

A SEVEN-DAY SMARTPHONE- BASED GPS HOUSEHOLD TRAVEL SURVEY IN INDIANA

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Traditional household travel surveys (HTS) typically collect a single day of travel from a sample of residents in a region. The picture of regional travel is thus based upon a sample of households' travel on a sampling of days. A growing body of work suggests that longer data collection periods are warranted to provide improved data for modeling purposes and understanding trends. However, for longer periods of data collection to be successful, all aspects of projects must be implemented with a mindfulness toward the impacts on respondent burden. Scalability is also a challenge when coupled with the demand for accurate GPS data and ever more detailed survey data for modeling purposes.

The In the Moment (ITM) Travel Study project, conducted by RSG on behalf of the Madison County Council of Governments (MCCOG) in Anderson, Indiana and the Federal Highway Administration (FHWA) Office of Planning and Office of Transportation Policy Studies, addressed these challenges by fully replacing the traditional telephone and web household travel diary survey experience with smartphone GPS data collection over a seven-day period. The smartphone's sensors passively collected location data (the "where and when" of travel data), while in-app survey questions obtain the remaining essential HTS data elements (the "why, who, and how" of travel behavior). The goal is to prompt respondents to answer these in-app survey questions in close to "real-time" at each trip destination and in a very low burden way, which facilitates the ability to conduct these projects for the longer data collection period.

KEYWORDS: Smartphone Surveys, GPS Surveys, Household Travel Surveys, Transportation Data Collection, GIS, Machine Learning, Mobile Application, Usability, Design Process

LITERATURE REVIEW

In the last several years, strong interest in smartphone-based travel surveys that collect data over a longer period of time has resulted in a number of projects outside the U.S. The best known project, the Future Mobility Survey (FMS), was a smartphone-based travel

survey conducted as a subset sample of at least 1,000 participants in the nationwide Singaporean Household Interview Travel Survey (1). Participants were asked to use an Android™ or iOS™ smartphone app to passively collect their spatial and temporal travel data and then go online to validate five days of travel (prompted recall) in order to receive an incentive equivalent to \$25 USD.

In Europe, recent smartphone-based GPS travel surveys have included a 2013-2014 travel survey of 1,000 participants across the Czech Republic who answered a questionnaire, then were provided with an Android™ smartphone for a two-week data collection period, and additionally completed paper travel diaries in parallel to carrying the smartphone (2). Although not currently a GPS travel survey, the German Mobility Panel annually collects seven days of travel data from approximately 1,500 households (3). In 2013, the Dutch Mobility Panel implemented a smartphone app called MoveSmarter where 600 panel members participated for a two week period (4). Among the 600 participants, approximately 40% used their own smartphone while the rest of the sample were provided with a smartphone, and all were asked to use a web-based prompted recall survey. Preliminary results indicate higher trip rates than previous Dutch survey methods.

In Sydney, Australia, a seven-day travel diary was conducted in 2013 with more than 600 participants (5). About half of participants used their own smartphones to passively record their travel over the seven days and then verify their trip details in an online diary where they could view maps of their daily travel. A preliminary result of the study was that users of the smartphone app were associated with higher trip reporting rates, as well as the fact that the majority (76%) of participants completed all seven days of data collection. Nearby in New Zealand, a 2014 trial of the national Household Travel Survey was recently conducted to compare methods among web-based, handheld GPS, and Android™ droid smartphone-based GPS survey approaches (6). The group of about 70 participants who participated via a smartphone had the highest study completion rates.

Although it is clear numerous countries are on a path to implementing smartphone-based GPS travel studies that collect data over a longer period of time, very few smartphone-based GPS travel surveys have been conducted in the U.S. This is especially true when excluding U.S. smartphone apps that detect trips and

primarily aim to provide users with feedback on their travel behavior rather than aiming to partially or fully replace a traditional household travel diary approach (7). Likely due in part to desires to manage project costs during recent economic downturns and to the need to test new methodologies and technologies in the U.S., U.S. surveys have largely been limited to one or two day travel diaries in recent years using known methodologies. However, smartphone penetration rates and technological advances in smartphone technology continue to increase rapidly in the U.S, which garners more interest in conducting smartphone-based surveys. This paper seeks to summarize the preliminary results of quite possibly the first multi-day smartphone-based GPS household travel diary survey in the U.S., which was conducted in May 2015.

INTRODUCTION

With any research project of this nature, it is important to start the project with focused goals. The project team worked together and determined the following specific project goals:

- Implement a smartphone-based household travel diary seeking to determine if such an approach is indeed a viable replacement alternative to traditional travel diary methods.
- Test an approach that will ultimately improve the quality of household travel diary data collected (closer to real-time, improved accuracy, and for much longer data collection periods), while aiming to substantially reduce respondent burden over existing travel diary methodologies.

To accomplish the project goals, the invitation pool for ITM consisted of participants from the 2014 Heartland in Motion Transportation Study, a household travel diary survey conducted for MCCOG in the spring of 2014. As is standard practice, in the 2014 study all participating households were asked their willingness to be contacted to participate in future transportation studies for the region. By re-inviting these “volunteer” households it would ultimately be possible to compare data from the household’s 2014 one-day travel diary completed via telephone or web to data from the household’s 2015 seven-day travel diary completed via a smartphone-based GPS app.

The project began in late fall 2014 and led to data collection in the spring of 2015. The data collection period was planned to have similar travel dates in both

spring 2014 and spring 2015, for data comparison purposes. Following the approximately five-month planning, testing, and app development timeframe, the rMove™ app was submitted to the Android™ and iOS™ app stores in very early April 2015. In late March 2015, households were invited by email to complete a web-based recruitment survey that was intentionally highly comparable to the recruitment questionnaire from the previous year. Once the app was published in both the Android™ and iOS™ stores in late April, recruited households were sent instructions for how to download rMove. The seven-day travel period occurred from May 5-11, 2015, with participants receiving reminders and encouragement throughout the process. About a week after the assigned travel period concluded, incentives were issued and a follow-up survey was sent to those who participated, those who recruited but did not download, and those who did not recruit, with a goal of determining user experience and reasons for non-participation.

Because key goals of the project included both obtaining data collection for a seven-day period and reducing respondent burden, the project did not ask participating households to participate by multiple means. Thus, households were not asked to complete parallel paper surveys or online surveys. Instead, the project focused on the rMove smartphone app passively collecting travel data such as the coordinates, timestamps, speed, and route of all travel during the seven-day period. Within the app, all other essential household travel survey questions were asked directly of the user. After stopping at a location, the app asked a short set of survey questions such as trip purpose, travel party makeup, travel mode, specific household vehicle (if auto), and travel costs. At midnight each night, a short daily survey also appeared to participants. Again, the goal was to focus on testing the future paradigm in which the entire travel survey experience occurs on the smartphone. This is in support of the theory that having respondents answer questions in real-time as trips occur and for a longer period of time will lead to high data quality.

SMARTPHONE APP DESIGN, DEVELOPMENT, AND CORE FEATURES

RSG has designed and developed several native mobile data collection platforms and authored dozens of online household travel surveys. This experience

was combined to meet the ITM study goals. The features of the rMove smartphone app focused on a few key areas; data quality, preserving battery life, and user experience. Development of rMove—to fulfill the ITM study goals—occurred from late fall 2014 to March 2015. After several iterations of testing and improvements among the project team and select external reviewers, rMove was made available in Google Play™ and iTunes™ in early April 2015. A required support website (<http://rmove.rsginc.com>) was included in both store listings to provide users of the app with contact information, FAQs, and user terms and conditions.

The mobile application ran natively on iOS™ 7.0 or later and Android™ 4.0 or later. Building for iOS™ proved slightly simpler than Android™, since the Android™ device ecosystem is much larger than iOS™ with thousands of unique models running Google's™ open OS globally. This is a well-understood challenge when developing apps for Android™ due to more variation in the manufacturer hardware and the resulting Android™ OS fragmentation. The team iterated on the building the application with structured software development periods, testing cycles, bug reporting, and then subsequent development cycles. An accompanying cloud service for the app's collected data was constructed with all open-source technologies, including a PostgreSQL database. In addition to the required technology coupling this provided to the rMove app, it also was a crucial study administration tool managing all study participants and household-level data, tracking missed survey responses, and displaying participant travel. Additional details and features of rMove included:

- 1)** Multiple smartphone sensors (GPS, compass, Wi-Fi, accelerometer) were utilized to automatically detect trip starts and trip ends without needing user intervention. While moving, the app also automatically recorded trip path, trip duration, and travel speed. Proprietary technology was also implemented to optimize battery life and minimize battery recharge needs, though this remains a challenge since GPS data collection is intensive for smartphones.
- 2)** To achieve a high quality user experience, the team wanted as little user intervention as necessary. To achieve this, the app automatically launched when the phone restarted and ran silently in the background. This means users did not need to start the app or select a field for data collection to occur. The app also automatically monitored the smartphone's own

hardware so notifications were enabled to alert users to reactivate (or turn back on) GPS/Wi-Fi if they had been turned off.

3) The rMove app was customized for each user. Participants used the same unique authorization code throughout the project; for the recruitment survey, upon download and launch of the app, and for the follow-up survey. For tracking purposes, households were given the same authorization code that they had used in the 2014 survey the previous year.

4) The design of the app's user interface was based on established key features for online household travel surveys including a trip roster, mapping the origin, path, and destination of travel, and then providing a mobile-optimized survey to capture purpose, mode, and travel party details as appropriate. The in-app surveys and survey questions enacted many best practices from online surveys. For example, once the user was stationary at a location for five minutes (and stopped moving), the in-app trip survey appeared on the app home screen and the respondent was alerted that they had a trip survey to answer. For each trip survey, respondents were able to select which household members and which household vehicle were used on the trip. The answer choices for these questions were based on the information provided by the household in the recruitment survey. Each trip survey also had real-time validation based on the user's response. For example, if the user reported parking at the end of their trip, they were asked about parking costs.

5) All collected data was automatically transferred to the server after travel was completed or a survey was completed (assuming a mobile network data connection or Wi-Fi connection). This aimed to minimize data loss in the event of a lost or damaged phone and also meant the user did not have to select a button or transfer data by their own initiative. As a best practice, all personally identifiable information was encrypted when transferring data to the server.

6) Lastly, adaptive activity detection was implemented where the app learned or inferred trip survey answers based on the user's previously answered trip surveys. For example, if the user made the same home-to-work trip, the trip survey answers were pre-populated. Users could then confirm the pre-populated answers (lower burden) or change the answers.

MATERIALS AND METHODS

Recruitment Survey

The invitation pool for ITM consisted of participants from the 2014 Heartland in Motion Transportation Study, separately conducted for MCCOG in the spring of 2014. In the 2014 study, 1,781 households indicated that they were willing to be contacted about future MCCOG studies, and of those, 1,427 provided a contact email address. These 1,427 households comprised the invitation pool for the ITM study, outwardly referred to as the "2015 Heartland in Motion Transportation Study" to ensure brand continuity for the study participants.

In order to determine which households were eligible to participate using rMove, the recruitment questionnaire collected updated household demographics and smartphone information. This questionnaire intentionally closely mirrored the 2014 Heartland in Motion recruit questionnaire, and was therefore similar to a standard recruitment survey for a household travel diary project.

Variables collected in the recruitment survey included the following:

- Household vehicle count and details (make, model, year)
- Household size
- Household member details (age, gender, employment, education, smartphone ownership, licensed driver status, vehicle most often used)
- Housing type and tenure
- Home location
- Household income
- Contact information for members age 16 or older

Response to Recruitment

The recruitment survey was open for ten days in late March 2015. Email invitations were sent to the pool of 1,427 households. Responses to the recruitment survey, specifically smartphone ownership details, determined the eligibility of a household to be invited to download rMove and participate in the study. Only Android™ and iOS™ smartphones were eligible for the study, and those persons that did not have a smartphone or those that owned a Blackberry or Windows smartphone were not eligible for the study.

In order to facilitate a larger sample size, if at least one household member had an eligible smartphone, then the person (and therefore their household) was invited to participate. In other words, it was not a requirement that all adults within a household own a qualifying

smartphone. Within each household, only members with an eligible smartphone were asked to download rMove and participate for the week of data collection. In total, 256 persons with Android™ phones and 256 persons with iPhones recruited into the study.

Among the 256 persons with an iPhone were 34 people with older phones produced mid-2010 or earlier and therefore lacking the requisite sensors for optimal use of rMove. These individuals with older Apple™ phones were not invited to the study. In the end, 222 iPhone users were invited. Because there are numerous Android™ smartphones (particularly when compared to iPhone models), the project team decided to invite all Android™ owners to download rMove and participate in the study for the week of assigned travel. (To further improve future studies, results from all participants are being assessed to determine whether specific older Android™ phone models provided data of lower quality.)

At the conclusion of the recruitment process, 478 people from 288 households were invited to download rMove. Selected participants represent 75% of the households that completed the recruit survey and 20% of the households that received the initial invitation to take the recruit survey. Of the eligible participants, those in 2-person households made up 36% of participants while 12% were in 1-person households. Over half of eligible participants were in 3-person households or larger.

rMove Invitation Dissemination

RSG sent an e-mail to the 478 invited participants asking them to download rMove to their smartphone. The invitation was sent on April 29, 2015 and included participation information such as the authentication code, the first day of assigned travel, the last day of assigned travel, download instructions for both iOS™ and Android™, and the rMove website link for FAQs and other information.

Following the initial invitation e-mail on April 29, reminders to download rMove were sent to those who had not yet downloaded the app on May 1, May 3, and May 4; these reminders were sent until assigned travel dates began on May 5. On the day before the first travel date (May 4), those who had already downloaded rMove received a brief reminder e-mail that surveys about trips would start showing up the next day.

On May 5, 2015 (the first travel date), 275 participants in 186 households had downloaded rMove, representing

57% of people and 65% of households invited to download rMove. Over the following six days of the travel study, that number rose to 295 participants in 200 households, indicating that 23 participants downloaded rMove after the travel period officially began on May 5, 2015. Overall, the study included 168 households in which every eligible member downloaded rMove and 32 households in which some but not all eligible household members downloaded rMove.

Of the 295 participants in 200 households who downloaded rMove, just more than half of these participants used Android™ devices (154 participants, 52%), with the remaining 141 (48%) using iOS™ devices. It is worth noting that these percentages are similar to the recruitment ratio and likely indicate that Android™ and iOS™ users had similar experiences downloading and launching rMove.

Recruitment Demographics

Household demographics from the 2014 study were compared to the demographics of those who downloaded rMove in 2015. The demographics for households who downloaded rMove represent households where at least one person downloaded the app, and is therefore based on 528 participants (295 of which were eligible rMove participants) in 200 households. Demographics from the 2014 study are based upon the final study sample of 1,926 households. A chi-squared test of proportions was conducted for the 2014 and 2015 data. It was expected that, due to differences in selection process, the pool of 2014 study participants would not have identical characteristics as the pool of 2015 study participants.

One- and two-person households represented a higher percentage of the sample in the 2014 HTS compared to the sample who downloaded rMove in 2015 ($p < .0001$). One possibility for this difference is that senior adults are more likely to live in one- or two-person households and are less likely to own smartphones. Similarly, the person-level age results show that people ages 65 and older have lower representation in the sample of 2015 participants who downloaded rMove than in the 2014 sample ($p < .0001$) while people 25-44 years old make up a higher percentage of the sample in the 2015 rMove download pool compared to the 2014 HTS sample ($p < .0001$). This is of interest, because traditional approaches to household travel surveys tend to have over-representation among older ages (and smaller household sizes) and lower-than-desired representation among younger, working age groups.

In 2014, households with annual incomes below \$50,000 comprised a larger portion of the sample than in 2015 ($p < .0001$). Additionally, people in households that recruited in 2015 are more likely to have bachelor's or graduate degrees than those in the 2014 HTS ($p < .0001$). These demographic differences between the HTS sample and the rMove pool reflect trends reported in the 2015 U.S. Smartphone Use study conducted by Pew Research Center, which found that adults age 18-50 with higher education and income levels have the highest smartphone ownership rates (8).

SEVEN-DAY TRAVEL DIARY

In addition to collecting location data from devices, rMove collected user-provided responses through two types of surveys: trip surveys (for each trip made) and daily summary surveys (one survey per day).

Trip surveys appeared in rMove shortly after the app sensed that a trip had been completed. A notification popped up letting the user know each time a survey appeared in rMove. Surveys were labeled with the trip timestamp, and once the survey was pressed, a map of the trip was shown, followed by trip-level questions. Once travel mode was chosen, additional questions (as relevant) were asked. Trip survey questions included:

- Trip purpose
- Trip party
 - Selection of household members, listed by name provided in recruit survey
 - Number of non-household members
- Detailed trip mode
- Auto details, if auto mode:
 - Selection of household vehicle used, listed by make/model
 - Type of parking
 - Parking payment
- Transit fare payment amount and method, if transit
- Taxi fare payment amount and method, if taxi

rMove recognized “repeat” trips using an algorithm to see if the start and end location closely matched the start and end location from a previous trip in the study period. When this type of trip was recognized, rMove inferred the trip details and asked the user to confirm or change the survey answers. These trip surveys were called “matched trip” surveys.

“Daily summary” surveys appeared in the app once per day at midnight after the travel day was complete. If the user traveled during the travel day, the daily summary asked one question about how many trips (if

any) rMove missed during the travel day. If the person's phone did not record any travel for the travel day, the daily summary survey first asked if rMove missed any trips, and if no missed trips were reported, the survey asked why the user did not travel that day.

Throughout the study period, several lines of communication existed between participants and RSG: participants could email the project email address, submit feedback through the rMove app, and RSG could send outgoing email communication to users when necessary. Participants submitted 47 comments through the feedback button within the rMove app and sent 71 emails related to any aspect of the study. These numbers include cases where multiple comments and/or emails were submitted by the same participant, so they are not reflective of the total number of participants who submitted feedback or sent emails. Questions about when to uninstall the app and whether the participant qualified for the gift card incentive were the most common type of communication received, followed by technical support questions (such as lack of clarity for how to close out of the app).

Outbound communication with participants—other than responses to incoming communication—was primarily intended to avoid participant attrition while not being so frequent as to potentially annoy participants. Outbound e-mails were sent to participants in the following situations:

- Their smartphone had not sent any trip data to the server
- Trip surveys had not been answered recently and were “queuing up”
- After the end of the assigned travel date period, not all in-app surveys had been answered
- All surveys were complete and RSG confirmed that the user could uninstall and would receive their incentive shortly

Trip Survey Completion

Overall, 240 participants fully completed (by answering every single question) every survey in rMove for all seven assigned travel days. At the household level, 138 households fully completed the study (prior to data cleaning), accounting for 82% of households where every participant downloaded rMove and 89% of all people who downloaded rMove.

The clear majority (89%) of participants completed all trip surveys in the app, and only a small percentage (5.6%) completed less than two-thirds of their



rMove surveys. This statistic of nearly 90% of people answering every single trip survey for seven consecutive days is encouraging for the viability of longer data collection periods. In many ways, a smartphone-based survey faces the same primary challenge that telephone or web surveys face; the biggest hurdle is the initial step to get the household to participate. By comparison and recognizing a somewhat different selection process, the 2014 study sample had an overall 81% conversion rate, whereby just over 4 out of 5 households that recruited went on to fully complete the household travel diary.

Trip Survey Timestamps

For trips where surveys were completed by the user, surveys were generally answered either within a few hours of the trip or after the participant’s travel was appeared to be done for the day. Figure 1 shows the hour of the timestamp for trip ends and survey completions for all trips that had surveys answered and were not reported as “not moving” errors. While trip totals peaked during the morning, noon, and evening rush hours, the highest rates of survey completion occurred between 7:00 p.m. and 11:00 p.m.

Although the survey completion peaked in the evening, 40% of surveys were completed within one hour of the trip ending and 71% of surveys were completed within five hours of the trip ending. The median time between trips and surveys was 1.71 hours, or 102 minutes. Seventeen percent (17%) of surveys were completed within 10 minutes of the trip end.

In summary, the high retention rate and the short period of time that elapsed for most trips before survey completion are positive indicators that the goals of the study were at least partially met. This indicates the potential for additional burden reduction in the future as rMove’s functionality improves and

as people obtain ever newer, advanced smartphones. Additionally, the short period of time between most trips ending and trip survey completion indicates that the trip details reported by the participant are likely to be more accurate. This time period compares favorably to the latency in traditional online and phone surveys, where typically the project team sees about 85% of households completing their travel diary within three days after the assigned travel date.

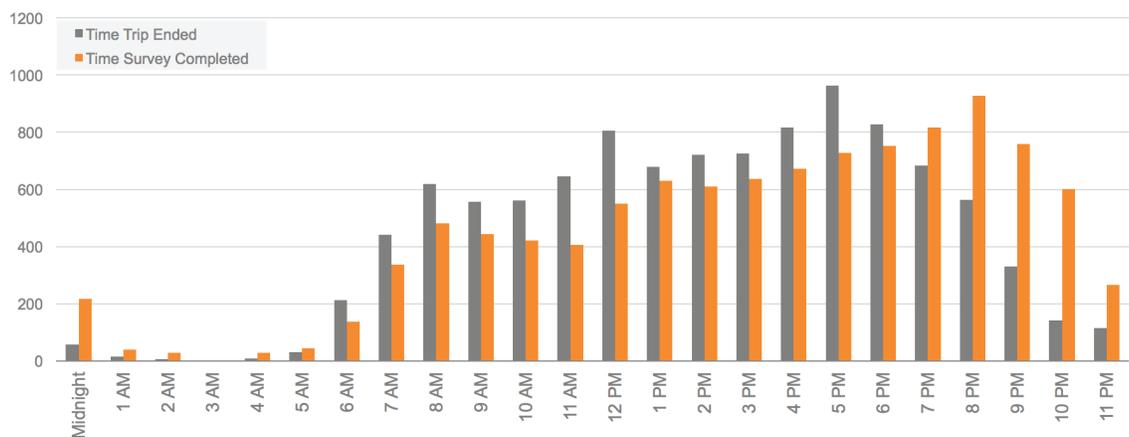
Matched Surveys

The “repeat trips” feature, in which rMove recognized matched trips and inferred survey answers, aimed to decrease burden for users who frequently traveled between the same locations (such as a trip from home to work). Overall, rMove recognized 951 “matched” trips. Of these, users retained 641 of the inferred surveys without changing the answers (68%), while 302 (32%) of the inferred surveys had at least one answer choice edited by the user. The fairly high level of “correct” survey inferences indicates a moderate success in burden reduction, although the overall number of trips that were recognized as “matching” trips is only 8.4% of overall trips where users filled out surveys. Therefore, further opportunity exists to improve this matching experience for users.

Preliminary Trip Totals

At this time, the final dataset has not quite completed quality control, so preliminary results are provided. At the conclusion of data collection and prior to any review or data cleaning, there were 10,196 trip surveys that users had answered over the seven day period. The server also had a total of 3,443 trips that were unanswered trip surveys, for a total of 13,639 trips for review and quality control. All trips were individually reviewed using a web dashboard that visually displayed every detail (survey questions, trip trace, and

**FIGURE 1:
TRIP ENDS
AND TRIP
SURVEY
COMPLETIONS
BY HOUR
TIMESTAMP**



meta-data such as timestamps). As part of the review process, a cross-check was also used to determine if the participant had reported an error as part of the trip survey. Data cleaning then involved merging and splitting trips, as well as removing spurious trips and other quality control review.

Following data cleaning and review, the dataset retained 191 unique households and 283 adults who sent any amount of data to rMove from their smartphone (whether they completed all their surveys or not). Moreover, the cleaned dataset included 9,417 trip surveys that users had answered over the seven day period, reflecting a reasonable decrease in answered trip surveys due to trip merging and removal of spurious trips. The number of unanswered trip surveys decreased by two-thirds to a total of 1,180 trips in the dataset without survey answers. This decrease of 2,263 trips included 1,892 trips where both the user reported a spurious trip and review confirmed the spurious trip. When considering these 1,892 trips across seven days for almost three hundred participants it yields an average of just under 1 spurious trip per day for participants. The remaining 371 unanswered trips that were removed during data cleaning were primarily spurious trips that the server captured but rMove did not display to the user. In many ways, this result is what the project team had intentionally aimed for in the sense that having slightly too many false positive trips in the dataset was preferable to potentially erring toward missing trips and having the app not capture them.

Among the daily surveys, 97% were completed by participants for a total of 1,830 complete daily surveys. The first question of the daily survey asked the user to report how many trips rMove had missed that day. Reasons for that rMove may have missed recording a trip include both user error (forgot to take smartphone with them) and technology error (where rMove didn't record a trip despite the person making one). Among the completed daily surveys, 82% reported that rMove had not missed recording any trips and fully captured their travel on the given day. An additional 13% of daily surveys indicated that rMove had missed 1 or 2 trips during the day, while 1.7% of daily surveys indicated that 5 or more trips had been missed on a given day. Of the daily summary surveys completed by users, 6.8% were reported as days where no travel occurred and on the first day of travel (a Tuesday), 5.1% of participants reported the day was a "no travel" day.

When comparing results across years, the primary trip purposes reported in 2015 were home (26%) and work (10%), compared to 30% and 11% of trips in the 2014 study. Drop-off/pick-up trips were reported at a higher rate in the 2015 smartphone-based GPS study than in 2014, 7% of trips compared to 3% in 2014. This is consistent with the belief that GPS studies capture the trips that are more frequently forgotten such as drop-off or pick-up trips.

Combined auto modes represented the highest share of trips for both the 2015 study and the 2014 study (90% compared to 94%, respectively). In 2015, walking trips accounted for 4% of trips captured via rMove, while in 2014 walking trips were 2.4% of trips – preliminarily indicating that shorter walking trips were indeed captured more often by the smartphone-based GPS method compared to the 2014 study using a telephone and web-based travel diary.

FOLLOW-UP SURVEY

Overview

The project team issued a follow-up survey on May 18, 2015 to invited participants shortly after their travel period ended. The follow-up survey intended to obtain feedback on user experience with rMove, as well as to understand the reasons why some invited participants did not recruit or download rMove. All questions in the follow-up survey were optional, and no additional incentive was offered for participation. The follow-up survey final response was as follows:

- 105 respondents who had downloaded rMove
- 20 people who were invited to download rMove but did not download
- 66 people who were invited to the recruit survey but did not recruit

Follow-up Survey Results

When comparing the experience of using rMove in 2015 to the online/phone-based survey experience in 2014, respondents generally favored the experience of participating via rMove. Eighty-seven percent (87%) of respondents agreed that participating in 2015 was easy, compared to 66% of respondents who agreed that participating in 2014 was easy. Similarly, 66% agreed that participating in 2015 was more fun than in 2014. While a slight majority of respondents (52%) agreed that they spent less time participating in 2015 than in 2014, 23% disagreed that they spent less time, which was the highest overall disagreement in any

category. However, this is likely partially attributed to the fact that 2015 encompassed a seven-day travel period, compared to a one-day travel period in 2014.

The follow-up survey asked a set of agree/disagree questions about various aspects of user experience. Battery-related issues were the most often agreed or strongly agreed with statements – just over half (56%) of participants agreed that they charged their smartphone more frequently when using rMove. Close to a third (31%) agreed that they occasionally turned off GPS or Wi-Fi to save battery over the course of the seven days. However, only a small percentage (6%) agreed that they turned off GPS or Wi-Fi to protect their privacy over the seven days, which could indicate a lower level of concern regarding location privacy.

Results of ease of use and user experience questions were compared between age groups (under 45 vs. 45 and older) and smartphone type (Android™ vs. iOS™). However, few significant correlations were discovered. The lack of significant results is likely due to the small overall sample size and high degrees of freedom in the agree/disagree rating questions.

Battery depletion was recounted most frequently in the open-ended questions, when participants responded to “what can be improved” (20% of the 91 people who answered the question). Spurious trips were another issue commonly cited (24%). Ease of use was the most common “best feature” response (37% of 98 people who answered), as well as accuracy of trips captured (17%).

The follow-up survey also asked participants when they answered trip and daily summary surveys, in “select all that apply” questions. The majority of respondents (62%) said that they answered trip surveys right after they appeared in the app, and 60% of respondents said they answered several surveys at once. A quarter of respondents said they answered trip surveys when waiting in line or during other “down times”, and 21% reported answering trip surveys all at once at the end of the day. Only one respondent (1%) said they answered trip surveys after several days. Responses to this question match the trip completion vs. survey completion trends observed in the data. With regard to daily summary surveys, the vast majority (98%) reported answering these surveys in the morning on the following day when they saw the survey in the app.

Reasons for Non-Participation

The survey asked respondents who did not recruit or download rMove two questions: one “select all that apply” question about the reason or reasons they did not participate, and one open-ended question to provide comments about why they did not participate. The most frequently selected reason for not participating is “other reason”, which respondents were required to clarify in a text box. The majority of “other” reasons provided were related to being out of town on the travel dates or no longer living in the study area. The second most often selected reason was “does not own a smartphone”, which could mean that they did not recruit or participate for this reason.

CONCLUSIONS

This paper details the design, approach, and preliminary results of a smartphone-based seven day household travel diary conducted in Indiana for the Madison County Council of Governments (MCCOG) in Anderson, Indiana and the Federal Highway Administration (FHWA) Office of Planning and Office of Transportation Policy Studies. While these projects are increasingly conducted internationally, very few have been conducted in the U.S. A primary goal of the research project was to fully test the viability of longer-periods of data collection using a smartphone-based GPS app to conduct a household travel diary over seven days. A second primary goal of the project was to employ as many innovative technological features as possible in the smartphone app’s passive data collection and active survey questions in order to further combat respondent burden and encourage sustained active participation. These project goals acknowledge the four trends of smartphone sensor technology rapid improvements, smartphone ownership rate rapid increases, continued decreases in response rates to traditional survey methods (paper, telephone, and web) which leads to higher project costs, and the transportation modelling community’s growing desire for ever more detailed, longitudinal data. Participation in a seven-day smartphone-based HTS proved successful on numerous fronts. Almost 90% of participants were active participants answering all surveys over the full seven day period and almost three-quarters (71%) of trip surveys were answered within five hours of the trip occurring. Indeed, 17% of trip surveys were completed within 10 minutes of the survey notification appearing to the participant. As part of the follow-up survey, 87% rated their 2015 survey experience as easy, while

66% rated their 2015 survey experience as more fun than their 2014 survey experience. Indeed, 52% rated their 2015 survey experience as requiring less time than in 2014. This despite the fact that only a one-day travel diary was required in 2014, while the 2015 travel diary was for a seven-day period. These results point to at least a perception of reduced burden among participants and to a potential improved accuracy of responses, given the small amount of time that elapsed between travel and survey completion.

As with any research project, it is essential to assess potential improvements. Areas of focus for future improvements include firstly focusing on the quality and completeness of data by further examining options for limiting battery drain, decreasing rMove's creation of spurious trips, and providing an improved means to report any missed trips (e.g. forgetting to take the smartphone on a specific trip). Ease of use will also remain a priority for ensuring actively engaged participants across regions and demographics, as well as for the researchers, modelers, and planners interested in utilizing the resulting datasets.

Further analyses will prove useful on a number of fronts, specifically comparisons between the 2014 and 2015 datasets for this project, as well as comparing this project to a second smartphone-based GPS project that collected almost 9,000 trips in May 2015 in the Seattle region using the same approach. Additionally, it should be noted that many lessons from this project are currently being applied in an updated version of rMove that is being fielded in fall 2015 in the Columbus, Ohio region.

For several years now, the travel survey community has been primed for a period of change and improvement. We remain optimistic that these approaches will lead to superior data for modeling, a noticeable improvement in participant burden, ultimately lower project costs (due to skyrocketing smartphone ownership rates), and improved understandings of travel behavior.

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