Design and Implementation of a Smartphone-based System for Personal Travel Survey: Case Study from New Zealand

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Corresponding Author:
Hamid Safi
PhD Candidate, School of Civil Engineering
The University of Queensland, Brisbane, 4072 QLD, Australia
Phone: (+61) 7-334-61349
h.safi@uq.edu.au

Behrang Assemi
Research Fellow, School of Civil Engineering
The University of Queensland, Brisbane, 4072 QLD, Australia
Phone: (+61) 7-336-53520
b.assemi@uq.edu.au

Mahmoud Mesbah
Lecturer, School of Civil Engineering
The University of Queensland, Brisbane, 4072 QLD, Australia
Phone: (+61) 7-336-51569
mahmoud.mesbah@uq.edu.au

Luis Ferreira
Professor, School of Civil Engineering
The University of Queensland, Brisbane, 4072 QLD, Australia
Phone: (+61) 7-336-54356
l.ferreira@uq.edu.au

Mark Hickman
ASTRA Chair and Professor, School of Civil Engineering
The University of Queensland, Brisbane, 4072 QLD, Australia
Phone: (+61) 7-336-53692
m.hickman1@uq.edu.au

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ABSTRACT

This study introduces a new smartphone-based system for performing personal travel data collection. The system, SITSS (Smartphone-based Individual Travel Survey System), is designed to deal with the challenges associated with applying smartphones in real-world travel surveys, including battery depletion, participant’s involvement and privacy concerns. A prompted-recall smartphone-based data collection approach was employed in the development of SITSS to facilitate the procedure of data collection while improving the accuracy of collected data. The system was employed as a part of the national household travel survey of New Zealand to investigate the various aspects of performing a national level travel survey using smartphone. The study confirmed the successful performance of SITSS in a multi-day travel survey. Participants found the data collection procedure as an interesting experience, and 71% of them continued their participation beyond the expected data collection interval. Participants found the procedure of data collection fairly straightforward and 94% of them could complete the task without any support request. In addition, it was found that the smartphone application did not interrupt participants’ interaction with their smartphones. The battery saving algorithms employed in the application could satisfactorily preserve the battery life of the smartphone. The study also addressed other challenges associated with implementing SITSS, including the procedure for labeling trips, respondent’s experience with the data collection method, and concerns related to the performance of the smartphone application.
INTRODUCTION

In recent years, several developments have occurred in travel survey methods, specifically the utilization of location and communication technologies provided on smartphones for monitoring personal travel behavior. The application of these technologies has provided the opportunity to more accurately reflect the details of individuals’ travel behavior that were not feasible to obtain using conventional data collection methods. The employment of Global System for Mobile Communications (GSM) signals in conjunction with Global Positioning System (GPS) signals improved the accuracy of positioning even in congested and under covered areas (1-3). The possibility of uploading the collected data through GSM data coverage (2; 4-7), and also the utilization of participants’ smartphones as the data collection medium have reduced participants’ burden and required human resources compared to conventional data collection methods (2; 4; 8). The possibility of supporting the data collection with smartphone-based questionnaires provides surveying institutions and authorities with the opportunity to collect participants travel activity, as well as their demographic attributes more accurately.

However, the real-world application of smartphone-assisted travel surveys has been faced with a set of challenges. One major challenge is the lack of an appropriate system design for dealing with the current concerns of employing smartphones for travel surveys. Some of these concerns are: significant level of participants’ involvement (6; 8-10), battery consumption of travel logging applications (6; 10; 11), interruption of participants’ daily travel activity (10; 11), and privacy concerns, which distress individuals’ participation in this type of data collection (2). In most of the previous smartphone-assisted data collection systems, participants were required to have a high level of interaction in the procedure of data collection (4; 6; 10; 11), which adversely impacts the quality of collected data as well as their participation rate. Some recent research efforts have focused on dealing with this concern through suggesting data processing tools for automatically detecting the travel attributes based on the collected spatiotemporal data of participants. Yet these tools require a massive amount of data transfer which causes difficulties for both participants and survey providers. Dealing with this concern, Gonzalez et al. and Nitsche et al. employed some limited smartphone devices, distributed between participants, and recollected the devices after the data collection (9; 12). This approach might be possible for pilot studies, but requires significant human and financial resources. The high rate of battery consumption of travel logging applications is another common concern in all previous smartphone-assisted travel data collections (3; 6; 9). This problem is caused due to working with the GPS sensor of smartphones, which is extremely power hungry (13). Although several efforts have been focused on addressing this concern (4; 5; 7; 14), a validated system design has not yet been proposed which can be applicable to real-world data collection.

This study attempts to address these concerns by proposing a smartphone-based travel data collection system, which is designed for real-world scale data collections. A smartphone-based prompted recall data collection approach has been proposed and employed in order to minimize participant’s involvement and facilitate survey implementation while improving the accuracy of collected data. Specifically, the objectives of this study are to:

- design and develop a smartphone-assisted travel data collection system, dealing with the current concerns of smartphone-assisted travel data collections; and,
- conduct a real-world experiment to evaluate the capabilities of the proposed system in addressing the challenges and issues associated with the data collection.
The rest of this paper is structured as follows. In Section 2, the proposed system, its structure and components, including the smartphone application and the servers are introduced. Section 3 explains the procedure of data collection and also the data model employed in this study. Section 4 depicts the experiment, where the proposed data collection method is applied as a part of a national household travel survey in New Zealand. Section 5 presents the results of the experiment and discusses the main findings of this study. Finally, section 6 provides some conclusions for both academics and practitioners along with a summary of further research opportunities.

9 SITSS: SMARTPHONE-BASED INDIVIDUAL TRAVEL SURVEY SYSTEM

SITSS is a new generation smartphone-based system for personal travel data collection. The system is developed as a prompted-recall data collection approach. In this approach, the travel activity of a participant is recorded passively by a smartphone application installed in his/her smartphone. At the end of the travel day, the participant is invited to recall and label his/her travel activity through the interface provided by the smartphone application. Unlike most of previous smartphone-assisted data collection studies (4-6), the procedure of recalling and labelling occurs on the smartphone of participant, and there is no need to perform any supplementary web-based survey to recall and label the collected data. This approach has been employed to allow participants to more conveniently record, recall, and report their travel behavior using their smartphone.

As presented in Figure 1, SITSS is developed as a client-server application. The client side of the system is a smartphone application which is installed on a participant’s smartphone and automatically records his/her travel behavior. The server side, which consists of a set of servers, supports the procedure of data collection and has no direct interaction with participants during the data collection.

Figure 1 SITSS system architecture.
Smartphone Application - ATLAS II

ATLAS II, which stands for Advanced Travel Logging Application for Smartphones, is the name of a smartphone application and is the main interface of the system, designed to collect the travel behavior of participants automatically. ATLAS II has some unique features which qualify it as the new generation of smartphone application for reflecting the travel activity of individuals:

- It is able to **automatically start and stop trips** as long as the phone is carried by a participant;
- It is able to **extend the tracking time to a full-working day** through advanced battery optimization algorithms applied in the application. While the normal battery life of a smartphone with GPS tracking is 4 to 5 hours, ATLAS II is able to track daily trips with a single battery charge. This was made possible by developing smart algorithms to detect the start of a trip and to use the battery consuming methods of GPS tracking only during an actual daily trip. The application returns to low battery consumption mode when the trip is finished.

This application is currently running on iOS-based devices and has five different tabs. Some screenshots from different tabs of the ATLAS II application are presented in Figure 2. The first tab is the ‘Today’ tab. A user can find a variety of information regarding his/her travel activity, such as the duration and travelled distance of their current trip, as well as a list of all previously recorded trips in the travel day in this tab. In addition, this tab is supported by Apple Maps API (Application Programming Interface) to visualize the trajectory of the current trip of the user. Although the application can automatically start and stop tracking, the participant can also manually define a new trip by tapping on the plus (+) button on the top right corner of this tab, or stop the tracking by tapping on the (x) button. It should be noted that the automatic feature of the application prevails over the recording process, which means if the participant by mistake stops the recording process during a travel activity, the automatic feature will restart recording soon after. The second tab, ‘History’, contains all previously recorded trips, and also a button on the top right corner to upload the labeled data to the SITSS server. Recorded trips are categorized based on their date and whether they are uploaded or not. The third tab is the ‘Profile’ tab, and contains the user’s account detail and a section to put a variety of questionnaires. The fourth tab is the ‘Help’ tab, and provides support for participants through tutorials and frequently asked questions. The last tab, ‘Info’, contains information regarding the research team and goals of the research. The application’s user interface was designed to be very simple and user-friendly and was tested over different screen sizes. The labelling procedure was designed as a straightforward procedure and enabled participants to correct their answers as frequently as they needed.
ATLAS II receives and processes GSM and GPS signals, when each of them is available, to detect and record the location of the device. The smartphone application is designed to receive the required data and transmit the user's data from/to the server when the user actively chooses to upload that information. Accordingly, it does not need any real-time communication with the server and thus, it does not rely on GSM data coverage. This feature allows the application to continuously record participants' trips, even in remote areas. However, if the participant wants to view his/her (current or past) trips on a map, the application retrieves the data through Apple Maps APIs (Application Programming Interfaces) which needs data transmission. When the application is working without data coverage, it is still able to provide trip details, such as the duration or total length of each trip.

The smartphone application is able to detect participant's movements and stops. The application relies on GSM signal changes (which are continuously evaluated by the device) to detect the participant's movements beyond a threshold, as GPS signal processing is energy-consuming. When a significant movement is detected, the application starts using GPS positioning to accurately record a trip until it detects the participant's stationary condition lasting beyond a threshold (i.e., 360 seconds). During a recording, the application automatically records the travel attributes of a participant (e.g., timestamp, GPS coordinates, speed, heading, and...
location accuracy) for every 10 meters of movement. In fact, the GPS sensors of the smartphone are only turned on when the application is recording a trip, which enhances the battery efficiency. Having this approach, the application may only miss up to 400 meters of the initial sections of a trip, until it starts recording the trip using GPS signals. This threshold can be revised based on the required spatiotemporal accuracy of data collection.

The architecture of ATLAS II is presented in Figure 3. The smartphone application consists of six major components: ‘connection manager’, ‘data manager’, ‘user-profile manager’, ‘survey manager’, ‘trip recorder’ and ‘trip visualiser’. The application also incorporates three major iOS components: Core Data, Core Location and Map Kit. The Core Data component supports the application data management tasks through retrieving, updating and deleting user's trip data on the device, in an interaction with the application's ‘data manager’ component. It also keeps the records of the user's profile as well as the application usage, along with the application's ‘user-profile manager’. Moreover, the Core Data component in conjunction with the application's ‘survey manager’ component provides online surveying functionality and records and updates user responses on the device. Surveys and their relevant questions are managed on the SITSS servers. Using the survey design functionality researchers can add, remove or change surveys at any time. The question types, contents and potential choices can be updated on the server while personalized questions/choices can be added for each individual participant.

Significant movements of participants are detected by the application's ‘trip recorder’ component along with the iOS Core Location component. When the iOS Core Location detects a significant movement, the ‘trip recorder’ component of the application turns on the GPS sensor to accurately track the user's locations, and the stream of data is recorded on the user's device through the ‘data manager’ component. The ‘trip visualiser’ component uses iOS Map Kit services to overlay the user's (current or past) trips on a map, when the user decides to see his/her trips. This component also illustrates general trip information, such as start/finish time and total trip length. The ‘trip visualiser’ component along with the ‘survey manager’ component support the prompted-recall procedure at the end of each day, in which user is invited to review his/her trips and label them by specifying their mode and purpose. When the trips are all labeled, the user can use the trip visualizer services to upload his/her trip data to the SITSS servers.
SITSS Servers

SITSS servers consist of three major components: a web-server, a database server and a web-portal. The SITSS web-server supports the ATLAS II application with real-time communication using SQL commands. The SITSS database server stores all the transferred data from the ATLAS II application to the server and provides required data management functionalities for the SITSS web-server, as well as the requirements of the SITSS web-portal for presentation/visualisation. The SITSS web-portal provides both participants and survey providers with uploaded data from the SITSS database server and illustrates the data in tables and on a map.

The SITSS database server supports survey providers with a set of functions to accurately monitor the travel activity of participants. For instance, the interaction of participants with ATLAS II application, such as the time and location of initiation/termination, is monitored and recorded in the SITSS database server and can be then used to complement the uploaded trip data for analysis purposes (e.g., detecting completed travel days). In addition, the SITSS database server allows real-time changes in the surveys appearing on the ATLAS II application, including adding/removing surveys and assigning questions to each survey, as well as defining enhanced survey functionalities including different question types (e.g., multiple choice - multiple answer and descriptive response / short answer).

The SITSS web-portal uses the Google Maps APIs to visualize trip trajectories and is accessible from any type of device through a web browser. The web-portal provides different levels of access to the uploaded data for participants and survey providers. This web-portal includes: (1) a title section which displays the system name, and user information; (2) a query bar which provides a user with the possibility of defining specific queries from the uploaded travel data; (3) an interactive table which will be updated based on the type of query and contains the list of selected trips as well as the detailed recorded attributes of each trip; and (4) a digital map for the visual display of trip details, such as origin, destination and trajectory. Figure 4 presents a screenshot of the SITSS web-portal.

![Figure 4 SITSS web-portal screenshot.](image-url)
DATA COLLECTION PROCEDURE

The procedure of travel data collection using SITSS can be divided into four stages. First, the participant is invited to download and install the smartphone application from the AppStore. Each participant is provided with a temporary username and password to login to the application. They are requested to complete a demographic questionnaire and also to reset their temporary password to confirm the confidentiality of their travel behavior. Second, in the ‘data collection’ stage, the participant is requested to launch the application before starting his/her travel day and run it in the background during the travel day. The application automatically detects significant movements and starts the recording when the participant moves significantly (more than 400 m), and stops recording automatically when the participant becomes stationary for a given time (360 seconds). If the participant launches the application during the travel day, he/she can see the trajectory, travelled distance and elapsed time of the current trip as well as a list of his/her previously recorded trips in the ‘today’ tab of the application. Third, ‘trip labeling’ starts when the participant finishes his/her travel day. In this stage, the participant is invited to review all of the trips recorded by the application during the travel day, and label them based on their mode and purpose. At this stage, which is considered as a compulsory part of the data collection, the participant is provided with the trajectory, origin and destination and their street addresses, the start time and finish time, and the travel distance of each trip to accurately recall and label all the recorded trips. Fourth, at the end of this stage, the participant uploads all labeled trips on the SITSS servers. The participant could decide on when to upload the recorded data on the server. In fact, all participants were encouraged to upload the recorded data via Wi-Fi to preserve their data quota. It should be mentioned that the prompted recall is recommended to be implemented at the same day of data collection to more accurately capture the correct responses of the participant. In addition, if the participant does not want to report a specific trip due to privacy concerns, he/she can delete the whole travel day. Deleting a specific trip is not allowed, since uploading incomplete travel days can adversely impact the quality of the collected data.

EXPERIMENTAL STUDY

SITSS was employed in the national household travel survey of New Zealand. A unique experiment was designed and implemented with the cooperation of the Ministry of Transport, New Zealand. 186 potential participants who had an iPhone were approached to be surveyed using SITSS; 112 of them were participants of previous household travel surveys and 74 of them were approached through other methods, such as commercial panels, computer-assisted telephone interview (CATI) or targeted advertising. The participants of this study were recruited among individuals who participated in the household travel survey (HTS) of New Zealand. Except for having access to an iPhone, no specific consideration was applied in the recruitment procedure. After an initial household profile survey, all of the potential participants were invited to participate in the experiment, in a stepwise procedure, based on the sampling methods of the New Zealand national household travel survey (HTS). More details regarding the procedure of recruitment can be found in (15). Based on the results of the initial household profile survey, more than 46 percent of the participants of the household travel survey of New Zealand had an iPhone (2). The significant rate of iPhone ownership and the consistent performance of different versions of iOS-based smartphones encouraged us to develop the smartphone application for iOS smartphones. Among the 186 approached individuals, 77 of them installed the application of their smartphone and created a profile. Figure 5 compares the demographic attributes of the
approached individuals and of the final participants. It is noticeable that females were more interested in participating in this experiment. In another study, a similar gender gap was noticed among the participants of the national household travel survey of New Zealand (2).

Figure 5 Comparison of the demographic attributes of approached individuals and participants.

Respondents’ interaction with the smartphone application and also their satisfaction from the whole procedure of data collection are two important issues which directly impact on their participation and data collection accuracy. In order to address these important issues, three strategies were employed in the experiment.

- **Self-learning approach**: In order to evaluate how the participants can be accustomed to the system, only passive training is provided for them through a detailed tutorial in the smartphone application for self-learning.

- **Continued participation**: The profile accounts of participants were not disabled after the survey period to evaluate their interest to continue working with the application and uploading additional trips.

- **Application performance reliability**: One of the requirements of the data collection is having the smartphone application running on participants’ smartphones. In some cases, the application might be terminated automatically by iOS or manually by participants, which leads to missing the travel record of the participant for a period of time. In order to deal with this concern, the ‘data manager’ component of the application reports the performance of the application to the server, regarding the time the application started working and whether it was terminated automatically or manually.

This experiment took around two months, from March 4 to April 30, 2014. Participants were informed by email to start the survey by installing the ATLAS II application on their smartphone and working with it for three weekdays. After the three-day interval, they received another email to remind them that the data collection was finished, and they can stop recording
their travel behavior by uninstalling the smartphone application. Among the 77 participants who installed the application on their smartphone, 73 participants (95%) uploaded at least one travel day to the server, while 65 of them (84%) successfully completed the experiment (upload their trips for at least three days).

RESULTS AND DISCUSSIONS

The experimental results are shown in Table 1(a) to Table 1(e) and explained in the remainder of this section. The 73 participants collected a total of 424 days’ worth of travel/activity data. As shown in Table 1(a), 1873 trips were manually labeled and uploaded by participants during the experiment. The total duration and length of uploaded trips are respectively more than 434 hours and 14 thousand kilometers.

Table 1 SITSS System Experiment Results

(a) Uploaded Data Summary

<table>
<thead>
<tr>
<th>Total days of experiment</th>
<th>58 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of participants who uploaded their trips</td>
<td>73</td>
</tr>
<tr>
<td>Total number of reported trips</td>
<td>1873</td>
</tr>
<tr>
<td>Total number of reported travel-days</td>
<td>424</td>
</tr>
<tr>
<td>Average participation days per participant</td>
<td>5.8</td>
</tr>
<tr>
<td>Total length of uploaded trips</td>
<td>14,402 km</td>
</tr>
<tr>
<td>Total duration of uploaded trips</td>
<td>434 hours and 29 minutes</td>
</tr>
</tbody>
</table>

(b) Recruitment Summary

| Total approaches | 186 |
| Participants who defined a profile on the app | 77 |
| Participants who uploaded at least one travel-day | 73 |
| Participants who uploaded more than three travel-days | 55 |
| Participants who uploaded just three travel-days | 10 |
| Participants who uploaded one or two travel-days | 8 |

(c) Participants' Support Summary

| Total number of IT support messages | 5 |
| Number of messages regarding username and password | 4 |
| Number of messages regarding the application | 1 |

(d) Smartphone Application Performance

| Average number of working days per participant | 6.9 days |
| Average number of manual starts per participant | 5.2 |
| Average number of manual terminations per participant | 4.9 |
| Average duration of working | 36.6 hours |

(e) Trips' Refinement Summary (Based on Application Performance)

<table>
<thead>
<tr>
<th>Total</th>
<th>Removed</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Days</td>
<td>424</td>
<td>85</td>
</tr>
<tr>
<td>Trips</td>
<td>1873</td>
<td>304</td>
</tr>
<tr>
<td>Average number of trips per participant per travel day</td>
<td>4.63</td>
<td></td>
</tr>
</tbody>
</table>
Recruitment summary

As presented in Table 1(b), among the 186 individuals approached in the first step of the experiment, 77 of them (41% of total) installed ATLAS II and started using it. This response rate, which is close to the response rate of other conventional household travel surveys (I6), shows an initial hesitation between potential participants to join the survey. However, most of the participants found this experiment as an interesting experience during the data collection and continued their participation. Although all participants were notified of the completion of the data collection at the end of the third day, 55 participants (71% of the total participants) continued their participation (See Table 1(b)). In fact, the actual number of participation days per participant is more than 5.5, which is almost twice the rate requested in the experiment. It shows the success of the SITSS in providing a pleasant experience for participants, which encouraged them to continue their participation. As shown in Figure 5, there is no obvious difference between the demographic attributes of those who were approached for the experiments and those who participated.

Participant’s support

Most participants could work with the smartphone application, recording, labeling and uploading their trips only by using the self-learning manual. Among the 77 participants, only 5 support requests were received, while 4 of them were related to a username/password problem, which is not directly related to the performance of the SITSS. This result shows that most of the participants could understand and conduct the procedure of data collection through the provided self-learning materials which reduced the administration requirements.

Application performance summary

As shown in Table 1(d), the average time of having the application installed on participants’ smartphone was 6.9 days, while the average participation days per participant was 5.5. It means that the application recorded some trips which were not uploaded by participants. In other words, the application recorded some trips, but a participant deleted them. Privacy issues could be one reason for this difference. In addition, it is found that on average the application has been started manually for 5.2 times during the data collection. Considering the average participation days per participant, it can be implied that participants started the application almost once per participation day. On the other side, the rate of manual terminations per participant is 4.9. This rate is reasonable to be less than the rate of manual starts, as in some cases the application is terminated automatically by the smartphone operating system.

Another interesting discussion regarding the difference between the rate of manual starts and the rate of manual terminations is the satisfaction of participants to have the application running on their smartphones. It was expected before the experiment that participants would terminate the application when they had heavy battery usage or any other concern regarding their smartphone. But it is found that the battery saving algorithms employed in the smartphone application could successfully preserve the battery of the smartphone, and this persuaded participants to have the application running in the background of their smartphone. The average working duration of the application, which was 36.6 hours, is more evidence that the application has worked fine in the background of the smartphone and did not interrupt participant’s interaction with his/her smartphone.
One of the concerns on employing a smartphone application for travel data collection is the possibility of the termination of the application by the smartphone operating system or the user, which can cause reporting of an incomplete travel record. In order to deal with this concern, those days in which the application did not work completely during the day were detected and removed from the database. As shown in Table 1(e), 85 travel days (20% of all travel-days) and 304 trips (16% of all trips) were removed from the database in this refinement procedure. The new average number of trips per participant per travel day (individual trip rate) is calculated as 4.63 trips per person per day. This value can be compared with the average number of trips per person in the traditional household travel survey of New Zealand. In fact, the rate of personal trips per household in a working day was 7 trips per household in 2011 (17), while the average household size was 2.5 persons (18). This means the average individual trip rate is 2.8 trips per person. Although all the participants of the SITSS experiment were more than twenty years old, and their trip rate might be more than an average household member, the estimated individual trip rate based on the traditional household travel survey of New Zealand is significantly less than the value in the current experiment. It shows that SITSS can record more trips compared to a traditional method as the trips are automatically recorded.

In summary, the results of this experiment demonstrate the success of SITSS system in performing a real-world individual travel survey. The proposed system reduced the required human and financial resources for performing the experiment, by employing a self-learning procedure for participants, and also uploading the collected data through GSM data coverage, which requires significant human resources in conventional GPS-assisted data collection methods (19-21). The implementation of battery saving algorithms and also designing the data collection process with respect to the privacy concerns of participant could successfully encourage participants to continue their participation in the experiment. In addition, the implementation of the prompted recall at the same day of travel data collection is another priority of SITSS, which improves the accuracy of labelled data by resolving the problem of forgetting the travel details (22; 23). Finally, the possibility of employing smartphone-based questionnaires for collecting participants’ demographic attributes, as well as any other specific information from participants, can obviate the necessity of initial household profile surveys and facilitates the procedure of data collection.

CONCLUSIONS

This study developed a new smartphone-based travel data collection system to satisfy the requirements of a real-world and scalable travel data collection effort. The system, called SITSS, is designed as a client-server application. The client side is a smartphone application which is developed to record participant's travel behavior automatically, and the server side supports the procedure of data collection. A prompted-recall smartphone-based data collection approach is proposed and employed in the development of SITSS to provide participants with a more convenient procedure to recall and report their travel behavior while improving the accuracy of collected data.

As a real-world experimental study, SITSS was employed as a pilot in the national household travel survey of New Zealand to investigate some of the issues related to the employment of a smartphone-assisted data collection. The study showed the success of SITSS in reducing the required human and financial resources for a data collection. The proposed system
could successfully interact with participants. The initial response rate to participate in this smartphone-based survey was comparable to conventional household travel surveys. Among the participants, 71% found it as an interesting experience and continued their participation for extra days beyond the requested period inasmuch as the actual number of participation days per participant was more than 5.5, while they were recruited for just three days. 94% of participants completely understood the procedure of data collection and finished it without any additional support request. It shows the success of the self-learning procedure employed in this experiment in adequately supporting participants and reducing the administration requirements. In addition, it is found that the smartphone application had been started manually on average 5.2 times during the experiment while the average rate of manual terminations was 4.9. It shows that the smartphone application did not interrupt participants’ interaction with their smartphone. Finally, it is found that for 16% of uploaded trips, the performance of the smartphone application was interrupted during the data collection. These trips were recognized and removed from the collected database since they provide an incomplete reflection of participants’ travel behavior. It is necessary to mention that the conclusions of this paper is based on the travel behaviour of those participants of the national household travel survey of New Zealand who were eager to participate in a smartphone-based travel data collection and had access to an iPhone.

As further steps of this research, it would be interesting to apply a series of data processing tools to validate the accuracy of detected and labeled attributes. The procedure of calibration and validation of these tools towards synthesizing the collected data for travel forecasting (as opposed to information obtained using traditional household travel surveys) could lead to a variety of practical findings. Moreover, the employment of a series of models within the smartphone application for automatically detecting the mode and purpose of trip based on the travel behavior of participant is another exercise and can lead to a completely passive data collection. Finally, research on the non-monetary incentives which can be provided for potential participants to encourage them in joining travel surveys could lead to very interesting practical results for revising the procedure of participant recruitment.

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