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Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering University of California at Davis

Deployment Support and Data Collection for Caltrans TSI Travel Behavior Survey Using the GPS-ATD

Kin Yen, Travis Swanston, Bahram Ravani & Ty A. Lasky: Principal Investigator

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DISCLAIMER/DISCLOSURE

The research reported herein was performed as part of the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, within the Department of Mechanical and Aerospace Engineering at the University of California – Davis, and the Division of Research and Innovation at the California Department of Transportation. It is evolutionary and voluntary. It is a cooperative venture of local, State and Federal governments and universities.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
AHMCT	Advanced Highway Maintenance and Construction Technology
API	Application Programming Interface
Caltrans	California State Department of Transportation
COTS	Commercial-Off-the-Shelf
DRI	Division of Research and Innovation
GB	Gigabyte
GIS	Geographic Information System
GPS	Global Positioning System
GPS-ATD	Global Positioning System-Automated Travel Diary
HMI	Human-Machine Interface
HSGPS	High-Sensitivity Global Positioning System
MB	Megabyte
MEMS	Micro-Electro-Mechanical Systems
MPO	Metropolitan Planning Organization
OS	Operating System
PDA	Personal Digital Assistant
RAM	Random Access Memory
SDRAM	Synchronous Dynamic Random Access Memory
TSI	Transportation System Information
TTFF	Time-to-First-Fix
UCD	University of California-Davis
USB	Universal Serial Bus
XML	eXtensible Markup Language

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CHAPTER 1: INTRODUCTION

Background and Motivation

As part of the Statewide California Household Travel Behavior Survey (CHTBS), it is fundamentally important that surveys can be carried on for a long duration while maintaining the survey data accuracy and integrity, and yet minimizing the burden on survey respondents. Under this and previous research, AHMCT developed the GPS-ATD (Global Positioning System-Automated Travel Diary) (See Figure 1.1 and Figure 1.2) to replace traditional paper-and-pencil and computer-assisted approaches for travel surveys. The GPS-ATD minimizes the user burden during longitudinal travel behavior surveys, while providing accurate, reliable, and spatially dense traveler behavior data at a significantly reduced cost. The GPS-ATD captures route choice, path, and speed profile. This information is not feasible with other survey methods. In addition, the questionnaire captures information such as marking trip start and end, trip purpose, cost of trip, and travel mode. The resulting survey data are crucial for modeling trip generation, predicting the effects of transportation policy changes, and supporting the decision making process at the Federal, State, county, Metropolitan Planning Organization (MPO), and city level.



Figure 1.1 – GPS-ATD

Figure 1.2 – Sample user interface of the GPS-ATD

The current Automated Travel Diary (ATD) app runs on the Android operating system, and has been tested on numerous Android phones. The ATD was developed at the AHMCT Research Center in response to the research needs of Caltrans Division of Transportation System Information (TSI). To increase survey participation, TSI is in the process of converting the ATD application to other platforms like the Apple iPhone, Windows Mobile and Blackberry. As part of the current research, AHMCT supported investigation into approaches for porting the GPS-ATD, including interactions with multiple vendors. This effort included development of a specification for the GPS-ATD.

Problem

Caltrans is responsible for conducting the California Household Travel Survey. The survey has become increasingly expensive to conduct, and paper diaries are particularly onerous for participants to use. The ATD represents an opportunity to address both survey costs and user burden. Caltrans envisions survey participants downloading an app to their smartphone in order for them to participate in the household travel survey. In this project, the Android version of the ATD has been proven to work. This research closed moved the ATD from a working proof of concept to a beta-tested deployable system

Business Case

Caltrans conducts the California Household Travel Survey every ten years. This survey provides inputs for land-use modeling, trip generation modeling, and other transportation modeling and analysis. The results are very important for intelligent transportation planning and operations. The survey results are used by other agencies at the state level, as well as by MPOs and local agencies. Current survey practice uses paper and pencil diaries to obtain input from the survey participants. This approach places unnecessary burden on the users, and increases the difficulty of the resulting compilation and analysis of the data.

The ability to gather enhanced data including detailed location and route choice, while at the same time reducing the burden on the user, will lead to improved travel survey results and accuracy. These improved results will have a rippling effect for land-use modeling and other analyses. In order for this approach to be effective, the data gathering tool must be available in a form or forms that allows sufficient survey participation.

Research Approach

The research methodology included:

- Formation of a technical advisory group (TAG),
- Enhancement of the GPS-ATD application,
- Server-side software development to receive data uploaded directly from the GPS-ATD app,
- Support for development of the GPS-ATD on other platforms,
- Execution of pilot / beta testing.

Overview of Research Results and Benefits

The key deliverables of this project include:

• Android GPS-ATD app and server-side software source code

- GPS-ATD specification
- Pilot / Beta testing results.

CHAPTER 2: GPS-ATD ENHANCEMENTS

The GPS-ATD was enhanced as a main effort of this research project. The enhancement is necessary for increase survey automation, reduce users burden, and ease of installation. Key enhancements included:

- Revision of the menu structure for improved ease-of-use and reduced user burden by reducing the number of survey questions and making each question and answer clear, concise, and easy to understand. The TAG had meetings to discuss the menu flowchart throughout the project. The TAG also requested input from other travel researchers, MPOs, and travel modelers on the menu flowchart. The original GPS-ATD menu flowchart is shown in Figure 2.1. It contains 25 questions. The final version of the menu flowchart is shown in Figure 2.2—it contains only 7 questions. The TAG has debated at length on the elimination of the travel mode question. However, the TAG was uncertain about the success rate of determining travel mode in post-processing. Figure 2.3 shows example screenshots of the travel survey questionnaires. The wording and layout were carefully considered for maximum clarity and readability so that respondents with impaired vision could use the app.
- Demographic questionnaire was added so that the users could input user demographic information using the smartphone before the beginning of their travel survey. The demographic questionnaire menu only shows up once in the beginning when the app is first run by the survey respondent. The TAG developed the demographic questionnaire using the same process used for revising the GPS-ATD flow chart. Professor Boarnet and Dr. Houston have provided valuable input on the GPS-ATD demographic questionnaire as shown in Appendix B.



GPS-ATD Active Mode Menu Flowchart (12/08/2006)

Figure 2.1 – Original menu structure (12/06/2006)



Figure 2.2 – Final revised menu structure (08/04/2011)

Development of the mechanism for automatic wireless data transfer for data collection • and processing automation. The travel survey concept of operation changed since the GPS-ATD's inception. In the original travel survey concept of operation, the smartphones would be mailed out to survey respondents, and the survey respondents would mail the smartphone back to the travel survey organizer. Thus, the smartphone would not require cellular network services and its associated cost. The current travel survey operation concept requires the respondents to download and install the GPS-ATD app from the Android market onto their own smartphone. After the respondents have completed a trip and the related travel survey questionnaire, the data are then uploaded to the server. Therefore, a new server and client software architecture, communication protocol, and added data compression and encryption had to be developed and added to the existing GPS-ATD app. To speed up the development process and enhance software robustness, open source tools and libraries were used whenever appropriate and possible. The detailed communication protocol and data encryption and compression format information are available in the GPS-ATD specification documentation. Server-side software was written using Java with Apache Tomcat open source software for the implementation of the Java Servlet. Apache Tomcat has been extensively tested and used by many for webservers. Tomcat code is extremely reliable, stable, and robust. Therefore we expect similar reliability and robustness on the ATD backend software. The choice of encryption and compression has to balance between power consumption, speed, and limited available bandwidth. Higher order encryption and compression could cause extensive power drain and delay.

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Select mode of travel.		What activit	t was you y for this the trip?	r trip part of
Auto / truck / van	•	Going hom	e	•
Public transit	•	Pick-up / d transit sta	rop-off (inclu tion, airport,	iding etc.)
On foot	•	Work		•
Bicycle	•	Business/v	vork-related	•
Motorcycle / moped	•	Education	/ childcare	•
Airplane (private)		Food / drink		>
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Figure 2.3 - Example menu screenshots

• Revision to the software to allow downloads from the Android Marketplace to improve ease of installation, software update, and error reporting. In order to use the Android Market, a Google account has to be setup. The Android Marketplace forwards app crash reports from the smartphone to the Google account email. This feature was instrumental in debugging incompatibility with different models of smartphone and versions of Android operating system. The Android Marketplace was easy to setup and simple to use. The new updated app is generally available on the Android Market within 10 minutes after uploading. No test user has expressed difficulties installing or updating the app from the Android market.

In addition to the enhancements of the app itself, numerous developments were needed on the back-end to support beta and pilot testing. A set of GPS-ATD data post-processing software tools were written in various languages such as python, java, and c-shell script to process the data to csv and kml format as well as providing statistics of the pilot test results.

Table 2.1 shows the app release schedule and changes throughout the project.

Version	Release	Change Summary		
	Date			
0.31	8/3/2011	Survey profile changed (08/01/11 version of the menu structure)		
0.30	8/3/2011	Survey profile bugfix		
0.29	8/3/2011	Survey profile changed (07/28/11 version of the menu structure)		
		Beta Test version, Beta Test started on July 5 th		
0.28	6/29/2011	• Added a driver safety warning screen.		
		• Resolving clashes when the app is not able to write to sdcard.		
0.27	6/16/2011	Fixed a couple typos/etc. The abbreviations made to some of the		
		survey/demographics text were simplified.		
0.26	6/14/2011	• Enabled landscape mode for user info screen		
		• Disabled FWD key in demographics		
		Minor encryption tweak		
		Refactored screen navigation code		
0.25	6/10/2011	• Fixed demographic bug when clearing user profile.		
		 Added updated demographic survey and travel survey. 		
		 Added encryption to log files. 		
		 Fixed drawables bug on Android 1.5 (1.6?). 		
		• Other misc. fixes.		
0.24	4/18/2011	Consolidated account setup window.		
		 Bugfixes in account setup / GPS enable. 		
		• Improved support for multiple displays.		
0.23	4/5/2011	 Minor change to GPS warning dialog. 		
		• Fixed a crash on an ATT HTC Inspire 4G. and on the Samsung		
		Continuum. This bug is either related to a bug in Android (issue		
		#6191) or an ambiguity in the Android docs. This bug is likely to		
		cause crashes on other devices as well.		
		• Warns user if GPS not enabled		
0.22	4/5/2011	• Fixed ViewFlipper crash (Android issue #6191).		
		• Warns user if GPS not enabled.		
0.21	4/3/2011	Initial release. Alpha test begins		

Table 2.1 -	GPS-ATD	releases	and	fixes
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CHAPTER 3: GPS-ATD SPECIFICATON DEVELOPMENT

To provide broad survey participation, it is important to develop the GPS-ATD on other smartphone platforms such as Microsoft Windows Mobile, Apple IOS, and Research In Motion Blackberry. Other researchers and software developers have expressed interest in developing or enhancing GPS-ATD for other operating systems and/or used for their own travel research. In addition, TSI also expressed interest in able to use other software developers (contractors and internal Caltrans IT) and researchers for GPS-ATD app development. To facilitate and support other researchers and software developers to develop compatible GPS-ATD app on other smartphone platforms, AHMCT researcher developed an open GPS-ATD software app specification. While the Android version of the GPS-ATD app source code is open, the GPS-ATD app specification enables other researchers and software developers to develop quickly compatible GPS-ATD app on other operating system without any reverse engineering effort spend on the source code. In order to use a single webserver and data post-processing tool, GPS-ATD app in any platform must have the same data storage structure and use the same communication protocol for data upload. They should also share a similar user interface and menu structure. Support for other travel behavior researchers and partner software developers in such porting activities is a crucial part of this project. Otherwise, each software developer may create a "GPS-ATD" app on different platform with a different user interface, data storage structure, and communication protocol which would lead to higher software support cost, complexity, server duplication, and need for extra data conversion tool.

Throughout the project, we have several meetings and email communications with other University researchers on porting or modifying the application for their travel research. These researchers includes: Dr. Marlon G. Boarnet, Professor of Department of Planning, Policy, and Design and Co-Editor, Journal of Regional Science at School of Social Ecology, University of California, Irvine, Dr. Douglas Houston, Assistant Professor at Department of Planning, Policy, and Design, School of Social Ecology, University of California, Irvine, Dr. Michael Nicholas, PH&EV Research Center, University of California, Davis, Dr. Joan Walker, Assistant Professor, Civil and Environmental Engineering, Transportation Engineering and Dr. Raja Sengupta, Associate Professor, Civil and Environmental Engineering, Civil Systems, University of California, Berkeley. Dr. Walker and Dr. Sengupta are interested in porting the GPS-ATD to IOS iPhone platform as well as using the data collected from the GPS-ATD app in their semiautomated / automated travel mode detection research. Prof. Boarnet and Dr. Houston are interested in using the GPS-ATD app for their research with Caltrans. Dr. Nicholas is interested in modifying the app for hybrid, plug-in electric hybrid, and electric vehicle travel research.

In addition, AHMCT, TSI, and DRI have met numerous teleconferences with cellular services providers (Verizon and Sprint) and software developers (John O'Connell from HTC, Vikram Aich, Aich Technologies, Sprint and Sierra Data Systems) on multiple occasions to explore and assist in porting of the application. TSI asked them to come up with a cost estimate for developing / porting the GPS-ATD app onto other smartphone platforms. The GPS-ATD specification is a critical document for any software developers and engineers to assess the required software complexity as well as to develop the time and cost estimate for developing the software. After our discussion with contract software developers, they all have asked for the software specification and requirement document in order for them to develop their cost

estimate. It is generally needed first for any contract software development and is a useful guide for software engineers for modifying or porting the app. Version 2.0 of the specification is provided in Appendix D.

The specification provides details in general operation of the software, user interface requirements, questionnaire profile XML file structure, data storage format structure and data uploaded protocol, etc. The specification includes:

- Introduction to the GPS-ATD Application
- Architectural Overview
 - o User Activity Component
 - Session Logging Service Component
 - o Upload Service Component
 - Upload Processing
 - Entry Points
 - Application Settings
- The Survey
 - o Overview
 - o User Interface
 - o Survey Sessions
 - Survey Architecture
 - The Profile XML File
- Logging and Storage
 - o Introduction
 - The Data Repository
 - Session Logs
 - o The Session Data Stream
- About GPS-ATD
- A Profile Example

- The Survey Diagram
- o The Profile File
- An Example Session Data Stream

CHAPTER 4: PILOT TRAVEL SURVEY / BETA TESTING

<u>Pilot Test Objectives</u>

The pilot testing objectives were:

- 1. To assess the GPS-ATD app compatibility on various Android smartphones with different operating system versions, manufacturer customization, screen resolution, and service providers.
- 2. To test the backend server software.
- 3. To evaluate and improve GPS-ATD app usability including the demographic questionnaire, travel survey menu, and general user interface.

The pilot testing was divided into Alpha and Beta testing phase. The primary focus of Alpha phase was to achieve Objective 1 and 2. Alpha phase testing was limited to a small group of advanced users. Revisions and fixes were made as soon as any software bugs were found. The main goal was to produce a stable, robust, and bug-free ATD app so that the Beta phase test users would not be distracted by software bugs and could concentrate on usability evaluation. The Beta phase testing opened to much larger and diverse set of users. The main objective of Beta phase testing was to reach Objective 3.

Alpha Testing (March 14, 2011)

To meet the Alpha testing objective, the GPS-ATD app was tested repeatedly and variously on various Android smartphones with different operating system versions, different manufacturer customization (Motorola Motoblur, HTC Sense, and Samsung TouchWiz), and carriers (AT&T, Verizon, Sprint, T-Mobile, and Virgin Mobile). Eighteen Android smartphones were purchased from AT&T, Verizon, Sprint, T-Mobile, and Virgin Mobile with data services for testing. In addition, Verizon graciously loaned several different models of Android phones for compatibility testing and evaluation.



Figure 4.1 - Android phones running the GPS-ATD app

The GPS-ATD app (Version 0.21) was made available on Android Market in April 2011. Anyone could download and install the GPS-ATD from the Android Market. However, respondents were required to enter a password to the GPS-ATD app for the first time. The purpose of the password is to prevent the general public, particularly minors, from using this app and unintentionally uploading their travel data to the AHMCT server and preventing them from exposing their privacy accidentally. The Alpha test users were composed of AHMCT researchers and TSI and DRI personnel who have very limited to advanced knowledge of the ATD app and Android operating system.

The compatibility testing was focused in following areas:

- 1. Download, install, and update from Android Market.
- 2. Usability evaluation of the ATD app running in different screen sizes and resolutions
- 3. Ease of use evaluation on entering respondent information
- 4. Demographic questionnaire user interface evaluation
- 5. Travel survey menu interface evaluation
- 6. Data upload
- 7. Battery life assessment

Alpha Testing Result

The GPS-ATD app works on any Android devices with OS version 1.6 or above. The tested smartphone models are shown in Table 4.1. Verizon has generously loaded phones for testing. Each smartphone user used the Android market to search, download and install the GPS-ATD app. In addition, the GPS-ATD app was then subsequently updated using the Android market feature. Initially, the GPS-ATD app does not show up in the Android market search when using Motorola Citrus because of its unusually low screen resolution (240x320 pixels). After testing the GPS-ATD app on Citrus low resolution screen, the GPS-ATD was found to be usable, but not recommended.

Whenever possible, AHMCT researchers conducted evaluation of the ATD app's user interface usability running on Android smartphones with different screen sizes and resolutions. Our evaluation determined that the ATD app user interface works well on any smartphone with screen resolution higher than 320x480 pixels. The app was initially designed for smartphone with 320x480 resolutions, but higher resolution screen allows more menu items to fit in one screen and eliminates the need for scrolling up and down.

The requirement of target battery life is 8 hours continuous run-time on a single full battery charge with the ATD running. From our test results, we determined that all the phones listed in Table 4.1 are capable of running the ATD app for 6 hours or more. However, some alpha test users complained about the short battery life. Users generally have higher expectation of battery

life, higher than 8 hours. Our test result suggested that, in practice, users often have other apps running in the background which leads to lower battery life.

Acer A500 tablet	HTC Droid Incredible ADR6300
HTC Droid Incredible2 ADR6350	Verizon LG Ally
HTC Inspire 4G	Motorola Droid
Motorola DROID2	Motorola DROID X
Motorola DROID X2	HTC Glacier
HTC Magic	HTC Sensation 4G
LG Optimus LG-P509	LG Optimus S LS670
Motorola Defy MB525	Motorola Atrix 4G MB860
Google Nexus One	HTC EVO 4G PC36100
Samsung Captivate SGH-I897	Samsung Infuse 4G SGH-I997
Samsung Continuum SCH-I400	Samsung Fascinate SCH-I500
Samsung Vibrant SGH-T959	Sprint HTC Epic 4G SPH-D700
Sprint Transform SPH-M920	LG Optimus V VM670
LG Vortex	HTC EVO Shift 4G

Table 4.1 – Android smartphone models tested

Several software bugs and incompatibility issues were discovered and fixed during this testing phase, as listed in Table 2.1. Some minor changes were made to the demographics questionnaire and travel survey menu after a few weeks of testing. The changes were made to address consistency issues and ease of understanding of the questions. The interface for entering respondent's name and email was changed to improve the ease of use and typing in respondent data (name and email address). The Alpha testing phase ended in June 2011. Even though user interface, app usability, and questionnaire were not the focus of the Alpha testing, test respondents provided significant feedback on the questionnaire structure and wording of questions. Detailed alpha testing user comments are provided in Appendix C.

Since the ATD backend server software is built on top of Apache Tomcat server software, it is expected to be reliable. It was extensively tested in the Alpha phase by AHMCT engineers. During the backend server testing phase, each trip upload is verified by comparing the log file on the phone and the file uploaded to the server. Each trip upload was check to ensure it was successfully uploaded. The backend server software also run continuously throughout the alpha and beta testing period flawlessly without any crashes.

Beta Testing

The GPS-ATD app, updated from the feedback from the Alpha Test to Version 0.28, was made available on Android Market for Beta testing, which started in July 2011. The Beta test users were composed of AHMCT researchers, students, Caltrans personnel, MPO personnel, and their family members except anyone under 18 years old. These volunteers were asked to download and install the GPS-ATD from the Android Market either using their own Android phone or one provided by AHMCT. Some Beta test users had very limited knowledge of the

ATD app and Android operating system. The Beta test focused on evaluation of the app usability. Users were asked to input fake or random information in the demographic questionnaire to eliminate privacy concerns. Test users were asked to provide feedback to either DRI or AHMCT directly. The ATD app was not updated until the end of the Beta phase testing in early August (Version 0.31). Details of update are shown in Table 2.1.

Beta Testing Results

The Beta test users' feedback was compiled together for subsequent meeting on the app improvement. Consequently the survey menu was revised (as shown in Figure 2.2) according to the feedback. Most changes are in the wording of the questions and answers so that they are easy to understand and eliminate user misunderstanding and ambiguity. The GPS-ATD app version 0.31 was the result. At the end of both Alpha and Beta testing, about 400 trips were collected with 80 respondents using 41different Android devices with 27 unique Android models. The data file size is approximately 900 bytes per minute of travel (53 Kbytes per hour of travel).

After the alpha phase testing, there was no report of software bugs and incompatibility issues. The GPS-ATD app was successfully tested on 27 different Android devices from all major US wireless network carriers (AT&T, Verizon, Sprint, T-Mobile, and Virgin Mobile). It runs on Android device with OS version 1.6 to 2.3. Based on the test results, the AHMCT researchers are confident that the GPS-ATD app should run on a majority of Android smartphones without modification.

In general, user feedback was positive, and they found the user interface easy to use. However, they sometimes forgot to enter trip information at the end of the trip. The GPS-ATD app has two set of questionnaires. The first questionnaires set is answered at the beginning of the trip, and the second set of questions (such as tolls and parking cost) are ask at the end of the trip. By random sampling and checking the GPS log data, forgetting to wake up the phone and answer the second set of question is common. Unfortunately, it was extremely time-consuming and costprohibitive to examine each file manually to determine the actual percent of this occurrence. Development of data post-processing too is needed to further analyze the data to provide more statistical data, but it was not within the scope of work. Some users also found some travel survey questions unclear in the Alpha testing phase (see user comment in Appendix C). Some work will be required to make the travel survey questions better in conjunction with reducing the number of questions.

The Pilot testing was successful in achieving the three test objectives. The current version of GPS-ATD app is ready for testing with a larger number of users with much more diverse background.
CHAPTER 5: CONCLUSIONS

The ultimate goals of these research activities are to enable the use of smartphone for travel survey to improve data accuracy, reduce respondents' burden, and lower travel survey cost. This research project has made positive contributions in the following areas:

- 1. Viable GPS-ATD app on Android Smartphone for travel survey;
 - a. Enhancement of the ATD app, including the ability to download and install from the Android marketplace, and having demographic questionnaire.
 - b. Support for wireless data transfer for automated data collection and processing.
 - c. Development of server and client software architecture and communication protocol
 - d. Design and development of the backend server and primitive data post-processing tools.
 - e. Extensive testing for user acceptance, verify bug free app, and to ensure Android smartphone compatibility. Android smartphones have higher diversity of OS version, hardware variations (CPU, screen sizes, GPS hardware, etc.), and phone manufacturers' custom User Interface (UI) such as HTC Sense, Samsung TouchWiz, and Motorola Blur. Testing and verification for compatibility is more complicated and labor intensive compared to the Apple iPhone platform.
- 2. Development of GPS-ATD specification and requirement document
 - a. Enable the development of compatible GPS-ATD app on other operation system by other developers and researchers
 - b. The development of GPS-ATD app on other smartphones will cover most users
- 3. Proof of concept demonstration on using smartphone app for travel survey
 - a. The Beta test demonstrated feasibility the concept of using smartphone app for travel survey and its potential for cost saving. Beta test users generally find the app easy to use without much training.
 - b. GPS-ATD app can supplement pencil and paper survey as smartphones become more popular
 - c. The use of GPS-ATD app in regional travel surveys for Caltrans and MPOs was proposed by researchers, TSI, and some MPOs. MPO members have expressed interest in using GPS-ATD app for their regional travel survey.

d. GPS-ATD app may be used for full-scale deployment in California Household Travel Behavior Survey provided that additional research works listed below are completed.

Future Work

This research project produced a viable Android smartphone GPS-ATD app for travel survey and demonstrated its feasibility. However, significant works remains in order to deploy it in a large full scale travel survey. Based on the successful results of the current study, following future work is recommended in three main areas:

- 1. GPS-ATD app
 - a. Optimizing survey menu to reduce respondents' burden. Based on current research by other researchers, techniques have been developed to extract respondents' travel mode and stops in data post-processing. These data post-processing technological advancements can reduce the number of questions required to be answered by the respondent. Finally, to support future surveys by TSI and its partners, travel survey contractors, researchers, and modelers should work to further develop and optimize the questionnaire portion of the application. A committee should be formed for questionnaire development.
 - b. Developing a "trip profile" system for common trips (such as going to work every morning) and a reminder to use the app at the end of the trip.
 - c. Improving smartphone battery life by reducing GPS update rate. Based on the discussion with other researchers, the GPS update rate may be reduced while maintaining data fidelity for data post-processing.
 - d. Testing on new Android smartphone models with Android 4.0 or higher operating system.
 - e. Porting the ATD application from the Android platform to three other smartphone platforms, Apple, Windows, and Blackberry to broaden survey participation. The development on all three smartphone platforms will be driven by the existing ATD specification document.
- 2. Travel Survey using smartphone
 - a. Developing suitable survey incentives for smartphone travel survey respondents. This effort should include development of marketing and incentives means to recruit survey participants. Proper survey incentives must be developed and tested to ensure high response rate for statistical analysis.
 - b. A larger a proof-of-concept survey should be conducted. This survey should be scoped to satisfy the needs of statistical analysis and determination of proper weighting scheme. The survey should aim to obtain broad demographic and geographic participation, and incentives to encourage participation. Statistical

analysis and weighting scheme development should follow, along with deployment assessment and project documentation and reporting. This pilot travel survey will provide data on the effectiveness of the respondent recruitment marketing methodology and survey inventiveness. In addition, larger pilot survey enables researchers and management to evaluate the feasibility of using smartphone app for travel survey on a larger diverse demographic user base.

- 3. Development of data post-processing tools
 - a. Advanced data post-processing and use of cloud computing could reduce user burden by reducing the number of questions that the respondent has to answer. A cooperative network with other researchers should be organized to develop an open-source data post-processing tool for travel survey data. The advanced post-processing software is needed to analyze large data sets generated by the ATD.
 - b. Developing and testing of travel mode detection algorithms to reduce number of questions in the questionnaire
 - c. Developing and testing algorithms on toll cost and parking cost estimations
 - d. Developing and testing algorithms for trip stop detection
 - e. The post-processing software must have built-in safe guard for respondents' privacy and address privacy concerns. For example, a post-processing tool should be developed to randomly truncate (500 to 1000 foot) GPS locations for the beginning and end of each trip. The access to both GPS and demographic data should be monitored. Institutional Review Board (IRB) Administration has well established training, guidelines, and policy on human subject research. Their recommended practices to safe guard individual respondents must be built into the design and development of the post-processing software. For smartphone-based travel survey to be successful in the long run, the trust of respondents in the researchers to safe guard their privacy much be the highest priority. Without their trust in privacy safe guards, their participation will be extremely low independent of how well the ATD app works or reduces their burdens.

APPENDIX A: INFORMATION FOR SURVEY RESPONDENTS

The GPS Automated Travel Diary (referred to as the ATD) application is part of a research study by the University of California at Davis (UCD). The research is being performed for the California Department of Transportation (Caltrans). The purpose of the research is to develop improved methods for conducting travel behavior surveys. Traditional surveys have been done using pencil and paper diaries, as well as telephone interviews. The ATD provides an electronic diary for the survey participants.

Travel behavior surveys are used by Caltrans, Metropolitan Planning Organizations (MPOs), and other California state agencies. Survey results are used to develop travel behavior models, to improve land use planning, and similar tools. The overall goal of travel surveys is improvements in the state's transportation system.

The current research that we are asking you to participate in involves testing the ATD prior to its use in larger Caltrans travel behavior surveys.

The information from all participants will be grouped for analysis and used by State and local governments to help plan the future of transportation.

The ATD application will collect one-time setup information, and information about individual trips. The one-time setup information includes your name, address, and email. This personally identifying data will be kept offline, and maintained by Caltrans, strictly for the purpose of awarding incentives for travel behavior survey participation. The researchers will not make use of this data, and will not have access to it upon transferring it to Caltrans. In the current research proof-of-concept, you should enter fictitious information for personally identifying information, with the only use being validation of procedures for protecting this information. There will be no incentives in the proof-of-concept research.

The one-time setup information also includes demographic data needed as part of any travel behavior survey. This information will include your age, your gender, your race/ethnicity (optional), age ranges of household members, number of cars available to your household, length of time you have lived in your neighborhood, years of education for you and your spouse (if applicable), and average annual household income.

Trip data collection does not start until the traveler indicates (via a menu choice) that the trip is beginning, and stops when the questionnaire is completed for that trip, and the ATD app indicates that your trip / activity is ended, and you press OK. The ATD app collects data related to traveler route choice and trip purpose. The ATD app collects detailed traveler location and time data. The ATD app also logs phone battery status, as well as GPS signal status.

The ATD app has a coded ID number that is connected to your personal information. The ATD app itself retains no direct personally identifying information. All ATD data will be encrypted on the smartphone, and secure means (SSH or SSL, methods that are used to transmit credit card information) will be used for data transmission to the server. Data will be transferred from the smartphone on availability of a data connection (e.g. cellular or WiFi). Once data has been

successfully transferred to the server, it will be deleted from the smartphone. The server system will be password-protected, and will use accepted methods of security, e.g. firewall.

The ATD application automatically transfers trip data using your cellular data plan. Trip data file size is typically about 100 kilobytes per hour of active traveling.

The ATD is not meant to be used while operating a vehicle. You must answer a set of questions before beginning a trip, and another set of questions after you complete that trip and stop your vehicle. Do NOT interact with the ATD application while operating a vehicle.

For further information on this research, please contact the principal investigator, Dr. Ty A. Lasky, at <u>talasky@ucdavis.edu</u> or 530-752-6366. The co-principal investigator is Professor Bahram Ravani.

Your participation in this study is entirely voluntary. By answering the one-time setup questions, and by providing trip data information, you are agreeing to participation in this travel behavior survey.

APPENDIX B: GPS-ATD Demographic Questionnaire

Demographic Information

Traffic researchers have learned that personal and family characteristics can influence travel. To help us understand how to improve transportation for a broad range of persons, we need to know some general information about you and your family.

Your full name: ______ Your address: ______ Your email:

The above information is for survey administration only. It will be stripped off from the remaining general information on the first data transfer.

1. Your age (check one):

	□ 7-15			41	-55
	□ 16-17			56	-65
	□ 18-24				ver 65
	□ 25-40				
2.	Your gender:		le	□Fer	nale
3.	Your race/ethni	city:			
	Hispanic/Latino	□ White	□ 1	Black/ Af	rican American
	American Indian/A	Alaska Native		Asian	□Native Hawaiian/Pacific Islander
	Other Do	o not wish to st	ate		

4. Please indicate how many people in your household are in the following age categories? (Include yourself.)

0-6	7-15	16-17	18-24	25-40	41-55	56-65	Over 65

5. How many people in your nousenoid unvet	5.	How many peop	ple in you	r household drive?	
--	----	---------------	------------	--------------------	--

6. On most days, how many cars are available for use by members of your household?

 \Box 6-10 years

 \Box 1-5 years

7. How long have you lived at your current residence?

Less than 1 year

\Box More than 10 years	☐ All of my life

8. What is the highest degree or level of school you have completed?

- □ Not a high school graduate, 12 grade or less
- High school graduate (high school diploma or GED)
- \Box Some college credit but no degree
- Associate or technical school degree
- Bachelor's or undergraduate degree
- Graduate degree (includes professional degrees like MD, DDS, JD)

9. What is the highest degree or level of school your spouse (if applicable) has completed?

- □ Not a high school graduate, 12 grade or less
- High school graduate (high school diploma or GED)
- □ Some college credit but no degree
- Associate or technical school degree
- Bachelor's or undergraduate degree
- Graduate degree (includes professional degrees like MD, DDS, JD)
- □ Not applicable

10. What is your average annual household income?

\$0-\$14,999	\$75,000-99,999
\$15,000-\$24,999	\$100,000-\$149,999
\$25,000-\$34,999	\$150,000-\$199,999



\$200,000-\$249,999

\$50,000-\$74,999

□ \$250,000 or more

APPENDIX C: ALPHA TESTING USER COMMENTS

Comments on the Application:

- 1. Add the "no cell phone while driving" clause to your signature block.
- 2. Keyboard input should have a horizontal option as well as vertical. (3 comments from users like this)
- 3. Force Close option does not let you back into application, it only closes the application.
- 4. Reminder to start the program before you start driving, and stop the program when you stop driving.
- 5. Another suggestion is to have a bell or ringer alert to help me remember to log in along my daily journey. I've sometimes forgotten to do so.
- 6. WI-FI has a better GPS location, even though it drains battery.
- 7. Can you turn off power save mode? Otherwise, the phone goes all the way to locking you out between the time you start driving and the time you stop.
- 8. When I had to reload my information in the second phone it asked for my race/ethnicity after we started the trip.
- 9. All the legal jargon or agreement information should be completed on the application once someone agrees to download. Not sure if you have worked that into the application.
- 10. Is there a way when you are at your destination to view your travel history? I.e. distance traveled, minutes traveled, etc.?
- 11. I'd like a print out of where I traveled and a print out of how many miles I've gone. This could be done daily or at the end of the study time period.
- 12. I'd like to second some comments others have made on getting some feedback to the user to reinforce the benefit of using this app. How far did you walk on a trip, how many gallons of gas did you save for a public transportation segment, how much greenhouse gas did you generate or save, etc. Both for the trip itself and in summary (i.e. for the last 60 days, etc.). Things that allow the user to get "feel good" points for doing this.
- 13. Things I really like/were user friendly:
 - 1. ATD Logo/Icon on main home screen.
 - 2. Like the menu selection/buttons are large font and easy to read.
 - 3. Like the flow of the application.
- 14. I find the number of entries needed in the middle of a multimodal trip to be bothersome. (i.e. what was purpose, changing modes, # of people, driver/passenger, etc.). It reduces my interest in doing this app as I constantly have to answer the same questions over and over on every trip. But, if there was a way to "profile" trips you normally make (i.e. commute) and reduce the number of keystrokes to two (STOP segment and START next segment) at every stop/transition/segment that would be really nice. It would be especially good if the app could automatically "learn" a profile trip by simply using one you do on a normal day - that would be good and easy for the user. Something on the order of predesignating a trip as a profile learning trip, giving it a name (i.e. Work to Home/Bus) and then doing the trip as you normally would with all the questions/answers then being used to populate that profile and used every time you call it up.

Comments on the Questions/Questionnaire:

- 1. More options on the race/ethnicity group.
- 2. Selection for education should be by degree, not years of education (i.e. I went to school for 15+ years, but only have my BS).
- 3. On parking selection, perhaps ask some details (i.e. parking garage, parking lot, private driveway, etc.).
- 4. On the start location, it should be the same list as the destination, (i.e. include restaurants, etc.).

- 5. Drop off/pick up selection should list items like people, groceries, food, etc.
- 6. Do you need to know ages of passengers? Does this help in determining if it is a work car-pool or a parent shuttle, etc.?
- 7. Is the pick up/drop off supposed to cover transit mode changes? If so, this may not be clear or you may want to add this as a separate menu option.
- 8. Things I really like/were user friendly:
 - a. Like that you can select if you are the passenger or driver.
 - b. Like the flow of the application.
- 9. Box 3 (Select mode of travel)
 - a. Add Multimodal as an initial selection.
- 10. Box 3A (Are you the driver or a passenger)
 - a. Why would you not ask for # travelers here as well even if you are a passenger? Or, why would you ask anyone about other travelers? Seems inconsistent to ask one and not the other.
- 11. Box 4 (Please continue your trip)
 - a. Why not just say "START TRAVEL" here? More meaningful. You can't continue if you haven't started and if you stop for a temporary reason or mode shift you still have to start again.
- 12. Box 5 (Have you stopped?)
 - a. Wouldn't the word "Stop?" be more appropriate? Then you wouldn't need the "NO" leg. Also, the "Yes I'm making a stop" branch might be better as "Temporary Stop" and the "Yes This is my final destination" could be simply "End of Trip"
- 13. Box 6 (What was your trip activity for this part of the trip?)
 - a. Are you wanting to know what was done during the immediately preceding travel portion or what was done during the stop? What if I'm waiting for a transfer during a bus trip?
 - b. For combined trips, this is a very confusing question? For example, I might be going home but decided to stop at the grocery store and do some shopping (making this a linked trip). Which answer is correct and appropriate for a good statistical analysis of travel behavior?
- 14. Box 6A (Pick-up / Drop-off)
 - a. Pick up/Drop off assumes you are dropping someone else off or picking someone else up. What if you are driving to a parking lot to park and get on transit/train? For Multimodal trips a new/expanded descriptive category is needed.
- 15. Box 7A (Press ok when you are ready to continue your trip)
 - a. Why not use the word "CONTINUE" for this. Relates directly to the interruption in travel.
- 16. Also, the APP itself doesn't really handle multimodal trips well and certainly not intuitively.
- 17. Doing a multimodal trip is not intuitive or perhaps not even possible with this app. The app should ask right up front if it is a multimode trip and the interim stops/wait points should be logged with a single (or at most two) key taps as you make the trip.
- 18. In addition, any general information (i.e. purpose of trip, etc.) should be entered before you start the trip not at the end when you are in the middle of getting out of the vehicle, into the store, at a gas pump, etc.
- 19. I find the number of entries needed in the middle of a multimodal trip to be bothersome. (i.e. what was purpose, changing modes, # of people, driver/passenger, etc.). It reduces my interest in doing this app as I constantly have to answer the same questions over and over on every trip. But, if there was a way to "profile" trips you normally make (i.e. commute) and reduce the number of keystrokes to two (STOP segment and START next segment) at every stop/transition/segment that would be really nice. It would be especially good if the app could automatically "learn" a profile trip by simply using one you do on a normal day - that would be good and easy for the user. Something on the order of predesignating a trip as a profile learning trip, giving it a name (i.e. Work to Home/Bus) and then doing the trip as you

normally would with all the questions/answers then being used to populate that profile and used every time you call it up.

- 20. What about "wait" times at bus/train stops in the middle of the trips being taken? Is it important to identify/document those specifically for your analysis/data collection?
- 21. Have you stopped?
 - a. New category suggestion: Instead of "Yes, I'm making a stop", how about "Temporary Stop"
- 22. There are numerous inconstancies in the way the questions are written, some have punctuation and others do not.

Comments on the Form(s):

- 1. Add the "no cell phone while driving" clause to your signature block
- 2. Change the text of "made up info."
- 3. Instructions on how to reboot or reload application if you get kicked out.
- 4. Is there something that tells the users to keep their phone on for at least XX amount of minutes after they arrive at their destination to allow time for the data from the application to be transferred?

Comments on the Flowchart:

- 1. For clarity, I would suggest entirely separate flows for Auto/truck/van, Public transit, Multimodal (new), and (as a group) the rest of the selections. Might clarify the flows for the reader/user and make it more user friendly less technical design oriented.
- 2. For the "If final destination answer is _____" flow
 - a. For "no" This isn't the appropriate "IF" statement. I'm assuming this is the path where the "Yes-I'm making a stop" was selected? If so, the statement should relate directly to the phrase selected not a logical inference.
 - b. For "yes" See comment on "If final destination answer is "no"" above. Directly relate to response/selection made by user.

Various other comments:

Date: 04/28/2011

Application crashed on the Virgin Mobile LG Optimus V while entering in the password. User entered in name and e-mail address, put the unit down, was reading the instructions then took the phone out of sleep state and the phone stated the "this application has caused an error" message. I sent in an error report for you to get via the Google error message feedback so you should have the system data as well. The app was completely crashed and will not let you start it (shows the error message when you restart the app). Even after a soft reboot (turning phone off and back on) the application is crashing.

It doesn't work even with a cache wipe.

Had to uninstall the app, redownload from the market and reinstall.

Oddly it went into standby mode again while entering in the email address but did not crash it this time.

Date: 05/03/2011

Doing a multimodal trip is not intuitive or perhaps not even possible with this app. The app should ask right up front if it is a multimode trip and the interim stops/wait points should be logged with a single (or at most two) key taps as you make the trip.

In addition, any general information (i.e. purpose of trip, etc.) should be entered before you start the trip - not at the end when you are in the middle of getting out of the vehicle, into the store, at a gas pump, etc.

Date: 05/03/2011

Here are my notes from last week and this past weekend:

1) Add the "no cell phone while driving" clause to your signature block

2) Change the text of "made up info."

3) Keyboard input should have a horizontal option as well as vertical

4) Force Close option does not let you back into application, it only closes the application.

5) more options on the race/ethnicity group

6) selection for education should be by degree, not years of education (i.e. I went to school for 15+ years, but only have my BS)

7) Reminder to start the program before you start driving, and stop the program when you stop driving.

8) WI-FI has a better GPS location, even though it drains battery

9) On parking selection, perhaps ask some details (i.e. parking garage, parking lot, private driveway, etc.)

10) On the start location, it should be the same list as the destination, (i.e. include restaurants, etc.)

11) Drop off/pick up selection should list items like people, groceries, food, etc.

12) Instructions on how to reboot or reload application if you get kicked out.

While I understand the "changed my mind in middle of trip" scenario (I frequently "bundle" my trips as I go also) the primary purpose is known before I start. And since the app selection generally only allows a single reason for the trip anyway, I don't see any advantage to putting it at the end rather than the beginning.

What about "wait" times at bus/train stops in the middle of the trips being taken? Is it important to identify/document those specifically for your analysis/data collection?

Date: 05/05/2011

I am ready to turn the second phone in. Below our my observations/recommendations:

1) Do you need to know ages of passengers? Does this help in determining if it is a work car-pool or a parent shuttle, etc.? I can ask, not too sure if they thought of this or not.

2) Can you turn off power save mode? Otherwise, the phone goes all the way to locking you out between the time you start driving and the time you stop. This is an Android feature and not an app feature. You can change the time for that in the phone's settings.

3) When I had to reload my information in the second phone it asked for my race/ethnicity after we started the trip. Was this on the loaner phone or another phone?

4) Is there something that tells the users to keep their phone on for at least XX amount of minutes after they arrive at their destination to allow time for the data from the application to be transferred? This is not set because it is expected that this would be used on someone's normal phone and they do not normally turn on and off the device throughout the day just to save battery power.

5) Is the pick up/drop off suppose to cover transit mode changes? If so, this may not be clear or you may want to add this as a separate menu option. We're addressing this in the next version. So you are not the only one.

6) All the legal jargon or agreement information should be completed on the application once someone agrees to download. Not sure if you have worked that into the application. We are actually looking into that for the final build since it will be something that will be needed. There is a debate on having it on the app itself or on a website where you have to go to download it.

7) Is there a way when you are at your destination to view your travel history? I.e. distance traveled, minutes traveled, etc.? That would be a neat feature, not too sure how hard it would be to implement it.

Things I really like/were user friendly:

- 1) ATD Logo/Icon on main home screen
- 2) Like that you can select if you are the passenger or driver
- 3) Like the menu selection/buttons are large font and easy to read
- 4) Like the flow of the application

Date: 05/11/2011

First of all, thanks for this opportunity. I've enjoyed using the Travel Diary, finding it rather fun! My suggestions and comments are below:

1. Have you stopped?

New category suggestion: Instead of "Yes, I'm making a stop", how about "Temporary Stop"

Another suggestion is to have a bell or ringer alert to help me remember to log in along my daily journey. I've sometimes forgotten to do so. I'd like a print out of where I traveled and a print out of how many miles I've gone. This could be done daily or at the end of the study time period.

Date: 05/12/2011

1. I find the number of entries needed in the middle of a multimodal trip to be bothersome. (i.e. what was purpose, changing modes, # of people, driver/passenger, etc.). It reduces my interest in doing this app as I constantly have to answer the same questions over and over on every trip. But, if there was a way to "profile" trips you normally make (i.e. commute) and reduce the number of keystrokes to two (STOP segment and START next segment) at every stop/transition/segment that would be really nice. It would be especially good if the app could automatically "learn" a profile trip by simply using one you do on a normal day - - - that would be good and easy for the user. Something on the order of predesignating a trip as a profile learning trip, giving it a name (i.e. Work to Home/Bus) and then doing the trip as you normally would with all the questions/answers then being used to populate that profile and used every time you call it up.

2. I'd like to second some comments others have made on getting some feedback to the user to reinforce the benefit of using this app. How far did you walk on a trip, how many gallons of gas did you save for a public transportation segment, how much greenhouse gas did you generate or save, etc. Both for the trip itself and in summary (i.e. for the last 60 days, etc.). Things that allow the user to get "feel good" points for doing this.

Here are the comments that I have gathered as well as my own.

The flowchart would be easier to read if you bundled up the text for each button instead of a list of text. Or some way to identify separate choices.

The flowchart is now confusing with all the new additions. Suggestion to remove all locations where lines cross over each other or minimize the crossing over.

Box 2 still does not align with Box 6 (6B), these should be identical since it does not make any sense to have more destinations than origins.

In Box 2 (and Box 6 and 6B), what is the difference between Work and Business/Work Related? If it is work related, that would fall under Work. You need to clarify the difference between the two.

Box 3 (and Box 3B) should have Airplane dropped from the choices. At least drop the one from Box 3B since it is against FAA rules to leave a phone's GPS operating while on a commercial flight and against the rules to have it operating during takeoff and landing.

Box 3 should also include Big Rigs or Cargo Trucks as an option.

Box 3B - Is Light Rail lumped into the Commuter Rail choice?

Box 3C - Why do you not ask this question if you are a passenger? You only ask this question if you are taking an Auto/Truck/Van anyway.

Box 4 should read, "Please start your trip" or "Start Trip" header and "Press here..." button.

You should make a Box 4A to have a "Please continue your trip" page to not confuse the user.

Box 5 does not need to be labeled "Have you stopped?" because you already answered that in the previous screen by clicking on the button. The "no" option could also be dropped from this screen since you only got to this screen if you stopped. This screen needs to be changed.

In Box 5 you should spell out "I am" instead of using "I'm". The use of abbreviations are usually avoided.

In Box 6 (and Box 6B), is the text in green added as a new button or part of the Pick-Up/Drop-Off button? If it is part of the Pick-Up/Drop-Off button, you need to make it short and to the point to keep with the theme of the app being easy and quick to use.

Box 6A and 6C need to have "drop off" hyphenated in the choices.

Box 6B needs to have the option for a pick-up/drop-off or mode or vehicle change replaced with the option as Airport/Transit Station/etc. to flow to Box 6C.

Box 6B and 6C are confusing at the beginning. You should either drop these two or drop Box 6 and 6A since they both seem to serve the same purpose.

In Box 6A (and Box 6C) the header still says Pick-Up/Drop-Off and does not indicate transfer or change of mode. They both also do not give the choice to say, "changing mode/transfer".

Box 7 could also be asked for public transit since lots of them are now charging for parking.

Box 7C - If you answer no in this box, it should go directly to Box 4 or Box 3C and not Box 3A.

Not too sure if you meant to have it do this, but while entering the demographic/info it had us enter in our name twice (can't remember now if it was first name then last name, or name twice but I think it was name twice) and the e-mail address 3 times. If this is intentional you might want to let people know that they are entering in their name/e-mail address again to verify it or at least let the user know that they didn't mess up.

Date: 04/12/2011:

While helping a user set up the app on her phone we came across some interesting things. Not too sure if you meant to have it do this, but while entering the demographic/info it had us enter in our name twice (can't remember now if it was first name then last name, or name twice but I think it was name twice) and the e-mail address 3 times. If this is intentional you might want to let people know that they are entering in their name/e-mail address again to verify it or at least let the user know that they didn't mess up.

One user had her phone send her to the "Securities and Location Setting" to turn on her GPS. She said that the check box was already checked so no idea why the app would send her there twice. After the second time it let her start using the app.

I checked the "System Info" optional window that used to display the phone's status and it is now blank except for the data about the phone. Don't know if you turned that off or not.

There were some complaints about the demographics answers, like the age range of 31-65 is a big large.

Date: 04/05/11:

The ATD should check to see if GPS is enabled, and if it is not, then it should enable it.

APPENDIX D: GPS-ATD SPECIFICATION VERSION 2.0

The GPS-ATD specifications, version 2.0, begin on the next page. These specifications are meant to guide ATD development on other platforms, for example the iPhone. The specifications are evolving, and it is strongly recommended to check with AHMCT for any update prior to beginning any development. Please e-mail TALasky@UCDavis.edu to check for updates.

GPS-ATD Application Specifications v2.0

Travis Swanston trav@t-s.net

AHMCT Research Center University of California Davis, CA

02/14/2011

About this Document

The purpose of this document is to provide a set of specifications for the **GPS-ATD** application. This is not yet a rigorous specification document, but rather a work in progress. Hopefully in its current state it will be sufficient as a first step toward understanding the application. I realize that many areas are likely still unclear or ambiguous, so any feedback is quite welcome.

Document History

version	date	notes			
v1.0	10/07/2010	Initial release			
v2.0	02/14/2011	New logfile format and data repo organization.			
		Added architectural overview.			
		Session data upload strategy.			
		Added section on raw/corrected paths.			
		Now reflects $09/21/10$ survey profile.			
		Other updates, elaboration, and corrections.			

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1 Introduction to the GPS-ATD Application

The purpose of the **GPS-ATD** application is to facilitate the capture of a user's daily travel behavior for later analysis. This is done by presenting the user with an interactive questionnaire, coupled with the simultaneous logging of positioning and motion data from the device's onboard GPS receiver.

The data from the questionnaire and the GPS receiver is stored on the device's SD card until it is later uploaded to a server. The exact circumstances as to when and under what circumstances the data is to be uploaded are still under consideration, however, for the time being, a good working assumption is that, at the very least, the data will be uploaded when the user selects an "upload" option from the application's main menu.

Figure 1 summarizes the data flow for the **GPS-ATD** system.



Figure 1: GPS-ATD data flow

2 Architectural Overview

2.1 Components

The GPS-ATD application consists of three fundamental components:

- user activity
- session logging service
- upload service

At no time should there be more than one instance of any individual component running. In other words, all three may be running simultaneously, but never should there be more than one user activity component running, more than one session logging component running, nor more than one upload component running.

2.2 User Activity Component

The user activity component is the user-facing, foreground portion of the application.

It is typically launched manually, like any other normal application on the device, and handles all aspects of the **GPS-ATD** user interface, including survey presentation (as described in Section 3), as well as other user-facing elements, such as the application settings menu (see Section 2.7).

2.3 Session Logging Service Component

The session logging component operates as a background service. It handles session management, interaction with sensors (GPS, etc.), as well as the logfile creation and output.

This component is invoked when a survey session is begun, and it terminates when the session has finished.

While a survey session is active, it remains in the background handling the session, permitting use of the device for other purposes (phone calls, etc.) without interrupting the survey session.

Also, while a survey session is active, any necessary wakelocks (e.g., CPU, GPS, aGPS) should be acquired to prevent the device OS from disabling those functions for power-saving reasons (sleep mode, etc.). The wakelocks should be released when the component terminates.

2.4 Upload Service Component

The upload component operates as a background service. When it is invoked (see Section 2.6), it checks the data repository for any pending uploads (completed sessions), decides (see Section 2.5) whether or not to upload them to the ATD server, and handles the upload and deletion of the session from the data repository.

When this component has finished considering sessions to upload, it terminates.

While the upload component is running, any necessary wakelocks (e.g., CPU, networking) should be acquired to prevent the device OS from disabling those functions for power-saving reasons (sleep mode, etc.). The wakelocks should be released when the component terminates.

2.5 Upload Processing

When the upload component is invoked, it determines if there are any completed session logs ready for upload to the **GPS-ATD** server. If there are, it then decides whether or not to upload the logs based on the current value of the "wi-fi preferred" application setting. If "wi-fi preferred" is false, it immediately begins uploading the session logs (one at a time). If "wi-fi preferred" is true, then it does so only if the device currently has an active wi-fi connection.

The upload is handled via a standard (RFC 1867) HTTP POST operation. The exact mechanics of this transaction (e.g., URL, credentials, etc.) are to be finalized in a subsequent version of this document.

2.6 Entry Points

Various events trigger the invocation of different components of the application, as summarized below.

- system boot: The upload service is invoked at system boot.
- app launch: The user activity component is invoked when the GPS-ATD app is launched by the user
- session begin: The session logging service is invoked when a new survey session is begun.
- session end: The upload service is invoked after a survey session has ended.
- new wi-fi connection: The upload service is invoked when a new wi-fi connection is established.

2.7 Application Settings

There are currently two user-modifiable application settings:

- account: The user's registered GPS-ATD system account
- wi-fi preferred: Whether the user prefers that wi-fi be used for uploads (default false)

3 The Survey

3.1 Overview

The interactive behavior of the application is specified and controlled by a "survey profile file". This is an XML file that describes the survey's "profile" — basically a set of questions and answers along with some logic that dictates the survey's behavior. ¹ The details of the survey profile XML file are given in Section 3.5, but for the moment it is important to note that a survey profile is made up of a set of different "screens", one (and only one) of which is designated as the "start screen", and the rest of which we'll call "regular screens". Each of these screens has exactly one prompt (a question or statement for the user) and a set of one or more responses for the user to choose from. Upon selecting a response, the user is navigated to another screen — dynamically determined not only by the response selected, but sometimes also from responses selected earlier in the session. This is forward navigation. Backward navigation is also possible through the use of the *Back* button, but only up to the most recent instance of the "start screen". That is, backing up into a previous session is not allowed.

 $^{^{1}}$ Currently this file is bundled with the application. However, in the future, multiple simultaneous profiles may be supported (i.e., for selection at runtime), and these profiles may be remotely updateable.

3.2 User Interface

The user interface for the **GPS-ATD** application primarily consists of a series of interactive "screens". Each screen has a question or statement to prompt the user, and a set of responses for the user to choose from. The user can also choose to navigate back to the previous screen (with one limitation which is described in a later section).

At the top of the screen is the prompt for the user (i.e., the question or statement), and below that is a list of responses for the user to choose from. If the responses do not all fit on the page, a scrollbar is displayed on the right side of the interface to inform the user that the list is scrollable. The scrollbar itself does not respond to touch, however.

Three buttons are at the bottom of the interface (*Back*, PgUp, and PgDn). The *Back* button is used to navigate back to the previous screen in the stack. It is only selectable when navigation backward is valid. The PgUp button is used to page-up the response list. It is only selectable when paging-up is valid. The PgDn button is used to page-down the response list. It is only selectable when paging-down is valid.

The response list can also be dragged up and down, so the PgUp and PgDn buttons are not strictly required for use.

See Figure 2 for a couple annotated examples of the UI on the Android version of GPS-ATD.



Figure 2: Two annotated UI screenshots

3.3 Survey Sessions

A **GPS-ATD** "survey session" refers to everything that happens in the interval between when a survey is begun and when it is finished. It involves the user's survey selections, as well as the GPS data that was logged during the session.

A new survey session is initiated any time the user navigates away from the "start screen" to a "regular screen", and the current survey session is closed any time the user navigates in such a way as to end up again at the "start screen".² It is important to note that this could happen either by forward or backward navigation. For instance, even if the user backs out of a survey session without finishing it, we still consider this to be a complete session, and it is to be recorded. The primary reason for this is to allow for application usability analyses during later postprocessing of the collected data.³

See Figure 3 for a high-level overview of GPS-ATD survey behavior.



Figure 3: GPS-ATD survey state machine

 $^{^{2}}$ By definition, sessions are inclusive — i.e., they do not exclude the first and last user responses, but rather these are recorded along with the rest of the responses from the session.

 $^{^{3}}$ For this reason, the user's entire screen path through a survey is also recorded, including even the screens that the user may back out of. This behavior is further detailed in Section 3.4.1.

3.4 Survey Architecture

The survey profile defines the interactive behavior or "personality" of a **GPS-ATD** survey. It is defined by an XML file which is processed dynamically at application startup, and specifies the questions, answers, and logic that dictate the survey's behavior.

Logically, a GPS-ATD survey can be thought of as a set of SCREEN objects, each of which contains a user PROMPT and a set of CHOICE objects. Each CHOICE object represents a possible response for the user to choose from, and can potentially navigate the user to one or more different screens, depending on the responses the user has selected in earlier screens in the survey. So, to this end, each CHOICE contains one or more TRANSITION objects, each of which represents a potential transition to another screen, based on the results of a boolean expression represented in the TRANSITION object. When the user selects a particular CHOICE, these TRANSITION objects are evaluated in order until one passes. At that point, the user is navigated to the screen pointed to by that TRANSITION. If no transitions pass, the user remains at the current screen.

A TRANSITION specifies a SCREEN id (for the destination screen), and can be conditional or unconditional. The TRANSITION is conditional if it contains AND objects, otherwise it is unconditional (i.e., it always passes). AND objects are used as boolean operands to a multi-operand boolean AND function that is evaluated for conditional TRANSITIONs. A conditional TRANSITION is defined to pass if every AND object it contains evaluates to true, otherwise it fails.

Each **AND** object specifies a **SCREEN** id and a **CHOICE** id for a choice in that particular screen, and is considered to evaluate to true if both the following conditions are true:

- the screen identified by the AND object's SCREEN id is part of the user's corrected path (see Section 3.4.1). through the survey in the current session
- the user selected the choice identified by the AND object's CHOICE id during the most recent visit to that screen in that corrected path

else, the operand is considered to evaluate to false.

Figure 4 summarizes the profile object hierarchy. ⁴



Figure 4: Profile object hierarchy

⁴There are some known limitations with this model, and it may be subject to change.

3.4.1 Raw Path vs. Corrected Path

During a survey, the path the user takes through the various screens is recorded in two separate ways: the "raw path" and the "corrected path". The "raw path" contains the complete path that was taken — including where the user may have selected a wrong choice, navigated back to a previous screen, and selected another choice. The "corrected path" only contains the screens and choices that the user intended to take — screens where the user ultimately navigated back to make a different choice are absent. The primary reason the "raw path" is tracked is for its value in subsequent usability analyses. The "corrected path" is tracked because it is needed for evaluating AND objects (as described in Section 3.4).

To understand the difference between the two types of paths, it may help to think of the "corrected path" data structure as a stack, and to think of the "raw path" data structure as a list.

Using the survey profile supplied in Appendix A, let's walk through an example.

1. User, at screen "welcomeScreen", selects choice "beginNewTrip":



2. User, at screen "fromWhere", selects choice "home":



3. User, at screen "travelMode", selects choice "autoTruckVan":



4. User, at screen "driverOrPassenger", navigates back to the previous screen:



5. User, at screen "travelMode", selects choice "motorcycleMoped":



3.5 The Profile XML File

The profile XML file defines the survey objects described in Section 3.4. This section documents the structure of this file. For reference, an example profile file is also provided in Appendix A.

The profile XML file contains exactly one <profile> element, at the top level of the DOM tree.

3.5.1 The <profile> Element

The **<profile>** element represents the survey profile. It should be at the root of the DOM tree for the survey profile, and there should be exactly one.

The <profile> element has the following attributes:

- id (xs:string): the profile's identifier
- version (xs:string): the profile schema version being used
- startScreen (xs:string): the profile's start screen identifier

An example:

Figure 5: The <profile> element

The <profile> element contains only <screen> elements, of which there must be at least one.

3.5.2 The <screen> Element

The **<screen>** elements each represent one screen in the user interface. They should only be found inside the **<profile>** element.

The **<screen>** element has the following attributes:

- id (xs:string): the identifier for this screen
- text_eng-usa-utf8 (xs:string): the text for this screen's user prompt (US English)
- text_spa-usa-utf8 (xs:string): the text for this screen's user prompt (US Spanish)

Currently, only the two language-country-encoding combos are supported, but it is not currently a violation of the profile file's specifications to include not-yet-supported combos in the file.⁵

An example:

```
<screen
   id="welcomeScreen"
   text_eng-usa-utf8="Welcome to the Automated Travel Diary."
   text_eng-spa-utf8="Bienvenidos al diario automático de viaje."
        ...
   </screen>
```

Figure 6: The <screen> element

The <screen> element contains only <choice> elements, of which there must be at least one.

⁵The attribute names for the user prompt strings are a combination of the language's ISO 639-2 alpha-3 code, the country's ISO 3166-1 alpha-3 code, and the Unicode transformation format used.

3.5.3 The <choice> Element

Each <choice> element represents one user choice in a particular screen.

The <choice> element has the following attributes:

- id (xs:string): the identifier for this choice
- text_eng-usa-utf8 (xs:string): the text for this choice (US English)
- text_spa-usa-utf8 (xs:string): the text for this choice (US Spanish)

Currently, only the two language-country-encoding combos are supported, but it is not currently a violation of the profile file's specifications to include not-yet-supported combos in the file.⁶

An example:

```
<choice
id="beginNewTrip"
text_eng-usa-utf8="Begin a new trip"
text_spa-usa-utf8="Iniciar un nuevo viaje"
>
...
</choice>
```

Figure 7: The <choice> element

The <choice> element contains only <transition> elements, of which there must be at least one.

3.5.4 The <transition> Element

Each <transition> element represents one possible screen-transition for a particular user choice.

The <transition> element has the following attribute:

• toState (xs:string): the identifier of the screen to which this transition points

An example:

```
<transition
toState="parkingPaid"
>
...
</transition>
```

Figure 8: The <transition> element

The <transition> element contains only <and> elements, of which there may be zero or more.

⁶The attribute names for the choice strings are a combination of the language's ISO 639-2 alpha-3 code, the country's ISO 3166-1 alpha-3 code, and the Unicode transformation format used.

3.5.5 The <and> Element

Each <and> element represents one boolean operand in a series of zero or more such operands in a <transition> element.

The **<and>** element has the following attributes:

- screen (xs:string): the identifier of the screen under consideration
- choice (xs:string): the identifier of the choice under consideration in that screen

An example:

<and< th=""><th></th></and<>	
S	creen="travelingStopped"
С	hoice="yesFinalDestination"
	>

Figure 9: The **<and>** element

4 Logging and Storage

4.1 Introduction

While a **GPS-ATD** survey session is active, UI and GPS data is logged. The emphasis is on allowing for maximum flexibility during subsequent post-processing of the collected data, so few if any decisions are made dynamically (i.e., at runtime) about what to log or when to log it. Neither is the data processed in any significant way other than the data transformations required for logging in conformance with **GPS-ATD** specifications. The basic idea is essentially to "log everything and sort it out later".

GPS fixes should be acquired and logged as fast as the platform allows, but no faster than 2 Hz. If a GPS fix cannot be acquired, the platform's location subsystem should not be permitted to fall-back on other location technologies (e.g., cell-tower or wi-fi).

4.2 The Data Repository

The data logged by the **GPS-ATD** application is stored on the device's primary SD card in the /gpsatd directory. Data from each survey session is stored in its own log file, the filename of which is formatted as "n.dat", where n is the timestamp at which the survey session began, represented in MS1970UTC format. ⁷

4.3 Session Logs

Session log files are proprietary-format binary files that encapsulate an XML stream that records everything related to the survey session.

Session log files are organized into three sections:

- 1. header section
- 2. session data section
- 3. footer section

4.3.1 Header Section

The format of the header section is shown in Table 1.

element	bytes	description
magic number	8	byte sequence:
		0x47 0x50 0x53 0x2d 0x41 0x54 0x44 0x3a
		(ASCII "GPS-ATD:")
logfile version	4	logfile format version (32-bit signed
		two's complement integer, high byte first)
encoded key length	4	length in bytes of encoded key (32-bit signed
		two's complement integer, high byte first)
encoded key	-	AES-128 key for this session,
		RSA-encrypted with the public half of
		the user's unique 2048-bit RSA keypair.

Table 1: Session Log Header

 $^{^7\}text{MS1970UTC}$ timestamp format: a long integer representing the number of milliseconds that have elapsed since 01/01/1970 $00{:}00{:}00$ UTC

4.3.2 Session Data Section

The session data section contains an XML stream that records everything related to the survey session. It includes general data about the session, along with various timestamped events such as the user's survey responses, GPS fixes, and the like. This XML stream is compressed (GZIP) and encrypted (AES-128-CBC) while being written into this section of the file. The AES-128 key used is unique to each session and is randomly generated when the session begins.

The unprocessed session data XML stream is described in detail in Section 4.4.

4.3.3 Footer Section

The format of the footer section is shown in Table 2.

element	bytes	description
magic number	8	byte sequence:
		0x3a 0x47 0x50 0x53 0x2d 0x41 0x54 0x44
		(ASCII ":GPS-ATD")

Table 2: Session Log Footer

4.4 The Session Data Stream

The session data stream is an XML stream that records everything related to the survey session. It includes general data about the session, along with various timestamped events such as the user's survey responses, GPS fixes, and the like.

This section documents the structure of this stream. For reference, an example is also provided in Appendix B.

The session data stream's XML tree contains exactly one **<atdSession>** element, at the top level of the DOM tree.

4.4.1 The <atdSession> Element

The **<atdSession>** element represents the entire survey session. It should be at the root of the DOM tree for the session XML tree. and there should be exactly one.

The <atdSession> element has the following attributes:

- logVersion (xs:string): the version of the log format used for this session
- appVersion (xs:string): the version of the app used for this session
- userId (xs:string): the user ID for the user to whom this session belongs
- profileId (xs:string): the id of the profile used for this session
- profileVersion (xs:string): the version of the profile schema used for this session
- profileHash (xs:string): the SHA1 hash of the profile file used for this session

as well as several other optional device-specific attributes (more on this later).

An example:

```
<atdSession
  logVersion="android:0.7"
  appVersion="android:0.12"
  userId="john@example.com"
  profileId="atdPilot-1.4"
  profileVersion="1.1"
  profileHash="436ced1ee4605f501d45313a9055828031a22a21"
  android_aid="22a0000015bb5e6b"
  android_deviceId="A0000015BB5E6B"
  android_simSerial="0123456789012345678"
  android_model="Google Ion"
  android_device="sapphire"
  android_board="sapphire"
  android_brand="google_ion"
  >
   . . .
</atdSession>
```

Figure 10: The <atdSession> element

The <atdSession> element can contain <surveyNav> elements, <gpsFix> elements, as well as various other elements (e.g. battery events, inertial events, etc.). These other events are not required to be implemented and can be ignored for the purposes of this specification.

4.4.2 The <surveyNav> Element

The <surveyNav> elements each represent one step of the user's path through the survey (i.e., when the user responds to a survey question). They should only be found inside the <atdSession> element.

The <surveyNav> element has the following attributes:

- softTimeMs (xs:long): the time when the user made this selection, represented as the number of ms that have elapsed since this session began.
- screenId (xs:string): the identifier for the screen where this step took place
- choiceId (xs:string): the identifier for the choice the user selected in that screen

An example:

```
<surveyNav
softTime="14875"
screenId="welcomeScreen"
choiceId="beginNewTrip"
/>
```

Figure 11: The <surveyNav> element

4.4.3 The <gpsFix> Element

The **<gpsFix>** elements each represent a newly-acquired GPS fix. They should only be found inside the **<atdSession>** element.

The <gpsFix> element has the following attributes:

- softTimeMs (xs:long): the time when the GPS system reported this new fix, represented as the number of ms that have elapsed since this session began.
- latitudeDeg (xs:double): this fix's latitude in degrees (North-positive)
- longitudeDeg (xs:double): this fix's longitude in degrees (East-positive)
- gpsTimeMs (xs:long): this fix's GPS time in MS1970UTC format⁸
- altitudeM (xs:double): this fix's altitude in meters (if available)
- bearingDETN (xs:double): this fix's bearing in degrees East of true North (if available)
- speedMPS (xs:double): this fix's speed in m/s (if available)
- accuracyM (xs:double): this fix's accuracy in meters (if available)
- numSats (xs:int): the number of satellites used to derive this fix (if available)

An example:

```
<gpsFix
softTimeMs="17329"
latitudeDeg="38.555556"
longitudeDeg="-121.468889"
gpsTimeMs="1271144734374"
altitudeM="8.3"
bearingDETN="42.37"
speedMPS="37.4"
accuracyM="3.0m"
numSats="8"
/>
```

Figure 12: The <gpsFix> element

 $^{^8}MS1970UTC$ timestamp format: a long integer representing the number of milliseconds that have elapsed since $01/01/1970\ 00:00:00\ UTC$
5 About GPS-ATD

The GPS Automated Travel Diary (**GPS-ATD**) app was developed by the Advanced Highway Maintenance and Construction Technology Research Center in the Department of Mechanical & Aerospace Engineering at the University of California-Davis.

The **GPS-ATD** app development is part of a cooperative research effort with the California Department of Transportation (Caltrans) Division of Transportation System Information and the Caltrans Division of Research and Innovation.

Appendices

Appendix A A Profile Example

A.1 The Survey Diagram



Figure 13: Example survey diagram

A.2 The Profile File

The following profile file implements the survey illustrated in Figure 13.

```
<?xml version="1.0" encoding="utf-8"?>
<profile
  xmlns="http://schemas.ahmct.ucdavis.edu/atd/"
  id="atdPilot-1.4"
  version="1.1"
  startScreen="welcomeScreen">
   <screen
     id="welcomeScreen"
     text_eng-us-utf8="Welcome to the Automated Travel Diary."
     >
     <choice
        id="beginNewTrip"
        text_eng-us-utf8="Begin a new trip"
         <transition toState="fromWhere"/>
      </choice>
   </screen>
   <screen
     id="fromWhere"
     text_eng-us-utf8="From?"
      >
      <choice
        id="home"
        text_eng-us-utf8="Home"
         <transition toState="travelMode"/>
      </choice>
      <choice
        id="work"
         text_eng-us-utf8="Work"
         >
         <transition toState="travelMode"/>
      </choice>
      <choice
         id="workRelated"
        text_eng-us-utf8="Business/work-related"
        >
         <transition toState="travelMode"/>
      </choice>
      <choice
        id="school"
        text_eng-us-utf8="School"
         >
         <transition toState="travelMode"/>
      </choice>
      <choice
        id="recreationEntertainment"
         text_eng-us-utf8="Recreation / entertainment"
        <transition toState="travelMode"/>
      </choice>
      <choice
        id="other"
         text_eng-us-utf8="Other"
         >
         <transition toState="travelMode"/>
      </choice>
   </screen>
   <screen
     id="travelMode"
```

```
text_eng-us-utf8="Select mode of travel."
   >
   <choice
     id="autoTruckVan"
     text_eng-us-utf8="Auto / truck / van"
     >
     <transition toState="driverOrPassenger"/>
   </choice>
   <choice
     id="publicTransit"
     text_eng-us-utf8="Public transit"
     <transition toState="publicTransitType"/>
   </choice>
   <choice
     id="onFoot"
     text_eng-us-utf8="On foot"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="bicycle"
     text_eng-us-utf8="Bicycle"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="motorcycleMoped"
     text_eng-us-utf8="Motorcycle / moped"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="airplanePrivate"
     text_eng-us-utf8="Airplane (private)"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="other"
     text_eng-us-utf8="Other"
     >
     <transition toState="commenceTrip"/>
   </choice>
</screen>
<screen
  id="driverOrPassenger"
  text_eng-us-utf8="Are you the driver or a passenger?"
  >
   <choice
     id="driver"
     text_eng-us-utf8="Driver"
     >
     <transition toState="numberOfPassengers"/>
   </choice>
  <choice
     id="passenger"
     text_eng-us-utf8="Passenger"
     <transition toState="commenceTrip"/>
   </choice>
</screen>
<screen
  id="publicTransitType"
  text_eng-us-utf8="Select public transit type."
   >
   <choice
```

```
id="localBus"
     text_eng-us-utf8="Local bus"
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="expressCommuterBus"
     text_eng-us-utf8="Express / commuter bus"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="commuterRail"
     text_eng-us-utf8="Commuter rail (BART, Metro, etc.)"
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="schoolRelatedBus"
     text_eng-us-utf8="School-related bus"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="dialARideParaTransit"
     text_eng-us-utf8="Dial-a-ride / Para transit"
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="taxiShuttleBusLimo"
     text_eng-us-utf8="Taxi / shuttle bus / limo"
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="heavyRail"
     text_eng-us-utf8="Heavy rail (Caltrain, Amtrak)"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="intercityBus"
     text_eng-us-utf8="Intercity bus (Greyhound, etc.)"
     >
      <transition toState="commenceTrip"/>
  </choice>
   <choice
     id="airplaneCommercial"
     text_eng-us-utf8="Airplane (commercial)"
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="other"
     text_eng-us-utf8="Other"
     <transition toState="commenceTrip"/>
  </choice>
</screen>
<screen
  id="numberOfPassengers"
  text_eng-us-utf8="Number of passengers (including yourself)?"
  >
   <choice
     id="1"
     text_eng-us-utf8="1"
     >
```

```
<transition toState="commenceTrip"/>
   </choice>
   <choice
     id="2"
     text_eng-us-utf8="2"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="3"
     text_eng-us-utf8="3"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="4"
     text_eng-us-utf8="4"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="5"
     text_eng-us-utf8="5"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="6"
     text_eng-us-utf8="6"
     >
     <transition toState="commenceTrip"/>
   </choice>
  <choice
     id="7"
     text_eng-us-utf8="7"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="8"
     text_eng-us-utf8="8"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="9"
     text_eng-us-utf8="9"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="100rMore"
     text_eng-us-utf8="10 or more"
     >
     <transition toState="commenceTrip"/>
   </choice>
</screen>
<screen
  id="commenceTrip"
  text_eng-us-utf8="Please continue your trip."
  >
   <choice
     id="stopTraveling"
     text_eng-us-utf8="Stop traveling"
     >
     <transition toState="travelingStopped"/>
   </choice>
</screen>
```

```
<screen
   id="travelingStopped"
   text_eng-us-utf8="Have you stopped?"
   >
   <choice
     id="no"
     text_eng-us-utf8="No"
     >
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="yesMakingStop"
     text_eng-us-utf8="Yes, I'm making a stop"
     <transition toState="tripActivity"/>
   </choice>
   <choice
     id="yesFinalDestination"
     text_eng-us-utf8="Yes, this is my final destination."
      <transition toState="tripActivity"/>
   </choice>
</screen>
<screen
   id="tripActivity"
  text_eng-us-utf8="What was your trip activity for this part of the trip?"
   >
   <choice
     id="goingHome"
     text_eng-us-utf8="Going home"
      <transition toState="continueTrip">
         <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
   <choice
     id="pickUpDropOff"
     text_eng-us-utf8="Pick-up / drop-off (including transit station, airport, etc.)"
     <transition toState="pickUpOrDropOff"/>
   </choice>
   <choice
     id="work"
     text_eng-us-utf8="Work"
     >
     <transition toState="continueTrip">
         <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
        <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
```

```
<transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="workRelated"
  text_eng-us-utf8="Business/work-related"
  >
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
     <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="educationChildcare"
  text_eng-us-utf8="Education / childcare"
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="foodDrink"
  text_eng-us-utf8="Food / drink"
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
     <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
   <transition toState="parkingPaid">
     <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="recreationEntertainment"
  text_eng-us-utf8="Recreation / entertainment"
   <transition toState="continueTrip">
     <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
```

```
<transition toState="parkingPaid">
      <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="socialCivicReligious"
  text_eng-us-utf8="Social / civic / religious"
  >
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
     <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="groceryShopping"
  text_eng-us-utf8="Grocery shopping"
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="otherShoppingBankingGas"
  text_eng-us-utf8="Other Shopping/banking/gas"
  >
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
   <transition toState="parkingPaid">
     <and screen="travelMode" choice="motorcycleMoped"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="other"/>
   </transition>
   <transition toState="tripOrActivityFinished"/>
</choice>
<choice
  id="medical"
  text_eng-us-utf8="Medical"
   <transition toState="continueTrip">
      <and screen="travelingStopped" choice="yesMakingStop"/>
   </transition>
   <transition toState="parkingPaid">
      <and screen="travelMode" choice="autoTruckVan"/>
   </transition>
```

```
<transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
   <choice
     id="otherOutOfHomeActivity"
     text_eng-us-utf8="Other out of home activity"
     <transition toState="continueTrip">
        <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
</screen>
<screen
   id="pickUpOrDropOff"
   text_eng-us-utf8="Pick-up / drop-off"
   <choice
     id="pickUpSomeone"
     text_eng-us-utf8="Pick-up someone"
      <transition toState="continueTrip">
         <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
   <choice
     id="dropOffSomeone"
     text_eng-us-utf8="Drop-off someone"
     >
      <transition toState="continueTrip">
         <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
        <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
```

<choice

```
text_eng-us-utf8="Get picked up"
      <transition toState="continueTrip">
         <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
        <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
   <choice
     id="getDroppedOff"
     text_eng-us-utf8="Get dropped off"
     >
      <transition toState="continueTrip">
        <and screen="travelingStopped" choice="yesMakingStop"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="autoTruckVan"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="motorcycleMoped"/>
      </transition>
      <transition toState="parkingPaid">
         <and screen="travelMode" choice="other"/>
      </transition>
      <transition toState="tripOrActivityFinished"/>
   </choice>
</screen>
<screen
   id="parkingPaid"
   text_eng-us-utf8="Did you pay for parking on your trip?"
   <choice
     id="no"
     text_eng-us-utf8="No"
     >
      <transition toState="tripOrActivityFinished"/>
  </choice>
   <choice
     id="prepaid"
     text_eng-us-utf8="Yes, prepaid"
     <transition toState="tripOrActivityFinished"/>
   </choice>
   <choice
     id="paidOnLocation"
     text_eng-us-utf8="Yes, paid on location"
      <transition toState="tripOrActivityFinished"/>
   </choice>
</screen>
<screen
  id="continueTrip"
   text_eng-us-utf8="Press OK when you are ready to continue your trip."
   >
   <choice
     id="ok"
     text_eng-us-utf8="OK"
     >
```

id="getPickedUp"

```
<transition toState="travelModeChange"/>
   </choice>
</screen>
<screen
  id="travelModeChange"
  text_eng-us-utf8="Are you changing your mode of travel?"
  >
  <choice
     id="no"
     text_eng-us-utf8="No"
     >
     <transition toState="driverOrPassenger">
        <and screen="travelMode" choice="autoTruckVan"/>
     </transition>
     <transition toState="commenceTrip"/>
   </choice>
   <choice
     id="yes"
     text_eng-us-utf8="Yes"
     >
     <transition toState="travelMode"/>
  </choice>
</screen>
<screen
  id="changeOfDrivers"
  text_eng-us-utf8="Is there a change of drivers?"
  >
  <choice
     id="no"
     text_eng-us-utf8="No"
     >
     <transition toState="driverOrPassenger"/>
  </choice>
   <choice
     id="yes"
     text_eng-us-utf8="Yes"
     >
     <transition toState="driverOrPassenger"/>
   </choice>
</screen>
<screen
  id="tripOrActivityFinished"
  text_eng-us-utf8="Your trip/activity is finished. Thank you for your cooperation."
  >
  <choice
     id="ok"
     text_eng-us-utf8="OK"
     >
     <transition toState="welcomeScreen"/>
   </choice>
</screen>
```

</profile>

Appendix B An Example Session Data Stream

An example session data stream is provided here. It is consistent with a survey session taken using the same survey profile shown in Appendix A.

Please note that for clarity, all but one of the <gpsFix> elements have been abbreviated, and many <gpsFix> elements have been removed (as noted in the text).

```
<?xml version="1.0" encoding="utf-8"?>
<atdSession
  logVersion="android:0.7"
   appVersion="android:0.12"
  profileId="atdPilot-1.4"
   profileVersion="1.1"
  profileHash="436ced1ee4605f501d45313a9055828031a22a21"
   android_aid="22a0000015bb5e6b"
   android_deviceId="A0000015BB5E6B"
   android_simSerial="0123456789012345678"
   android_model="Google Ion"
   android_device="sapphire"
   android_board="sapphire"
   android_brand="google_ion"
   >
   <atdEntry
      screenId="welcomeScreen"
      choiceId="beginNewTrip"
      softTime="0"
      />
   <atdEntry
      screenId="fromWhere"
      choiceId="work"
      softTime="1965"
      />
   <atdEntry
      screenId="travelMode"
      choiceId="autoTruckVan"
      softTime="3700"
     />
   <gpsFix
      softTimeMs="3849"
      latitudeDeg="38.556822"
      longitudeDeg="-121.468942"
      gpsTimeMs="1271144823945"
      altitudeM="7.3"
      bearingDETN="23.34"
      speedMPS="0.1"
      accuracyM="6.0m"
      numSats="5"
     />
   <gpsFix ... />
   <gpsFix ... />
   <gpsFix ... />
   <atdEntry
      screenId="driverOrPassenger"
      choiceId="driver"
      softTime="5086"
     />
   <gpsFix ... />
   <gpsFix ... />
   <atdEntry
      screenId="numberOfPassengers"
      choiceId="1"
      softTime="6488"
      />
   <gpsFix ... />
   <gpsFix ... />
```

```
<gpsFix ... />
   <gpsFix ... />
<gpsFix ... />
   (NOTE: a few thousand <gpsFix> elements were removed here)
   <gpsFix ... />
   <gpsFix ... />
<gpsFix ... />
   <gpsFix ... />
   <gpsFix ... />
   <atdEntry
      screenId="commenceTrip"
      choiceId="stopTraveling"
      softTime="2743021"
      />
   <gpsFix ... />
   <gpsFix ... />
   <atdEntry
      screenId="travelingStopped"
      choiceId="yesFinalDestination"
      softTime="2745378"
      />
   <gpsFix ... />
   <atdEntry
      screenId="tripActivity"
      choiceId="goingHome"
     softTime="2747197"
     />
   <gpsFix ... />
   <gpsFix ... />
   <atdEntry
      screenId="parkingPaid"
      choiceId="no"
      softTime="2748562"
      />
   <gpsFix ... />
   <atdEntry
      screenId="tripOrActivityFinished"
      choiceId="ok"
      softTime="2751790"
      />
</atdSession>
```