Collecting activity-travel diary data by means of a GPS enabled personal digital assistant

T. Bellemans, B. Kochan and G. Wets

Transportation Research Institute (IMOB), Faculty of Applied Economics, Hasselt University

Wetenschapspark 1 bus 13, B-3590 Diepenbeek, Belgium

{Tom.Bellemans; Bruno.Kochan; Geert.Wets}@UHasselt.be

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Samenvatting

Verzameling van activiteiten- en verplaatsingsgegevens met behulp van een met GPS uitgeruste zakcomputer.

In deze paper wordt de ontwikkeling van een software toepassing voor de verzameling van activiteiten- en verplaatsingsgegevens in de vorm van dagboekjes uiteengezet. De software wordt ontwikkeld voor gebruik op een met GPS uitgeruste zakcomputer.

De opbouw van deze paper is als volgt: eerst wordt een verantwoording voor de keuze voor het verzamelen van activiteiten- en verplaatsingsgegevens onder de vorm van dagboekjes gegeven. Vervolgens worden de voor- en de nadelen van het gebruik van een met GPS uitgeruste zakcomputer toegelicht.

De functionele beschrijving van de software toepassing wordt op basis van de functionele modules waaruit de toepassing bestaat uiteengezet. Vervolgens wordt elk van de reeds in een prototype van de software geïmplementeerde modules in detail beschreven. Tenslotte worden een aantal in de toekomst te implementeren modules vermeld.

Summary

Collecting activity-travel diary data by means of a GPS enabled personal digital assistant.

This paper presents the development of an activity-travel diary data collection tool that runs on a GPS enabled personal digital assistant (PDA).

The outline of this paper is as follows: first, the decision to collect the data as activity-travel diaries is justified. Next, the advantages and the disadvantages of a GPS enabled PDA are presented.

A functional description of a general GPS enhanced activity-travel diary data collection tool is presented based on the composing functional modules. Next, each module that is implemented in the activity-travel diary data collection tool prototype is described in detail. To conclude, some modules that need to be incorporated in the prototype in the future are listed.

1. Introduction

The demand for transport services is expected to grow considerably as incomes rise, the trend toward urbanization continues and as the process of globalization moves forward with expected increases in world trade and personal travel. In order to meet this rising demand and because governments cannot afford to allow transport constraints to have a negative impact on the future competitiveness of their products, considerable future long-term investments are indispensable. In order to better guide and substantiate the decisions of transportation planners, the use of traffic and transportation models has been advocated by governments and by research communities.

Since 1950, due to the rapid increase in car ownership and car use in the US and in Western Europe; several models of transport mode, route choice and destination were used by transportation planners. These models were necessary to predict travel demand in the long run and to support investment decisions in new road infrastructure which originated from this increased level of car use. In those days, travel was assumed to be the result of four subsequent decisions which were modelled separately. Within transportation literature these models are also referred to as four-step models. More recently, especially in the eighties and early nineties, several researchers claimed that very limited insight was offered into the relationship between travel and non-travel aspects in the widely used four-step models. Indeed, travel has an isolated existence in these models and the question why people undertake trips is completely neglected. This is where activity-based transportation models came into play. The major idea behind activity-based models is that travel demand is derived from the activities that individuals and households need or wish to perform. The main difference however between traditional (i.e. four-step) transportation forecasting methodologies and activity-based transportation models is that the latter attempts to predict interdependencies between several facets of activity profiles. These facets are often identified as *which* activities are conducted *where*, *when* and for how *long*, with *whom*, and with which *transport* modes.

Obviously, data is needed for all these facets in order to be used in an activity-based transportation model. This paper focuses on a hand-held GIS-based logging system which will be put into use in order to collect data for all these facets. The paper contributes to the line of research which has explored the use of computer-assisted geographical information systems for geocoding the location of activities, such as Chase [4], Chase-GIS [8] and REACT [9].

The aim of this paper is to present the functional description of an enhanced activity-travel diary data collection tool designed for a GPS enabled mobile platform. Although the functional description of the mobile application is complete, it needs to be stated that the application itself is still a prototype.

The remainder of this paper is organized as follows. Section 2 gives a justification for the decision to collect the data as activity-travel diaries. In section 3, the advantages and disadvantages of a hand-held computer-assisted data collection tool are discussed. In section 4, the functional description of the data collection tool is given further consideration while section 5 presents a detailed description of the modules that are implemented in the application prototype. Finally, the paper concludes and defines some topics for future research.

2. Activity-travel diaries

As outlined in the previous section, activity-based transportation models have set the standard for modelling travel demand. It seems common practice nowadays to collect activity diary data to estimate activity-based transportation models. This section will discuss the potential advantages of diaries as opposed to traditional questionnaires, as well as other specific operational decisions regarding the format of these activity diaries.

The questionnaire, asking people for their average behaviour during a certain time period, has long been the dominant form of data collection in transportation research. It has been argued, however, that there is significant accumulated evidence that travel surveys under-report mainly off-peak, non-home based trips of short duration [3]. In [10], it was argued that a diary outperforms a travel survey in this respect. This seems to be consistent with the findings of other authors [2], who have reported that the diary resulted in a 13 to 16 percent higher level of trip-making than the travel survey. The available literature therefore seems to suggest that the diary is likely to outperform the questionnaire in terms of the validity of the data collected.

Diaries mainly differentiate by means of the type of information which is collected. The leading question in a trip diary is obviously related to the trips (out-of-home activities) that are made, while the activity diary mainly focuses on all the activities (in-home and out-of-home activities) the respondent says to be engaged in. Since an activity diary provides a richer source of information that allows additional and more detailed kinds of analyses and since a fully operational transportation model should be able to take the interrelationship between in-home and out-of-home activities into account, it is argued that despite the fact that only out-of-home activities generate traffic, in-home activities can provide useful information and should be collected as well. In order to emphasize that both activities and trips are considered in the collected diaries, the term activity-travel diaries will be used throughout the remainder of this paper.

However, collecting data by means of activity diaries is more demanding for respondents. Therefore, one should be aware of three potential sources of bias: 1) respondents who are very busy and make a lot of travel activities cannot afford the time to fill in the diary; 2) respondents with a relatively low level of out-of-home activities may decide not to participate because they feel their case is not relevant; 3) respondents may not always understand the need for collecting in-home activities as well and may drop out. All three concerns may potentially result in flawed diaries with non-response biases.

It is difficult to evaluate what the influence of hand-held computer-assisted information systems is on these concerns. Some researchers have argued that data collection is facilitated, while others state that it is experienced as an additional burden. However, it remains indisputable that electronic data collection yields information of higher quality. This was evidenced in [11] and in [6].

3. Advantages and disadvantages of a data collection tool based on a GPS enabled personal digital assistant

In the past, desktop computer-assisted data collection tools were used for filling out scheduling surveys which provided activity-travel diary data. However, these systems are not able to trace the actual activity-travel execution in real time due to their limited portability. In order to solve this problem, a Personal Digital Assistant (PDA) equipped with GPS technology can be used to enhance the data collection tool's mobility [7].

The portability of a PDA data collection tool enables in-situation data input while preserving the ability to perform consistency checks on the data provided by the respondent.

The potential advantages of equipping a Personal Digital Assistant with GPS technology to supplement activity-travel data are numerous: 1) when using a desktop computer-assisted data collection tool, the respondents have to remember the exact locations of their start and end positions, whereas with a PDA with GPS, trip origin, destination, and route data are automatically collected without burdening the respondent for the data; 2) as the respondent may forget to report an activity trip, another advantage exists in recovery of unreported trips, as all routes are recorded; 3) accurate trip start and end times are automatically determined, as well as trip lengths; 4) the GPS data can be used to verify self-reported data; 5) both the data entry cost and the cost of pre- and post-processing the data, constitute a significant share of the total data collection cost [12]. Fortunately, both can be reduced to a minimum with computer-assisted forms of data collection.

One of the most important shortcomings of GPS technology is the fact that the system is not always reliable throughout the entire trip-recording period. E.g., civilian GPS receivers exhibit position errors resulting from selective availability and other accumulated errors such as the "multipath" problem [1]. Hence, the GPS data needs to be verified before it can be used for further research. Another disadvantage associated with the use of a hand-held device is that the duration of data collection is subject to the storage capacity of the device used. Moreover, as the device makes use of a battery, it has to be recharged regularly, which is an extra burden.

The drawbacks of a GPS enabled PDA for collecting activity-travel diary data are outweighed by the ability of this technology to provide enhanced activity-travel diary data as discussed above. In the next section a general functional description of a data collection application designed for a GPS enabled portable platform is outlined.

4. General functional description of a mobile GPS enabled data collection application

This section presents a general functional description of a data collection application designed for a GPS enabled portable platform.

The application consists of two Graphical User Interfaces (GUI's) (the Household Survey GUI and the Activity Based Survey GUI), a GPS logger, a data structure (Activity Diary & Household Database and GPS Database), a data quality control module (Data Integrity Checks), a Trip Identification module, a GIS module[1] and a Communication module (Figure 1). In the remainder of this section each of these modules will be presented in more detail.

[1] Geographic Information System (GIS)

The GPS logger will be used to trace the physical travel paths and travel time. The logger collects data continuously and therefore it needs to operate in the background in order to allow for in-situation data input. This automatic feature has two main advantages. In the first place, it will facilitate data capturing because the survey respondent does not have to remember to activate/deactivate the logging application. Secondly, although the survey respondent may forget to register a new activity, the GPS logger will capture the user's position during the travel period. By applying a trip identification algorithm to these GPS logs, trips that were forgotten by the survey respondents can be detected.

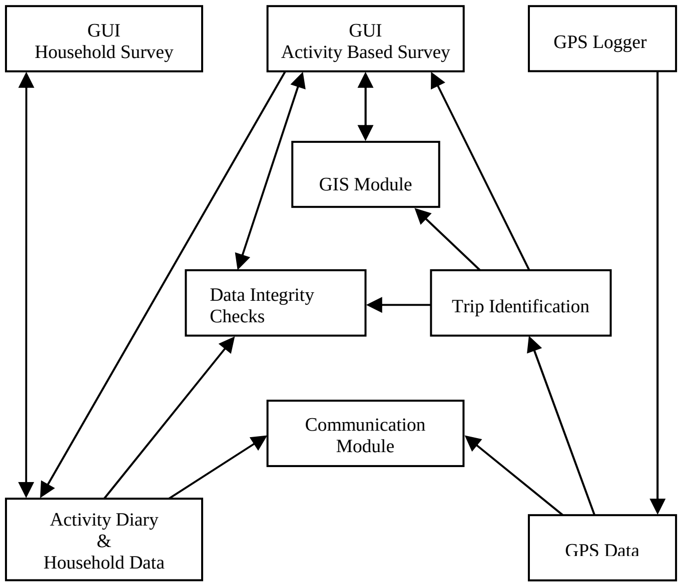

Figure 1: Schematic representation of the functional modules composing the activity-travel diary data collection tool. The arrows denote the flow of information between the modules.

Whenever active, the GPS logger captures the data that originates from the GPS chip in the form of "NMEA sentences"[2] and stores these strings in the GPS Database module. NMEA defines an electrical interface and a data protocol for communication between instrumentation. The GPS chip typically sends a group of NMEA sentences at intervals determined by the unit's update rate. A typical update rate for a civil general purpose GPS unit is once per second. The NMEA sentences contain information such as e.g. location information (longitude and latitude) and time.

The Household Survey GUI inquires for personal demographic and activity/travel-related information. This information is collected at the beginning of the survey period and it is

[2] NMEA is the acronym for the National Marine Electronics Association (http://www.nmea.org)

stored in the Activity Diary & Household Database module. In case some necessary information has not been input, the respondent still has the opportunity to add the missing parts afterwards.

During the survey period, the respondent will be in close contact with the Activity Based Survey GUI, which is the most important interface. This GUI captures the dynamic activity scheduling processes over the survey period and is triggered only when the survey respondent is going to perform an activity or when the Data Integrity Checks module explicitly asks the respondent to adjust inconsistencies (e.g. city names that do not exist) in the Activity Diary & Household database.

Once the survey period has come to an end, the information contained in the hand-held devices must be downloaded to a data server using the Communication module. If the mobile platform possesses data communication facilities (e.g. GSM, WiFi), these can be used to automatically make scheduled backups of the data.

As mentioned above, the NMEA sentences stored in the GPS Database module, can also be used for Trip Identification. Once the performed trip is identified it can be used to verify whether the information about activities, reported by the respondent, is consistent with the actually recorded trip. In case there are inconsistencies, the respondent will be prompted for further clarification.

Computer-assisted data collection tools have the advantage of data quality control. Indeed, a computer system can easily check for anomalies and prompt the respondent for additional information. Errors such as activities where the beginning hour of an activity is later than the ending hour, activity locations that do not seem to exist and many others can be easily checked by the Data Integrity Checks module.

The spatial dimension or the “where”-facet is the most difficult to collect in traditional paper-and-pencil diaries. People often do not precisely recall the exact location or the street name where a particular activity was carried out. For this reason, traditional diaries are often restricted by limitations about the detail of information which is collected. Obviously, computer-assisted data collection tools can make a significant contribution here. Therefore, on the PDA, a GIS module is implemented which enables the user to either pinpoint a location on a map or to manually enter a location.

In the next section the implementation of an enhanced activity-travel diary data collection tool prototype based on some of the functional modules presented in this section is described.

5. Implementation of a mobile activity-travel diary data collection tool prototype

This section describes the implementation of and design choices for a prototype of a mobile activity-travel diary data collection tool that was developed at the Transportation Research Institute (IMOB) at Hasselt University. The tool will be deployed in a large scale activity-travel survey to be conducted in Flanders, Belgium during the period 2005-2006. As the development of the tool is still ongoing, not all the modules described in Figure 1 are developed yet. However, due to the modular approach presented in Figure 1, the prototype can be deployed in trial runs in parallel with the implementation of additional modules. This allows for an efficient feedback loop between design, implementation and testing.

5.1. Hardware platform requirements

In order to be able to support all the functionalities described in Figure 1, the hardware platform needs to provide GPS functionality (GPS Logger module) as well as communication facilities (Communication module). These communication facilities can range from basic SMS functionality to GPRS or even WiFi functionality. Moreover, the hardware platform needs to have sufficient data storage available (Activity Diary & Household Database module and GPS Database module).

The mobile activity-travel data collection tool is being developed for the Pocket PC platform. The most notable advantages of the Pocket PC platform are the readily available hardware matching the above requirements and the fact that the Pocket PC platform is currently one of the most prevalent standards for mobile computing. Hence, the Pocket PC platform ensures maximal flexibility in hardware choice and minimises the risk of future compatibility problems as mobile computing technology advances.

5.2. Requirements imposed by the survey on the activity-travel diary data collection tool

Besides collecting the GPS location data, the activity-travel diary data collection tool prototype also needs to facilitate the collection of activity diaries as described in Section 2.

The use of the electronic activity-travel diary data collection tool allows for more complicated surveys such as the collection of data on the evolution from planned activities to executed activities within a diary. These data are collected as follows: first, a respondent inputs the activities he plans to do in the future as planned activities in the tool. If the respondent changes his mind and alters his/her planning, these changes are also input in the tool. After a change to an activity attribute is made, the tool asks why the change was made. If a planned activity is executed, the respondent changes the status of the planned activity to ‘executed’, reviews the activity attributes and updates the attributes if necessary. Whenever updates are made to an activity attribute, the tool asks the respondent why these changes were made. This way, information is collected regarding the decision and scheduling processes that result in an evolution from an intention to execute some activities to an executed activity diary.

The mobile activity-travel diary data collection tool prototype facilitates the extensive data collection compared to the traditional pencil-and-paper approach. Besides the collection of activity-travel diary data, the prototype also logs detailed location information.

5.3. Detailed description of the activity-travel diary data collection prototype

Currently, the prototype includes the following modules: Activity Based Survey GUI, GPS Logger, Data Integrity Checks (basic functionality) and the Activity Diary & Household Database and the GPS Database (Figure 1). This section discusses the functionality and the implementation of these modules in the prototype tool.

If the activity-travel data collection tool is started, the main GUI is shown. The main GUI is presented in Figure 2.

As can be observed in Figure 2, there is no button provided to control the GPS logger. However, if the tool is operational, the GPS logger is automatically operational in the background. Whenever a respondent is making a trip, the location information can be collected by simply switching on the PDA and by starting the activity-travel diary data collection application. In order to prevent the touch screen from being accidentally activated while the PDA is stowed during a trip, the 'Vergrendelen'[3] button provides a screen lock functionality. Whenever the screen lock is activated, the touch screen is switched off to conserve energy (battery stamina) while the GPS logger continues registering NMEA sentences. A blinking led provides the respondent with visual feedback that the GPS logger is still active. The screen can be reactivated by simultaneously pressing a button combination on the PDA.

The 'Afsluiten' button shuts down the tool completely i.e. the GPS logger is deactivated and the PDA is switched off. This status is used to conserve energy during long activities such as e.g. working.

Figure 2: Main GUI shown after start-up of the application. The main GUI contains buttons to control the input of the activity diaries (buttons 'Agenda' and 'Planning') as well as buttons to lock the screen during GPS logging and to close the application.

The GUI's and the functionality behind the 'Agenda' and the 'Planning' buttons on the main GUI (Figure 2) are now be discussed in more detail.

The 'Planning' button in the main GUI starts the planning GUI. The planning GUI implements part of the Activity Based Survey GUI module shown in Figure 1. In the planning GUI, the respondent is provided with an overview of the planned activities. The planned activities are grouped by day and are listed in the same order they were entered. An example of the planning GUI is shown in Figure 3. A new planned activity can be added to the planning by clicking the white button 'Klik hier om planning toe te voegen' (click here to add

[3] The activity-travel diary data collection tool was designed to be deployed on a large scale in Flanders, Belgium. Hence the GUI language is Dutch as can be observed in the screenshots.

a planned activity) at the bottom of the GUI. It is obvious that one can only plan activities in the future. Hence, the planning GUI is only available for the future surveyed days and the planning GUI can exclusively contain planned activities.

The ‘Agenda’ button in the main GUI starts the agenda GUI which contains the activity diaries. The agenda GUI is also a part of the implementation of the Activity Based Survey GUI module shown in Figure 1. The agenda GUI takes its name from the fact that its layout resembles an agenda as can be seen in Figure 4. The height of each depicted activity is scaled according to the activity duration and the activity position in the GUI is determined by the start hour of the activity.

Figure 3: The planning GUI, which allows to input the planned activities for a day. The planned activities for a day are shown in the order they were entered. The respondent can browse through the surveyed days using the black arrows on top of the GUI.

The agenda GUI is used for browsing the executed activities in the past as well as the planned and the executed activities of the current day. Hence, the agenda GUI can contain both planned and executed activities. 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. In the agenda GUI a new activity is added by clicking the area where the activity needs to be added.

The planning and the agenda GUI graphically differ since they need to achieve different requirements. The agenda GUI needs to facilitate the input of executed activities. The agenda GUI component provides visual feedback about timing and duration of the activities in order to avoid mistakes. E.g., it is easy to locate ‘gaps’ in between consecutive executed activities in a diary using the agenda GUI.

The planning GUI on the other hand needs to facilitate the input of the activities the respondent plans or intends to execute. It is argued in the literature that a list of activities is more preferable than an agenda-like interface for collecting planned activities [12]. This due to the fact that an agenda-like interface introduces a bias on the planned activities that are input due to the visual feedback of the interface.

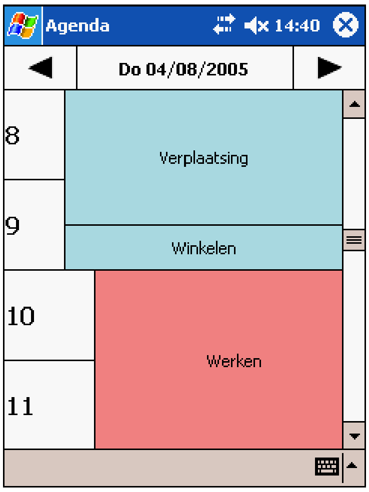

Figure 4: The agenda GUI allows the respondent to browse the activities in the past as well as the activities for today and for the past. Executed activities are depicted in blue and are wider than planned activities, which are depicted in red.

Whenever a new activity is added to either the planning GUI or the agenda GUI, a number of attributes characterizing this activity need to be provided. Which attributes need to be stored for each activity in the Activity Diary & Household database is determined by the survey conducted. The Activity Diary & Household database consists of a data file in the eXtensible Markup Language (XML) format for easy access and flexibility [5].

Based on the activity attributes to be stored in the database, a GUI was designed to allow the user to input the required information. Since the screen of a PDA is rather small, the GUI needed to be split in two parts as shown in Figure 5. First, the GUI on the left hand side is shown. By pressing the ‘Ga verder’ (next) button, the GUI on the right hand side is shown. Going back from the second to the first GUI is achieved by using the ‘Annuleren’ (cancel) button. The GUI’s in Figure 5 are not only used to input attributes of new activities but they are also used if the attributes of an existing activity need to be changed (e.g. rescheduling) or completed.

The most important activity attributes the activity-travel diary data collection tool prototype stores are (Figure 5):

- Activity status: executed (‘Uitgevoerd’) or planned (‘Gepland’). Depending on the status, the activity is shown in blue (planned) or red (executed). If a respondent executed an activity, the status of that activity in the tool is updated from planned to executed using the radio buttons.
- Activity type (‘Activiteit’)
- Date (‘Datum’): The date the activity is planned/was executed.
- Start hour of the activity (‘Van’)
- End hour of the activity (‘Tot’)
- Location (‘Locatie’): The city or municipality where the activity takes place.
- Mode of transportation (‘Welk vervoersmiddel gebruikt u?’)
- Travel time (‘Reistijd’): The travel time spent using this mode of transportation.
- Travel party (‘Met wie’): An indication of the people travelling with the respondent.

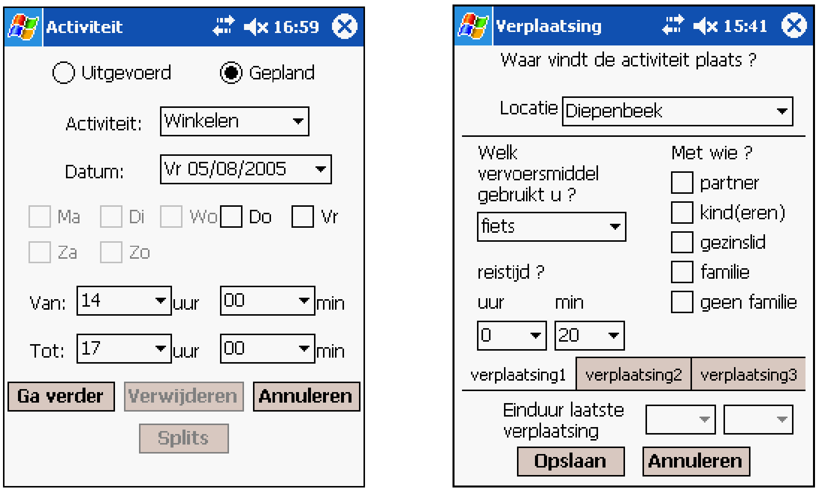

Figure 5: GUI’s used to input or update the attributes of an activity. Switching between both GUI’s can be done using the ‘Ga verder’ (next) and the ‘Annuleren’ (cancel) buttons.

Since the journey to an activity location often consists of several trips with different modes of transportation and/or different travel parties, the GUI allows the respondent to use the tabbed panes (‘Verplaatsing X’) to input a journey as a sequence of up to three trips. For each trip the respondent needs to provide a mode of transportation, a travel time and a travel party (Figure 5, right).

The choice options for the activity type, the date, the location and the mode of transportation are customisable through a configuration file for improved flexibility.

By pressing the ‘Opslaan’ (save) button in the GUI on the right hand side of Figure 5, the attributes are saved to the Activity Diary & Household database. However, before the data is saved to the database, the Data Integrity Checks module (Figure 1) is activated followed by a check to verify which activity attributes have changed.

If the data integrity checks succeed and there are activity attributes that have changed, an inquiry about the reason for the change is displayed (Figure 6). The choice options for the reason of the attribute change are attribute specific and are configured using a configuration file. If the respondent confirms the reason for the activity attribute, the activity attributes and the reason for the change of the attribute are saved to the database.

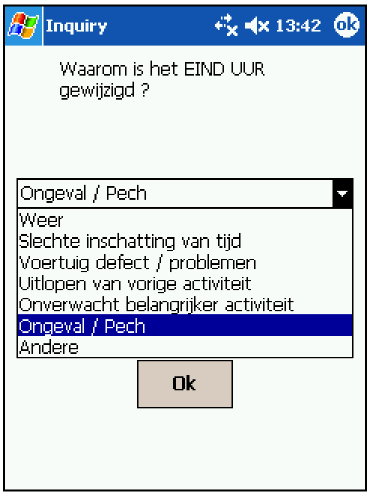

Figure 6: GUI inquiring why the activity attribute ‘einduur’ (end hour) was altered by the respondent.

If the data integrity checks fail, the respondent receives an error message such as illustrated in Figure 7 and the activity attributes GUI is redisplayed. The respondent needs to solve the data conflict before the data can be saved to the database.

The GUI's illustrated in Figures 2 through 7 are the prototype implementation of the Activity Based Survey GUI module in Figure 1. The Data Integrity Checks module from Figure 1 combines the data stored in the Activity Diary & Household database with the data that the user inputs in the GUI's to ensure data consistency and data quality.

In the prototype tool, there currently are four types of consistency checks implemented:

- A check in real-time to ensure that the data the respondent inputs is consistent. E.g. the start of the activity needs to take place before the end of the activity.
- A check in real-time to ensure that the data the user inputs is not conflicting with data present in the 'Activity Diary & Household' database. E.g. two activities can not simultaneously be executed at two different locations.
- A check that runs once daily to verify whether there are still planned activities in the past. If so, the respondent is asked to confirm these activities as executed or to reschedule the activities such that they are planned in the future.
- A check that runs once daily to verify whether there are 'gaps' between consecutive executed activities in the past. If so, the respondent is asked to update the activity diary such that consecutive activities join together exactly.

Figure 7: An example of a typical error message triggered by the data consistency module.

This section described the implementation and the functionality of the modules from Figure 1 that are currently operational in the activity-travel diary data collection tool prototype. Although the prototype is operational, the next section lists some modules from Figure 1 that still need to be implemented or that can be enhanced.

6. Further improvements to the activity-travel diary data collection tool prototype

Modules that need to be implemented in the future to add extra functionality to the activity-travel diary data collection tool prototype include: the Household Survey GUI, the GIS module, the Trip Identification module, the Communication module and a more advanced version of the Data Integrity Check module.

These modules are currently unimplemented either because their functionality is less important to the current research project or because more research is needed before they can be implemented.

Currently some enhancements of the Data Integrity Check module are being investigated. A next step will be the implementation of the Trip Identification module. The output of the Trip Identification module can be used as input of the enhanced Data Integrity module as shown in Figure 1.

7. Conclusions

Due to the evolution towards more detailed activity-based transportation models, the need for reliable and more detailed activity-travel diary data grows. These more demanding data specifications require a more advanced approach to data collection than the traditional pencil-and-paper survey techniques.

This paper presented a functional description of an activity-travel diary data collection software tool to be deployed on a personal digital assistant. The software tool is able to use the GPS capabilities of the personal digital assistant to enhance the collected activity-travel diary data with detailed location and time data. The software tool has a modular structure and the functionality of each of the modules was presented.

The modules from the functional description that were already implemented in a prototype tool were presented in detail. In conclusion some modules from the functional description that will be included in the prototype in the future were listed.

Acknowledgements

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