to be bought and that there are costs incurred by the delivery and pick-up of the PDA's at the respondent's homes. In order to limit the costs incurred by delivery and pick-up of the PDA's, a decentralised modus operandi was implemented. Co-workers living scattered over Flanders were recruited such that the travel costs could be minimised by optimising the allocation of tasks to co-workers.

By comparison of the data collected with PARROTS with the data collected using the traditional paper-and-pencil approach, the impact of PARROTS on response rates and data quality can be investigated. Important advantages of PARROTS over paper-and-pencil are the availability of detailed replanning and location (GPS) information, the checks on the data leading to higher data quality and the immediate electronic availability of the data.

ANALYSES AND RESULTS

The analyses of the collected data that are presented in this section are twofold and consist of the analysis of the survey data that was inputted by the respondents in PARROTS on the one hand and of the location data that was logged by GPS on the other hand. The data collected by using the traditional paper-and-pencil tool is used as a point of reference for the performance of the PARROTS survey tool. This section reports on the following analyses: the analysis of the impact of GPS-enabled PDA technology on the user response rates, the impact of PDA technology on the quality of the collected diary data and PARROTS usage patterns.

Impact of GPS-enabled PDA Technology on User Response Rates

Households selected to participate in the survey were sent a letter stating the survey purpose and the survey method (paper-and-pencil vs. PDA). Two days later, they were contacted by telephone in order to ask for their participation. 21.03% of the households was willing to take part in the survey using the paper-and-pencil procedure. This is slightly higher than for the PDA procedure (18.33%), which indicates that a number of people are reluctant to join a survey using less ubiquitous technology.

The respondents that indicated during the telephone conversation that their refusal to participate in the survey was related to being required to use a PDA were proposed to participate in the paper-and-pencil based survey. Approximately 4.12% of the respondents that were contacted to take part in the survey using a PDA preferred to switch to the non-PDA procedure during the telephone conversation. It can be assumed that this switch to non-PDA is induced by an aversion towards PDA technology.

During the PDA delivery, and after having the PARROTS tool explained and demonstrated to them, 3% of the respondents decided to switch to the non-PDA procedure. From the experiences during the PDA deliveries, it was learnt that the majority of these people deem the PDA tool either too complex or too intrusive. Whether these people remain motivated to complete the survey with paper-and-pencil or interpret the switch to paper-and-pencil as an easy way out in a face-to-face situation is hard to establish as the number of samples in this group is only 22 respondents.

Since the survey spans seven days, requires keeping track of and logging of detailed activity-travel information and requires carrying a GPS-enabled PDA during each trip, the respondent burden is rather high. Some respondents stop reporting activities and trips before the survey period is over. Hence, the data returned needs to be investigated for respondent activity in order to determine respondent attrition.

First, the respondent activity in terms of the number of executed activities that is registered in PARROTS is determined. A respondent is labelled active for a survey day if at least one executed activity is reported for that day. A comparison of respondent activity for both the paper-and-pencil and the PARROTS survey tools is facilitated by computing the fraction of the number of active respondents for the survey day considered relative to the number of active respondents during the first survey day. The overall average activity fractions are 0.89 and 0.90 for the paper-and-pencil and the PARROTS surveys respectively. In Figure 2 (Top) an attrition of the active respondents as the survey days pass can be observed for both survey tools. This attrition can be attributed to the respondent burden and to the extensive survey period. Figure 2 (Top) also shows that the attrition over time for the paper-and-pencil and for the PARROTS tools are nearly equal. Hence, it can be concluded that in terms of respondent activity, there is no significant impact of the survey instrument on respondent attrition.

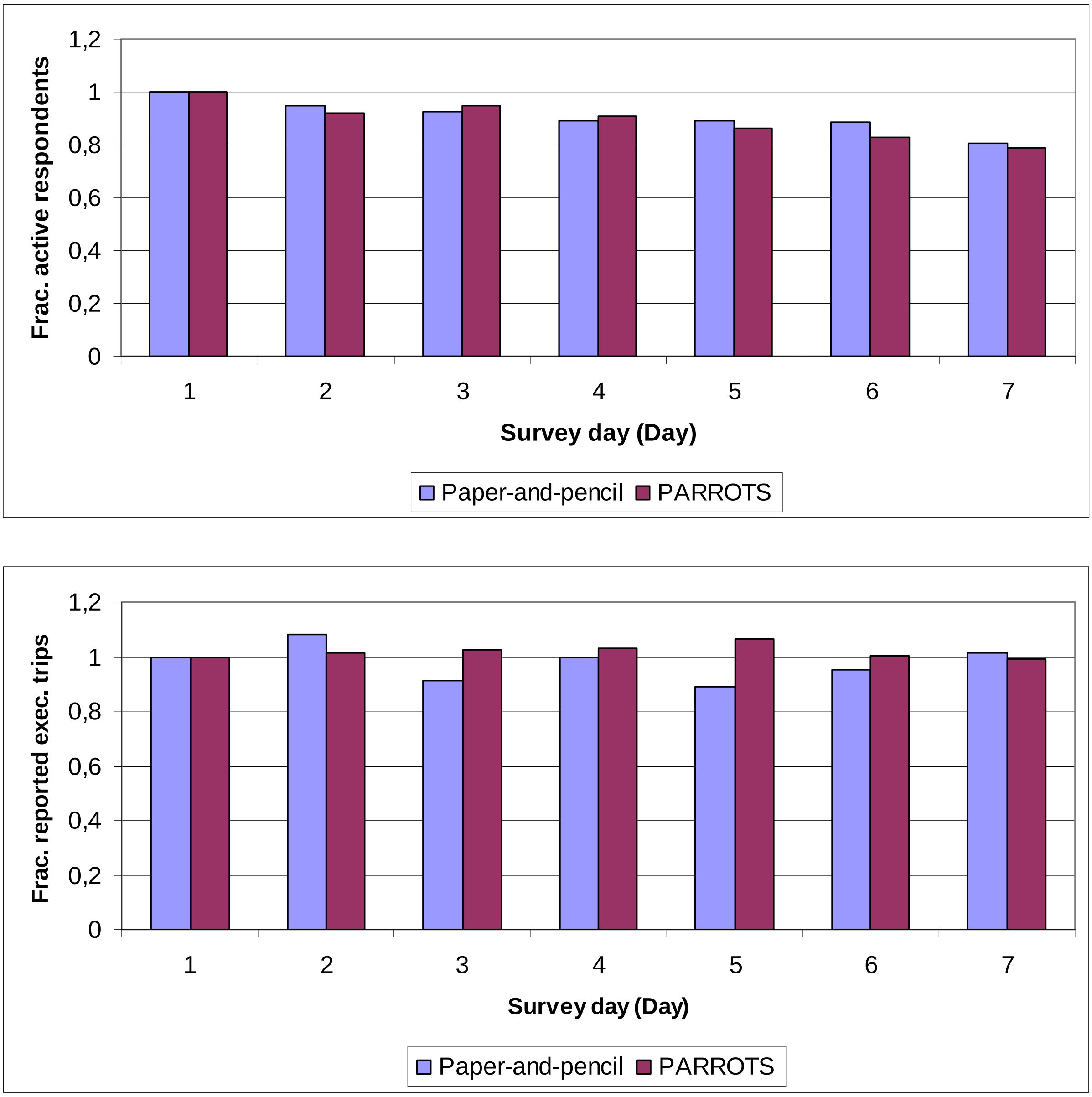

FIGURE 2 (Top) Overview of the number of respondents that reported executed activities on a survey day using either paper-and-pencil or PARROTS, expressed as a fraction of the number of respondents that reported executed activities the first survey day. (Bottom) Overview of the average number of executed trips for the datasets collected with paper-and-pencil and with PARROTS, expressed as a fraction of the number of executed trips on the first survey day.

Figure 2 (Bottom) depicts for the datasets collected with paper-and-pencil and with PARROTS the average number of reported executed trips per person and per survey day as a fraction of the number of trips per person for the first survey day. The average number of reported executed trips for survey day 1 is 2.82 and 3.44 for the paper-and-pencil and the PARROTS survey tools respectively. From these averages and from Figure 2 (Bottom), it can be concluded that on average more trips are reported using PARROTS and that the number of reported trips using PARROTS remains more stable throughout the survey. This effect cannot be due to day of the week effects as the starting days of the surveys were randomised.

Based on the above observations it can be concluded that despite respondent attrition, respondents who continue to report activities and trips keep reporting more or less the same number of activities and trips each day. Hence, it makes sense to run the survey for this extended period of time as there is a significant number of respondents that provides usable data throughout the whole period.

Not only registering the activities and trips in the PARROTS tool poses a burden on the respondents, but also carrying the PDA during all travel is experienced as a large burden by many respondents. In the remainder of this subsection, the response rate in terms of using the PDA as a location logger is investigated.

During the trips, PARROTS captures the location data that is provided by the GPS receiver and stores it in a file. An analysis of the quantity of GPS logs as a function of the survey day indicates the way respondents deal with the burden of carrying the PDA around. Figure 3 shows the total number of GPS strings recorded by all respondents as a function of the survey day. The absolute values are converted to a fraction of the number of strings of the first survey day (7,205,550 strings). It is clear that the number of registered strings decreases monotonically as the survey progresses. This can result from a decrease of the number of logs that is recorded by each person daily, by a decrease of the number of persons still active at the survey day (See also Figure 2 (Top)), or from a combination of both. Figure 3 also shows the average number of logs per person per survey day as a fraction of the average for the first day. It can be observed that the number of logs per person stays approximately constant for the first four survey days but starts rapidly decreasing starting from the fifth survey day. Hence, the decrease in logged GPS strings as the survey period progresses results from a combination of respondents dropping out of the survey and active respondents logging less trips.

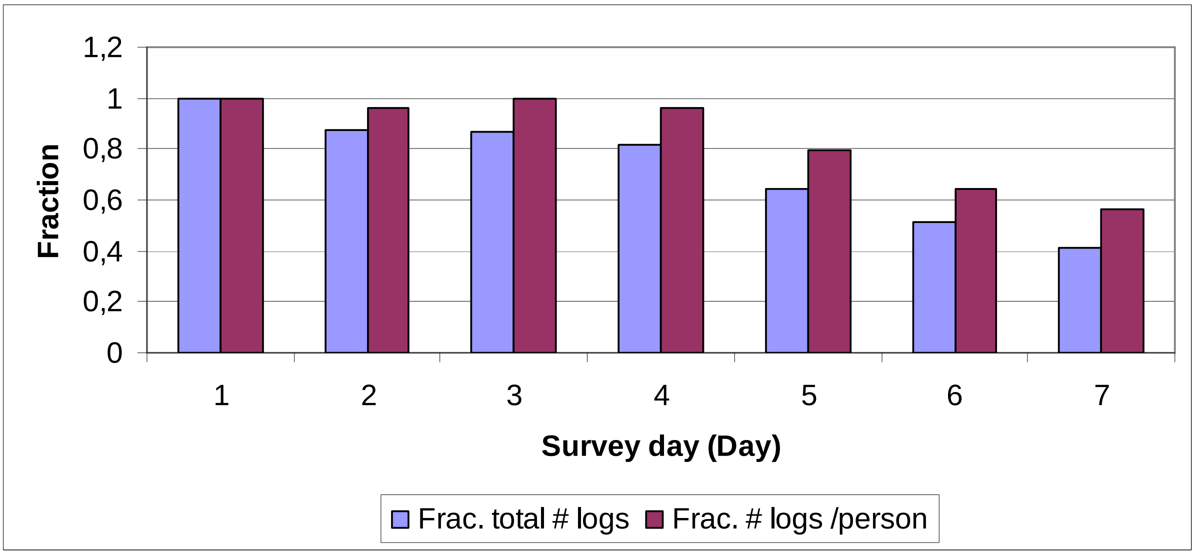

FIGURE 3 Evolution of the total number of GPS strings logged by all respondents and the average number of strings logged per person for each survey day, plotted per survey day, and expressed as a fraction of the corresponding value on survey day 1.

An explanation for the reduction of the average number of GPS strings logged per person, despite the continued registration of activities and trips, can be sought in the additional burden of being required to carry the PDA tool and to switch it on during trips. An additional burden is introduced by the battery of the PDA, which has an autonomy of around 6 hours in logging mode. Hence, forgetting to recharge the PDA results in the inability to log trips and a PDA that switches off. As will be illustrated later on, 76.60% of the users suffered low battery induced PDA shutdowns. This phenomenon probably contributes to respondents giving up on logging trips.

Impact of GPS and PDA Technology on Data Quality

In this subsection a number of data quality measures are computed for the data in order to investigate the impact of the survey tools on the data quality. First, the data quality of the data inputted by the respondents is investigated, followed by a brief investigation of the data quality of the GPS logs.

An important indication of survey data quality is in terms of item non-response rates. As the attributes of planned trips and activities are not required to be filled out, only item non-response rates for the executed activities and trips are considered here as a measure for data quality. A selection of the computed item non-response rates is presented in Table 1. As PARROTS performs consistency checks during imputation, the item non-response rates for all items of its executed activities and trips were exactly 0.

TABLE 1 Non-Exhaustive List of Item Non-Response Rates for Paper-and-Pencil Reported Executed Activities and Trips

Activity/Trip Attribute	Item Non-Response Rate (%)
Date: DD	4.43
Date: MM	4.55
Date: YYYY	6.08
Activity type	12.29
Act. start: HH	2.78
Act. start: MM	4.87
Act. duration: HH	6.75
Act. duration: MM	5.86
No. persons act.	21.78
Transp. Mode	22.87
Trip duration: HH	30.52
Trip duration: MM	24.23
Car label/type	25.50
Check Planning	28.52
Planning ID number	18.53

From Table 1 it can be observed that for activities the date, the start time and the duration are fairly well reported. However, the item non-response of 12.29% for activity type yields a lot of data that is unusable in the context of activity-based modelling. Similarly, the number of persons participating in the activity, the transport mode used and the duration of the trips, all important attributes from the point of view of the model to be built, exhibit an item non-response of 20% or more (Table 1). The attributes “Check Planning” and “Planning ID number” are used to link planned activities with the corresponding executed activities as both are registered in separate booklets. These attributes exist only for the pencil-and-paper survey as PARROTS generates them automatically. It can be observed from Table 1 that by using the paper-and-pencil survey tool the link between planning and execution is lost for a significant number of activities and trips while this is not the case if PARROTS is used.

For reasons of comparability with different household travel surveys and to obtain a more global measure of the information content of the data set, Stopher *et al.* (*20*) recommended calculating a Missing Value Index (MVI) for any travel survey. This is essentially the number of missing data items (including erroneous items) relative to the total number of (applicable) items in the set, so a lower ratio, indicates a higher information content. The MVI for the executed activity-travel diaries for the current data set was found to be 11.62%. As the non-response rates for the executed data collected with PARROTS were 0, the MVI for this dataset is 0.

The data quality of the registered GPS strings can be expressed in terms of the availability of location information in the strings. PARROTS is designed to read and store all information provided by the GPS receiver. This data is provided over the (internal) serial interface according to the industrial NMEA standard (*21*). However, whenever the GPS receiver is unable to determine the location (e.g. due to being indoors), NMEA strings are provided without any location information. These ‘empty’ strings are logged by PARROTS as well.

The quality of the GPS data is influenced by how the respondents use the PDA. Although the respondents are made aware of the fact that not stowing the PDA too far away positively impacts the quality of the GPS data, no guidelines are provided on how the device should be carried during trips in order not to needlessly burden the respondents even more. Based on the fraction of the number of NMEA strings containing location information, relative to the total number of logged NMEA strings, an indication of the quality of the automatically collected GPS data can be obtained. In total 36,940,569 strings were logged in the current dataset and in 38.38% of the strings location information is present.

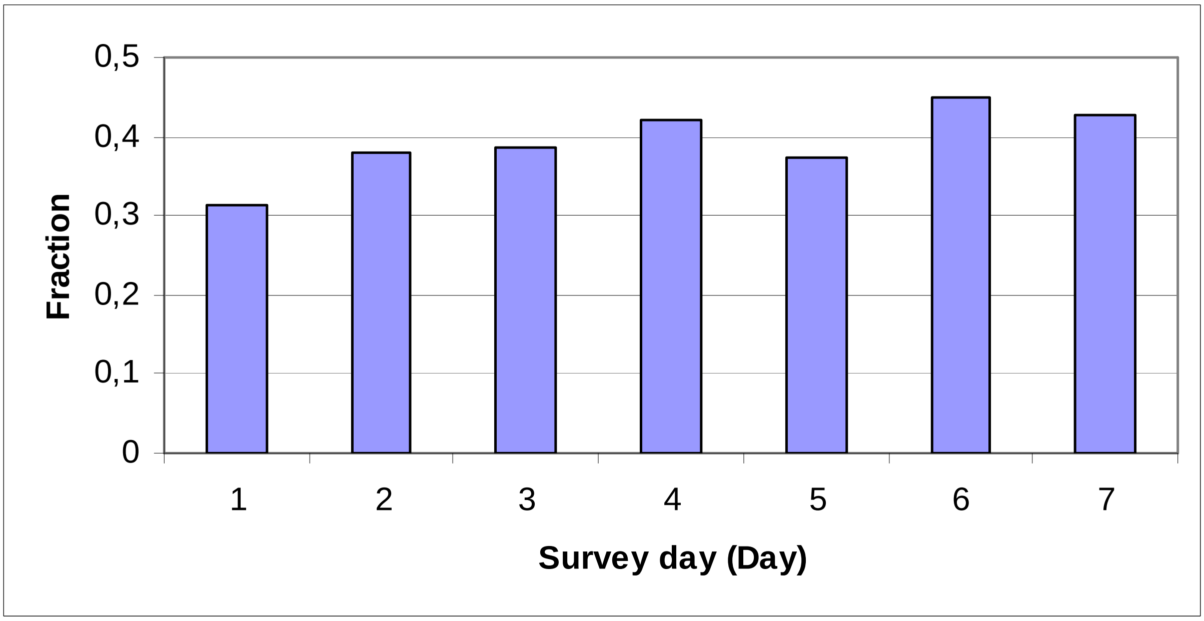

FIGURE 4 Fraction of the number of NMEA strings per day containing location information relative to the total number of NMEA strings logged per day.

Figure 4 depicts for every survey day the fraction of the number of NMEA strings containing location information over the total number of NMEA strings logged for that survey day. The increasing trend of the fraction towards the end of the survey could be intuitively explained as follows: near the end of the survey a higher fraction of motivated respondents remains and near the end of the survey respondents need less time inputting their data in the PDA, resulting in less NMEA strings being logged indoors during the imputation process. However, further investigation on this topic is required before conclusions can be drawn.

PARROTS Usage Patterns

This subsection analyses the PARROTS usage patterns based on the detailed logs generated by PARROTS. First, it is investigated whether the respondents use the replanning facilities provided by PARROTS, followed by an analysis of the GPS logs resulting in the PARROTS usage as a function of the time of day. This subsection is concluded with a visualisation of the occurrence of low battery shutdowns of the PDA.

The PARROTS interface allows the user to access and modify all planned activities and trips. If attributes of the activity or trip are altered, this new information is added to the PARROTS database on top of the older data. This way, a detailed log of the replanning process is generated. As the user only needs to be concerned with keeping the planning up-to-date in the PARROTS GUI, and all checks and the linking of sequences of replanned activities are taken care of by PARROTS, detailed replanning information can be collected at an acceptable burden for the respondent. It was found that 9.40% of the activities (859 activities) and 14.22% of the trips (546 trips) are replanned at least once. This results in replanning information that could not be collected by using the paper-and-pencil procedure.

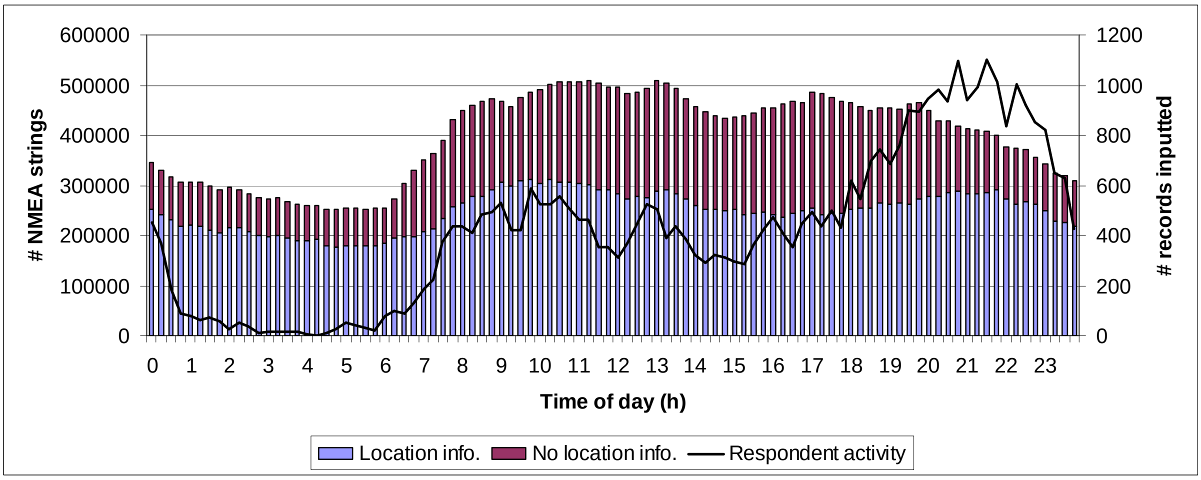

FIGURE 5 Plot of the number of records inputted in PARROTS by all respondents and as a function of time. The records are aggregated in 15 minute bins. Evolution of the number of NMEA strings (with and without location information) logged by all respondents and as a function of time of day.

As PARROTS is a portable tool and as it provides replanning abilities, PARROTS can be used for in the field imputation. By investigating the time stamps recorded for all data saved in PARROTS by all respondents, the usage pattern of PARROTS can be determined. In Figure 5 the total number of records stored in PARROTS by all respondents is plotted as a function of time of day. The average number of records inputted during a 15 minute interval in Figure 5 is 420. It can be observed that during the night (1h – 6h), activity is very low and the activity increases in the morning to a level near the average activity level. There is a small dip in the activity in the afternoon (14h – 15h) and a clear activity peak during the evening (18h – 23h). The activity peak during the evening can be explained by two phenomena; first, the respondents were explicitly asked to review their planning for the next day in the evening and second, part of the respondents will not register their activities immediately but register them in the evening as they are revising their planning for the next day. However, given the sustained level of activity on the PDA throughout the day, it can be concluded that a significant number of respondents uses PARROTS to register activities and trips in the field.

Figure 5 also shows the total number of NMEA strings that was recorded as a function of time of day. It can be observed that conform Figure 4, the majority of registered NMEA strings does not contain location info. The fraction of the number of NMEA strings with location information, compared to the total number of NMEA strings varies with time of day. This can be interpreted as follows. Although very little activities are registered, many NMEA strings are logged during the night. This can be attributed to respondents keeping the PDA indoors (no reliable GPS signal) and switched on during charging at night. During the day, the fraction of NMEA strings containing location information increases, since more people are recording their trips during the day. During the peak of the imputation activity in the evening the fraction decreases again, which is partially caused by respondents imputing their activity-travel data while being indoors.

In order to protect the data on the PDA, PARROTS shuts down gracefully in the event of a battery running low and writes a low battery event to its logs. As the PDA unexpectedly shutting down is a rather disruptive event to the respondent, which might contribute to the attrition of the GPS logs captured as presented in Figure 3, the low battery events were investigated and a histogram is shown in Figure 6. It can be observed that 88 (23.40%) respondents did not encounter low battery events. There are on average approximately 7 low battery events per respondent. Assuming a respondent is active throughout the whole survey, this results in 1 low battery event per survey day on average. However, it needs to be noted that the low battery events tend to cluster in time as often a respondent tries to restart a PDA with a low battery several times. The correlation between the number of low battery events and the data quality of the imputed data and respondent attrition is subject to further research.

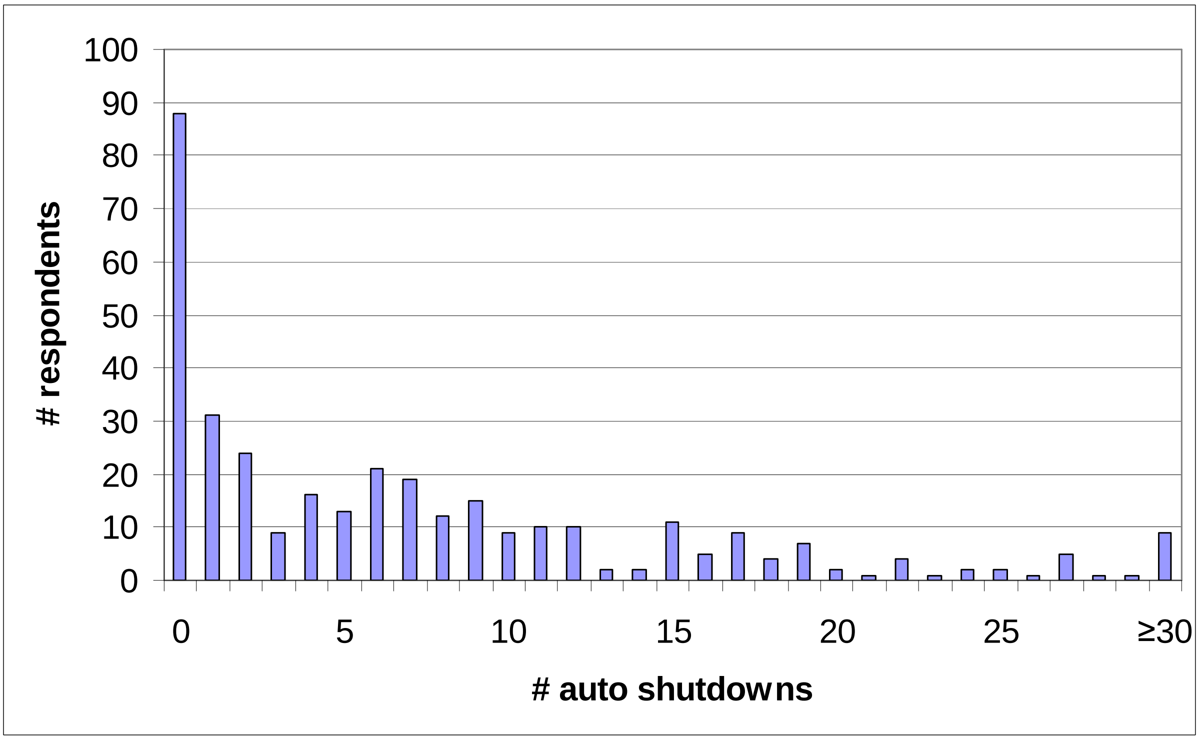

FIGURE 6 Histogram of the auto shutdowns of the PDA.

CONCLUSIONS AND DISCUSSION

In this paper, some results of one of the largest activity-travel surveys using GPS-enabled personal digital assistants (PDA) were presented. The data were collected in the context of the development of the Feathers-model, a dynamic activity-based model of transport demand for Flanders. A custom GPS-enabled PDA-based activity-travel survey tool, PARROTS, was developed because it was expected that (i) it allowed the inclusion of semi-automated error detection and correction, improving data quality, (ii) it would reduce respondent burden and (iii) it would produce more reliable and more detailed location data.

To empirically test these assumptions, the performance of PARROTS was compared with the performance of the traditional paper-and-pencil survey tool in a large survey in Flanders using both instruments. The response rates were investigated in order to check whether a negative attitude towards the use of PDA technology exists or a higher burden is experienced in using PARROTS. It was found that the response rate for PARROTS was only slightly lower than for the traditional approach during the recruitment process.

During the survey, the respondent attrition in terms of the number of active respondents was similar for PARROTS and the paper-and-pencil approach. However, the reported number of executed trips was more stable throughout the survey and on average more trips per person were reported for surveys using PARROTS. The unit non-response rate and the missing value index were computed for the datasets obtained with the paper-and-pencil and with the PARROTS tools. Where the paper-and-pencil method suffered from item non-response on attributes that are important in the scope of the Feathers model, PARROTS realised a unit non-response of 0 due to enforcing all the attributes of executed activities to be provided and featuring consistency checks on the provided data. This leads to a missing value index of 0 for the data collected with PARROTS which is significantly better than for paper-and-pencil (MVI 11.62%). In conclusion, the consistency checks and enforcing filling out all attributes, yield a better data quality for PARROTS while no additional respondent attrition was observed compared to the paper-and-pencil survey.

The analysis of the data quality of the GPS logs in terms of the number of logged NMEA strings showed an attrition of the total number of NMEA strings logged as survey days pass. This is caused by respondents dropping out of the survey on the one hand and by a decrease of the number of logged NMEA strings per person starting from the fifth survey day on on the other hand.

The analysis of the data quality of the GPS logs in terms of the fraction of NMEA strings containing location information versus the total number of logged NMEA strings showed that the data quality increases as more survey days pass. The evolution of this fraction as a function of time of day was correlated to the usage pattern of the PARROTS tool.

Analysis of the PARROTS activity patterns revealed the use of PARROTS as an in the field activity and trip registration tool, although this modus operandi was on a voluntary basis.

If the results of this study are replicated in future similar research, these findings illustrate the potential advantage of using instruments such as PARROTS.

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REFERENCES

(1) Clarke, M., M. Dix and P. Jones. Error and uncertainty in travel surveys. In *Transportation* 10, 1981, pp. 105-126.

(2) Ettema, D.F., H.J.P. Timmermans and L. van Veghel. Effect of data collection methods in travel and activity research. European Institute for Retailing and Services Studies, Eindhoven University of Technology, Eindhoven, The Netherlands, 1997.

(3) Dowling, R.G. and S.B. Colman. Effects of increased highway capacity: Results of household travel behaviour survey. In *Transportation Research Record* 1493, 1995, pp. 143-150.

(4) Sun, A., S. Sööt, L. Yang and E. Christopher Household travel survey nonresponse estimates: The Chicago experience. In *Transportation Research Record* 1493, 1995, pp. 170-178.

(5) Ettema, D.F., A.W.J. Borgers and H.J.P. Timmermans. Using interactive computer experiments for identifying activity scheduling heuristics. Paper presented at the *Seventh International Conference on Travel Behaviour*, Santiago, Chile, 1994.

(6) Doherty, S.T. and E.J. Miller. A computerized household activity scheduling survey. In *Transportation* 27, 2000, pp. 75-97.

(7) Lee, M.S., S.T. Doherty, R. Sabetiashraf and M.G. McNally. iCHASE : An Internet computerized household activity scheduling elicitor survey. *Proc. 79th Ann. Transpn Res. Board Meeting*, Washington D.C., 2000.

(8) Kreiz, M. and S. Doherty. Spatial behavioural data: collection and use in activity scheduling models. In *Transportation Research Record* 1804, 2002, pp. 126-133

(9) Lee, M. and M.G. McNally. Experiments with a computerized self-administrative activity survey. In *Transportation Research Record* 1748, 2001, pp. 125-131.

(10) Janssens, D., G. Wets, E. De Beuckeleer and K. Vanhoof. Collecting activity-travel diary data by means of a new computer-assisted data collection tool. *Proc. of the European Concurrent Engineering Conference (ECEC)*, Hasselt, Belgium, 2004, pp.19-21.

(11) Tan, A., H.J.P. Timmermans and B. de Vries. Using a stereo panoramic interactive navigation system to measure pedestrian activity scheduling behaviour: A test of validity. In *Environment and Planning* B 33, 2006, pp. 541-558

(12) Wolf, J.L., R. Guensler and W.H. Bachman. Elimination of the travel diary: an experiment to derive trip purpose from GPS travel data. In *Journal of the Transportation Research Record* 1768, 2001, pp. 125-134.

(13) Wolf, J. and M.G.S. Oliveira. Impact of trip underreporting on vmt and travel time estimates: Preliminary findings from California statewide household travel survey GPS study. CDROM. Presented at *82nd Annual Meeting of the Transportation Research Board*, Washington, DC, 2003.

(14) Asakura, Y. and E. Hato. Tracking individual travel behaviour using mobile phones: recent technological development. Paper presented at the 11th *International Conference on Travel Behaviour Research*, Kyoto, August 2006.

(15) Bullock, P.J., P.R. Stopher and F.N.F Horst. Conducting a GPS survey with time-use diary. CDROM. Presented at *82nd Annual Meeting of the Transportation Research Board*, Washington, DC, 2006.

(16) Arentze, T.A., F. Hofman, N. Kalfs and H.J.P. Timmermans. System for logical verification and inference of activity (SYLVIA) diaries. In *Transportation Research Record* no. 1660, 1999, pp. 156-163.

(17) Kochan, B., T. Bellemans, D. Janssens and G. Wets. Dynamic activity-travel diary data collection using a GPS-enabled personal digital assistant. *Proc. of the Innovations in Travel Modeling Conference*, Austin, Texas, U.S.A, May 21-23 2006.
(18) Rindsfüser, G., H. Mühlhans, S.T. Doherty and K.J. Beckmann. Tracing the planning and execution of activities and their attributes: design and application of a hand-held scheduling process survey. *Proc. 10th Int. Conf. on Travel Beh. Res.*, Lucerne, Switzerland, 2003.
(19) Zhou, J. and R. Golledge. Real-time tracking of activity scheduling/schedule execution within a unified data collection framework. In *Transp. Research: Part A* 41(5), 2007, pp. 444-463.
(20) Stopher, P.R., P. Bullock and J. Rose. Simulating household travel data in Australia: Adelaide case study. In *Road and Transport Research*, 12 (3), 2003, pp. 29-44.
(21) The National Marine Electronics Association (NMEA) homepage. National Marine Electronics Association, Maryland, USA. www.nmea.org . Accessed Jul. 27, 2007.