REPORT: 2015 HOUSEHOLD TRAVEL SURVEY

PUGET SOUND REGIONAL TRAVEL STUDY

RSG
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PREPARED FOR:
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1.0 INTRODUCTION

1.1 | STUDY OVERVIEW

In spring 2014, PSRC commenced the Puget Sound Regional Travel Study. The study began with a Household Travel Study (HTS) to collect current information about household- and person-level travel patterns for residents throughout the PSRC four-county region. PSRC will use the results of this study to update the region's travel demand and land-use models and to calibrate local traffic and travel models. The study can also help PSRC and its regional partners develop plans that accommodate the diverse travel needs and preferences of residents. Additionally, the study results can potentially be compared to the results of previous studies conducted in 1999 and 2006 to understand changing trends in travel behavior over time.

The primary goals of the study were to collect complete travel information for a 24-hour weekday period from a representative sample of households (HHs) from the Puget Sound region. The study also sought to collect a sufficient sample of HHs that—while more difficult to reach—are important to transportation policies and plans. This includes (but is not limited to) low-income HHs, low- or no-vehicle HHs, HHs in policy-relevant neighborhoods (such as regional growth or transit-oriented development areas), and HHs that frequently make transit or non-motorized trips. The study collected information from HHs across the four counties (i.e., King, Kitsap, Pierce, and Snohomish) in the PSRC region, including HHs from 82 cities, towns, and rural areas (see Figure 1).

The primary goals of the study were to collect complete travel information for a 24-hour weekday period from a representative sample of households (HHs) from the Puget Sound region.

The results of the spring 2014 HH data collection effort were documented in a report that was delivered to PSRC in 2014 and posted on the PSRC website. In fall 2014, a person-based travel diary survey that was similar to the HTS was administered to colleges and universities in the Puget Sound region. The college survey captured travel of university students, a population that is often insufficiently represented in a regular HTSs. Data and documentation for the college survey were delivered to PSRC in January 2015.

Finally, in spring 2015, a second HTS data collection was conducted as part of an effort to:

- Collect cross-sectional data more frequently;
- Obtain panel/longitudinal data from HHs that had completed the 2014 survey; and
- Conduct a small sample smartphone GPS survey to assess the feasibility of 100% (or a larger percentage of sample) smartphone-based data collection for the future

This report presents the methodology and results of the spring 2015 cross-sectional and panel HTS data collection effort.

FIGURE 1: PUGET SOUND REGIONAL TRAVEL STUDY AREA (FROM PSRC'S WEBSITE)

1.2 | STUDY OBJECTIVES

The following key objectives were identified in the Scope of Work:

- Build better urban system models (land-use and travel models) that predict the impact of changes (e.g., land uses, policies, demographic or economic standing, etc.) on travel behavior.
- Develop a more complete assessment of current travel times and costs, both actual and perceived, facing users in the region.
- Improve the "predictive" ability of planners in evaluating the impacts of future actions on travel patterns and facility usage.
- Support both long- (such as HH location choice) and short-run (such as destination and mode) choice models.
- Establish a continuous survey program for ongoing collection of travel behavior.

1.3 | SPRING 2014 DATA COLLECTION REFRESHER

The initial goal for the spring 2014 data collection was to collect data from a minimum of 4,700 HHs in the region. In addition to the PSRC-funded HHs, the City of Bellevue funded collection of 300 additional HHs, and the City of Seattle funded collection of 150 additional HHs. Data collection took place between April 8 and June 12, 2014. Table 1 provides the spring 2014 data collection numbers.

TABLE 1: SPRING 2014 SURVEY COMPLETION OVERVIEW

SAMPLE AREA	TARGET HHs	RECRUITED	RETRIEVED	RETENTION RATE	PERCENTAGE OF TARGET
King County	2,625	3,615	2,993	82.8%	114%
Kitsap County	311	442	369	83.5%	118%
Pierce County	926	1,247	1,020	81.8%	111%
Snohomish County	756	984	798	81.0%	105%
PSRC Subtotal	4,618	6,288	5,180	82.4%	112%
City of Bellevue Supplement	299	403	337	83.6%	113%
City of Seattle Supplement	150	670	577	86.1%	385%
Total	**5,067**	**7,361**	**6,094***	**82.8%**	**120%**

**Number of HHs delivered to PSRC in August 2014. Includes pilot data.*

1.4 | FALL 2014 COLLEGE DATA COLLECTION OVERVIEW

The college survey was conducted to capture travel of university students, who are unlikely to be sufficiently represented in regular HTSs. This under-representation occurs because students traditionally comprise a hard-to-reach population of young, transient residents who often lack a permanent address or landline phone. To complement the HTS sample with data from the region's college population, PSRC conducted the Puget Sound College Survey in fall 2014, surveying students, faculty, and staff at Bellevue College, Everett Community College, Green River Community College, Seattle Colleges, and the University of Washington.

The travel diary format of the Puget Sound College Survey closely resembled that of the 2014 HTS. The primary difference between the College Study and the HTS was that respondents to the College Study answered only for themselves in the survey, rather than reporting travel at a HH level. Additionally, rather than recording their travel on an assigned travel date, respondents of the College Study answered travel details about the most recent weekday.

Undergraduate and graduate students from all aforementioned colleges were invited, and Everett Community College, Green River Community College, and Seattle Colleges also invited their faculty and staff. The survey was designed to accommodate anyone affiliated with these institutions, including all full- or part-time students, faculty, and staff. After administering the Puget Sound College Survey for approximately one month in fall 2014, data were cleaned and processed, resulting in a final dataset of 4,454, of which 59% were undergraduate students, 22% graduate students, and 13% faculty or staff.

1.5 | SPRING 2015 DATA COLLECTION OVERVIEW

In spring 2015, 2,430 additional HHs were surveyed using comparable methodology and materials as in 2014. The booster sample of 2,430 HHs included 821 cross-sectional HHs and a panel of 1,609 HHs that participated in the 2014 survey. In addition, a subsample of HHs (also drawn from the 2014 survey) used rMove™, a smartphone-based application, to collect GPS paths. Table 2 provides an overview of the cross-sectional administration by county, and Table 3 summarizes the panel administration by criteria of reinvitation to take the survey.

TABLE 2: SPRING 2015 SURVEY COMPLETION—CROSS-SECTIONAL HHs

SAMPLE AREA	TARGET HHs	RECRUITED	RETRIEVED	RETENTION RATE	PERCENTAGE OF TARGET	RESPONSE RATE
King County	351	455	371	81.5%	106%	7.9%
Kitsap County	39	61	47	77.0%	121%	6.5%
Pierce County	115	122	97	79.5%	84%	4.2%
Snohomish County	95	133	104	78.2%	109%	5.9%
PSRC Subtotal	600	771	619	80.3%	103%	6.5%
City of Tacoma Supplement	125	291	202	69.4%	162%	4.9%
Total	**725**	**1,062**	**821***	**77.3%**	**113%**	**6.0%**

**Number of HHs delivered to PSRC in July 2015.*

TABLE 3: SPRING 2015 SURVEY COMPLETION—PANEL HHs

PANEL TYPE	RECRUITED	RETRIEVED	RETENTION RATE	RESPONSE RATE
Rode revised bus routes	88	78	88.6%	57.4%
In block group of revised bus route riders	376	333	88.6%	54.9%
Commutes to downtown	230	206	89.6%	55.8%
Lives downtown	118	110	93.2%	53.4%
Randomly sampled	970	882	90.9%	55.5%
Total	**1,782**	**1,609***	**90.3%**	**55.4%**

**Number of HHs delivered to PSRC in July 2015.*

2.0 2015 HTS SURVEY SAMPLING

The 2015 PSRC HTS sampling plan had two primary sample types:

1. Cross-sectional: New HHs (HHs not previously invited to the 2014 study).
2. Panel: HHs that participated in the 2014 HTS and agreed to participate again.

2.1 | 2015 HTS CROSS-SECTIONAL SAMPLE METHOD

The primary goal of the 2015 HTS cross-sectional sample plan was the same as in 2014: To yield data that reflect the demographic and travel behavior characteristics of study area residents in order to ensure that representative parameters can be generated for the PSRC travel demand model. Therefore, the 2014 sampling plan was largely retained in 2015. The 2014 sampling plan also utilized 2014 response rates (RRs) to inform estimates for 2015 and emphasized five Regional Growth Centers (RGCs) and the 2014 landslide region, which were geographies that PSRC prioritized.

The 2015 sampling plan encompassed the following:

- Used American Community Survey (ACS) HH income estimates at the block group level to estimate RRs.
- Leveraged 2014 RRs for refined response rate estimation (Table 4).
- Was monitored at:
  - The 2014 sample segment levels *and* the county level (four counties in the PSRC region), resulting in 24 total monitoring cells (segment and county).
- Retained the ratio of oversample HHs to proportional from 2014.
- Up-sampled the five RGCs shown in Table 4 by reducing the estimated RRs, thus sending more invites to addresses in block groups corresponding to these RGCs:
  - Redmond Downtown
  - Everett
  - Silverdale
  - Bremerton
  - Renton
- Included block groups in the 2014 landslide area in Snohomish County that were removed from the 2014 mailings.

Table 4 lists the 2014 sample segments with the expected and actual RRs for the PSRC sample in 2014. Table 4 also includes the total number of HHs completing the survey and the corresponding actual RR by segment and county in 2014. The by-segment-by-county RRs from 2014 were leveraged to update the expected RRs for the 2015 HTS cross-sectional sample.

TABLE 4: 2014 EXPECTED AND ACTUAL RRs, BY SEGMENT AND COUNTY

SEGMENT	EXPECTED RR	ACTUAL RR	KING	KITSAP	PIERCE	SNOHOMISH
Regular Higher Income	7.0%	7.2%	930 (8.1%)	104 (7.3%)	393 (6%)	342 (6.8%)
Regular Medium Income	5.5%	5.9%	339 (6.3%)	82 (5.7%)	222 (5.1%)	199 (6%)
Regular Lower Income	4.0%	4.7%	61 (4.3%)	10 (4.2%)	38 (4.2%)	34 (6.1%)
Oversample Higher Income	7.0%	9.2%	546 (10.4%)	57 (8.6%)	10 (6.3%)	25 (4.1%)
Oversample Medium Income	5.5%	7.9%	757 (9.1%)	52 (8.7%)	71 (5.1%)	41 (5.6%)
Oversample Lower Income	4.0%	5.1%	840 (6.3%)	64 (5.6%)	286 (4.1%)	84 (3.4%)

In most cases, the 2015 estimated RR was assigned to the block groups in each county and segment using the Table 5 crossover table. Exceptions were made at the segment level if the number of HHs collected in a given grid was small, and if the observed RR was much higher than the expected RR. For example, because only 34 households fell into the Regular LI Snohomish cell, the anticipated RR in 2015 for the Regular LI Snohomish cell was estimated based on the RR of the Oversample LI Snohomish cell. As such, a 4.0% estimated RR was assigned to Regular LI Snohomish HHs. Additional exceptions were made at the block group level for block groups in the five RGCs selected for up-sampling.

TABLE 5: ESTIMATED 2015 RESPONSE RATE CROSSOVER TABLE

RR RANGE 2014	ESTIMATED RR 2015
8+%	8.5%
6–8%	6.0%
5–6%	5.0%
3–5%	4.0%

The estimated total completes by segment and sample cell for the 2015 PSRC cross-sectional HHs are in Table 6. The target sampling rate, which is higher for oversample segments, is also shown. The target percent of oversampled HHs (HHs obtained beyond proportional sampling) proposed in the 2014 sampling strategy was used when determining the 2015 sampling rate for regular and oversample segments. The summary table does not include additional samples obtained for the City of Tacoma after the PSRC sampling plan had been finalized.

While the majority of the PSRC study area was given a uniform set of sampling targets, the block groups within the City of Tacoma were grouped separately because Tacoma contributed additional funds to increase the total number of samples within their City. However, the Tacoma stratification methods were the same as those of the rest of the region.

TABLE 6: SAMPLE PLAN TARGETS BY SAMPLING SEGMENT

SAMPLE AREA DESCRIPTION	ACS HHs	TARGET SAMPLING RATE	TARGET COMPLETE HHs	EXPECTED RESPONSE RATE	TOTAL INVITATIONS
Regular Higher Income	729,827	0.0299%	218	7.1%	3,164
Regular Medium Income	333,550	0.0299%	100	5.7%	1,829
Regular Lower Income	47,928	0.0299%	14	4.5%	317
Oversample Higher Income	86,190	0.0762%	66	7.7%	900
Oversample Medium Income	102,945	0.0762%	78	7.5%	1,078
Oversample Lower Income	161,663	0.0762%	123	5.0%	2,576
Total	**1,462,103**	**0.0410%**	**600**	**6.3%**	**9,864**

(1) HHs in Census block groups from the ACS 2008–2012 5-year data.

(2) Target Sampling Rate = % of total HHs in sampling area desired in the final dataset.

*(3) Target Complete HHs = Target sampling rate * Total # HHs.*

(4) Total Mailed Invitations = Target Complete HHs / Expected Response Rate. Rounded up to account for bad addresses.

The sampling targets for the counties are summarized in Table 7. Again, the Pierce County sample target and invitation quantities do not include the additional City of Tacoma sample.

TABLE 7: SAMPLE TARGETS BY COUNTY

COUNTY	ACS HHs	TARGET SAMPLING RATE	TARGET COMPLETE HHs	EXPECTED RESPONSE RATE	TOTAL INVITATIONS
King	796,555	0.0441%	351	7.5%	4,895
Kitsap	97,668	0.0399%	39	5.4%	745
Pierce	299,334	0.0384%	115	4.9%	2,412
Snohomish	268,546	0.0350%	94	5.4%	1,812
Total	**1,462,103**	**0.0410%**	**600**	**6.3%**	**9,864**

COUNTY	ACS HHs	TARGET SAMPLING RATE	TARGET COMPLETE HHs	EXPECTED RESPONSE RATE	TOTAL INVITATIONS

(1) HHs in Census block groups from the ACS 2008–2012 5-year data.

(2) Target Sampling Rate = % of total HHs in sampling area desired in the final dataset.

*(3) Target Complete HHs = Target sampling rate * Total # HHs.*

(4) Total Mailed Invitations = Target Complete HHs / Expected Response Rate. Rounded up to account for bad addresses.

CITY OF TACOMA SUPPLEMENTAL SAMPLE

The City of Tacoma contributed additional funds to obtain at least 125 additional HHs from within the City's boundaries. This sample target was not included in the primary cross-sectional stratification calculation due to the timing associated with the contracting process. Although the goal of the City of Tacoma add-on sample was to obtain at least 125 HHs, the same sampling methodology with six segments was applied to facilitate weighting. The overall expected response rate was informed by 2014 RRs within Tacoma, and adjusted downward to a conservative 3% to make sure the sample target would be met.

TABLE 8: TACOMA SAMPLE PLAN TARGETS BY SAMPLING SEGMENT

SAMPLE AREA DESCRIPTION	ACS HHs	TARGET SAMPLING RATE	TARGET COMPLETE HHs	EXPECTED RESPONSE RATE	TOTAL INVITATIONS
Regular Higher Income	22,650	0.1048%	24	4.1%	590
Regular Medium Income	22,454	0.1048%	24	4.0%	585
Regular Lower Income	4,571	0.1048%	5	4.1%	117
Oversample Higher Income	1,111	0.2670%	3	2.6%	115
Oversample Medium Income	4,610	0.2670%	12	2.5%	489
Oversample Lower Income	21,604	0.2670%	58	2.6%	2,304
Total	**77,000**	**0.1623%**	**125**	**3.0%**	**4,200**

(1) HHs in Census block groups from the ACS 2008–2012 5-year data.

(2) Target Sampling Rate = % of total HHs in sampling area desired in the final dataset.

*(3) Target Complete HHs = Target sampling rate * Total # HHs.*

(4) Total Mailed Invitations = Target Complete HHs / Expected Response Rate. Rounded up to account for bad addresses.

2.2 | 2015 HTS PANEL SAMPLE METHOD

The panel sample was drawn from a pool of 5,561 HHs that participated in the 2014 HTS and indicated they were willing to participate in future PSRC studies. The goal of the 2015

HTS panel was to achieve a final sample of 600 HHs, including targeted groups of interest. Based on panel participation rates from previous studies conducted by RSG, a conservative response rate of 20% was initially estimated for the HTS panel, resulting in 3,150 invited HHs (including 150 households added to account for potential household moves). The panel sample selection primarily targeted all HHs with certain travel characteristics identified in their 2014 HTS participation, followed by a random sample to reach 3,150 HHs. The panel samples were selected in the following order:

1. HHs who in 2014 reported using bus routes that were altered or discontinued between spring 2014 and spring 2015.
2. HHs in the same block groups of those HHs who used altered or discontinued bus routes (but for whom did not use the bus routes in the 2014 survey)
3. HHs where at least one worker commuted to the downtown Seattle area in the 2014 survey.[1]
4. HHs who lived in the downtown Seattle area in the 2014 survey.
5. Random sample of HHs in the four-county area for the remainder of invited 2015 panel HHs.

Table 9 shows the number of qualifying HHs in each panel sample group. For example, 148 panel HHs reported using bus routes in 2014 that were since discontinued. Approximately half of the households in the panel sample (46%) were invited based on characteristics of interest, and the remainder were randomly sampled. The final number of HHs invited is somewhat lower, after RSG excluded HHs that were flagged by address-checking software as having moved (mail forwarding in effect), and HHs that PSRC had removed as part of 2014 HTS processing.

TABLE 9: PANEL SAMPLE HHs BY SAMPLE TYPE

PANEL SAMPLE TYPE	HHs INVITED	PERCENTAGE OF HHs INVITED
1. Rode revised bus route	148	4.7%
2. In block group of revised bus route riders	670	21.3%
3. Commutes to downtown Seattle	401	12.7%
4. Lives in downtown Seattle	234	7.4%
5. Randomly sampled	1,697	53.9%

[1] For this study, the downtown area is defined as the following four Regional Growth Centers in Seattle: Seattle CBD, South Lake Union, First Hill/Capitol Hill, and Uptown Queen Anne.

Total	**3,150**	**100.0%**

Below is the list of altered or discontinued King County Metro bus routes, provided to RSG by PSRC in February 2015:

- Route 7
- Route 19
- Route 47
- Route 48
- Route 61
- Route 62
- Route 139
- Route 152
- Route 161
- Route 173
- Route 202
- Route 203
- 205 South Mercer Island to University District
- 209 North Bend to Issaquah TC
- 210 Issaquah TC to Downtown Seattle
- 211 Issaquah Highlands P&R to First Hill
- 213 Mercer Island P&R to Covenant Shores
- 243 Jackson Park to Bellevue
- 250 Overlake TC to Downtown Seattle
- 260 Finn Hill to Downtown Seattle
- 265 Overlake TC to Downtown Seattle to First Hill
- 280 Nt Downtown Seattle to Bellevue TC to South Renton P&R to Tukwila
- 306 Kenmore to Downtown Seattle
- DART 909 Kennydale to Renton TC
- DART 919 Southeast Auburn to Auburn Park & Ride
- DART 927 Downtown Issaquah to Lake Sammamish Plateau
- DART 935 Totem Lake to Kenmore

2.3 | MONITORING DURING DATA COLLECTION

HHs that agreed to participate in the study (i.e., recruited HHs) and reported their travel (i.e., retrieved) were monitored daily using both the real-time tracking website and other means throughout the study to help estimate how closely the final dataset was likely to match the sample targets in each segment. Adjustments were made at the halfway point of the survey period to ensure that the final sampling targets would be met and maximized. Significant sample adjustments made during 2015 data collection are detailed in the following sections.

CROSS-SECTIONAL: ADJUSTMENT DUE TO HIGH RESPONSE

After two weeks of data collection, it was clear the expected final dataset would exceed the sample targets in the King County segments, despite already having increased estimated RRs based on the 2014 data collection. To avoid budget overruns due to the additional incentive payments that would be required, the following adjustments were made:

- The incentive was limited to $10 for all cross-sectional HHs that recruited during the last three weeks of travel dates (i.e., low-income and large [four+ person] HHs were no longer offered $20).
- The call center stopped recruit-calling any/all HHs that lived in King County.

The adjustments made to limit cross-sectional response were also driven by the exceptionally high panel retention (over 50%) in King County.

PANEL: ADJUSTMENT DUE TO HIGH RESPONSE

Panel retention from 2014 far exceeded the 20% estimate in all counties; retention was particularly high in King County. At the two-week data collection mark, the final sample size was estimated at 1,500 to 1,600 HHs (i.e., 2.5 times the target of 600 HHs). Given the attractiveness of HH panel data for modeling and analysis, RSG and PSRC made adjustments to accommodate a final sample size of 1,600 HHs. To avoid budget overruns due to the additional incentive payments that would be required, the following adjustments were made:

- The incentive was limited to $10 for all panel HHs that recruited during the last three weeks of travel dates (i.e., low-income and large [4+ person] HHs were no longer offered $20).

Note that panel HHs were not recruit-called at any point in the 2015 data collection. Final responses and RRs are provided in Section 7.0 of this report.

3.0 2015 HTS QUESTIONNAIRE DESIGN

3.1 | OVERVIEW

Because of the panel data component, the 2015 questionnaire was designed to maintain continuity from 2014; thus, only a few changes were made to the 2014 questionnaire. These changes are described in this section. For a detailed description of the HTS questionnaire, see the 2014 report. The full wording and design of each survey question, along with all survey screenshots, are provided as an appendix item.

The questionnaire comprised three primary sections:

- Recruit survey with information about the HH and its members and vehicles.
- One-day (24-hour) travel diary for each person over age 5 (Retrieval Survey).
- Person-level travel behavior and attitude questions.

3.2 | RECRUIT SURVEY EDITS

There were no major changes to the recruit survey, aside from updating 2013/2014 text to 2014/2015. Incentive criteria for 2015 matched the most recent incentive criteria of the 2014 HTS, which had changed over the course of the survey.

Recruit survey changes included:

- Updates to the vehicle database to include 2015 vehicles;
- HH income question asked about 2014 income, rather than 2013 income;
- Updates to incentive criteria to match most recent criteria from the 2014 study;
- New wording to provide context to HTS panel HHs who were returning to the study; and
- Google Translate bar added, with support for Chinese (Simplified), Filipino, Korean, Russian, Spanish, and Vietnamese (also included as a feature in the retrieval survey).

3.3 | RETRIEVAL SURVEY EDITS

The 2015 trip diary asked a new question to obtain parking location for trips where the respondent parked two or more blocks from the destination. Other than that travel diary edit, the most significant changes to the retrieval survey were in the person-level travel behavior and attitude questions after the travel diary. Several questions about carshare, rideshare, and bikeshare were added, based on questions from the PSRC College Survey. Traveler information questions from 2014 were removed. Several attitudinal questions were added to the end of the survey based on e-mail/phone discussions. Most notably, two questions were added: one about autonomous vehicles, and a second—that the PSRC planning department requested—regarding transit and bicycle infrastructure improvements and their impact on traveler behavior. A full list of changes is below.

TRAVEL DIARY CHANGES

- Modest edits to allow for clearer wording for proxy respondents.
- For bike trips, added "did you use a bikeshare bike" on a bike trip (identical to College diary survey and similar to taxi trips).
- Question added: Parking location for trips where parked 2+ blocks from destination.

AFTER-DIARY QUESTION CHANGES

- Fare payment question and options edited (based on "Other" responses from 2014).
- Question added: Typical commute mode.
- Question added: Carshare membership (from 2014 College diary).
- Question added: Pronto Cycle Share membership/knowledge (from 2014 College diary).
- Question added: Carshare/rideshare frequency (from 2014 College diary).
- Logic added to work commute questions (based on feedback from 2014 respondents).
- Text added to commuter benefit question (based on feedback from 2014 respondents).
- Questions added: Work parking location geocoder if respondent did not at their work location.
- Questions removed: Traveler information questions—four total.
- Questions added: Autonomous vehicle attitudinal questions—two total.
- Question removed: Walk/bike/transit more often (replaced with new questions).
- Question added: Likelihood of taking transit given improvements (per Planning Dept. request).
- Question added: Likelihood of biking given improvements (per Planning Dept. request).
- Slight text edit on alternative commuting mode question.
- Question added: Telework likelihood if offered (per Planning Dept. request).

4.0 2015 PUBLIC OUTREACH

Project awareness was increased through a thoughtful and tailored public outreach process. The public outreach goals were as follows:

- Increase the public's confidence in the legitimacy of the project and their willingness to participate.
- Provide information to alleviate concerns about the survey and/or how the data would be collected, processed, secured, and handled by PSRC.
- Inform the public that PSRC will use the data for both updating travel demand models and to inform future transportation planning decisions.

The 2014 report describes the project branding and public outreach efforts in more detail. This section summarizes the website updates and public outreach efforts made in 2015.

4.1 | WEBSITE UPDATES

As in 2014, PSRC hosted the project website (https://survey.psrc.org) and RSG maintained and updated this website. The website included information about the study and the region, a link to the online survey, FAQs, links to news stories about the study, and contact information.

The following updates were made prior to the 2015 survey administration:

- "Did you participate last year?," a new page with information for households who participated in 2014, with a link to the 2014 survey results published on PSRC's website, and encouragement to participate again, if invited.
- The FAQs were updated and smartphone-specific FAQs were added.
- A small number of new press mentions was added.
- The press release list in the "News" section was updated.

4.2 | PUBLIC OUTREACH

PSRC and King County Metro Transit worked with TTI for public outreach in 2014 and 2015. The 2015 effort began with PSRC sending TTI a list of community organizations in the survey region. TTI identified a subset that represented hard-to-reach populations of interest for the study, and e-mailed these organizations to ask for permission to display logos and quotes of support for the project.

5.0 2015 HTS SURVEY ADMINISTRATION

The 2015 survey administration began with e-mail invitations to panel HHs when the survey first opened. Cross-sectional and panel HHs later received the same set of printed invitation materials closer to their assigned travel dates. Communication with participating HHs continued through online and phone channels. Invitations were sent by first-class mail in early April 2015 for arrival prior to the first travel date of April 21, 2015. This section describes the invitation process for cross-sectional and panel HHs, participation methods, and how communication was maintained with invited HHs during the study.

5.1 | INVITATION MATERIALS

First-class mailings initiated contact with cross-sectional HHs. They received: 1) a prenotice postcard informing them of the study; 2) an invitation packet inviting them to participate in the study; and 3) two reminder postcards.

Below are more details about the first-class mailings.

- **Prenotification Postcard**
  - Delivered approximately seven days before the assigned travel date.
  - Provided an introduction to the study and a link to the study website.
  - New for 2015: Password included.
- **Invitation Packet**
  - Delivered approximately four days before the assigned travel date.
  - This packet included:
    - A large envelope branded with the study logo and PSRC's logo to help it stand out from other mail received by the HH.
    - A letter signed by PSRC's executive director, Josh Brown, with information about the study, the survey link, and the HH's unique password and assigned travel date. The HH could begin participating (the recruitment survey) immediately.
    - A FAQ sheet (on the back of the letter) with more information about the study's purpose and how to track and report trips.
    - Travel logs for recording the HH's travel day trips.
- **Reminder Postcards**
  - The first postcard was delivered on the travel date (approximately).
  - The second postcard was delivered two days after the travel date (approximately).
  - All HHs received these postcards regardless of whether they had completed their travel diaries, as they were printed and mailed prior to the travel date.

5.2 | TRAVEL DATES

As in 2014, each HH received a preassigned travel date (24-hour period), which was printed on mailing materials, and all members of each HH were asked to report all the trips they made on that date. The 2015 survey administration spanned five weeks of Tuesday, Wednesday, and Thursday travel dates:

- Two weeks in April 2015 (April 21 to April 30).
- Two weeks in May 2015 (May 5 to May 14).
- One week in June 2015 (June 2 to June 4).

This schedule:

- Allowed for two weeks in May 2015 without any data collection;
- Skipped Seattle's bike-to-work day;
- Avoided having a majority of travel dates during bike-to-work month in May;
- Retained a substantive sample collected in June; and
- Minimized any potential impact on "typical travel" from the Memorial Day holiday (May 25).

The preassigned travel dates were spread evenly over five weeks so the recruitment and survey retrieval process could be tracked and final numbers forecasted, which permitted adjustments to sample sizes, incentives, and recruitment/reminder protocols. The Tacoma add-on sample was the exception, in which case the delayed contracting meant the earliest and only option for travel dates was in June 2015.

5.3 | PARTICIPATION METHODS

HHs had the option to participate online or over the phone. ETC Institute (ETC) conducted the phone recruitment and completion efforts. The online and phone surveys were identical, with ETC entering answers into the online survey instrument while speaking to participants on the telephone.

ONLINE SURVEY METHODS

The online survey was hosted by PSRC and implemented using RSG's proprietary survey software, rSurvey™. The rSurvey architecture includes rigorous Web 3.0 protocol to protect data during and after data collection (e.g., encryption of all submitted data over the Internet) to ensure proper consideration of all data privacy concerns and continuous "uptime" of all technology. HHs invited to take the survey were able to enter their unique password and complete the survey through the online survey portal, which was accessible from the project website. rSurvey has several features that help improve data quality and minimize respondent burden.

One feature of rSurvey is that participants who stop midway through the survey arrive at the question they last answered when they return to the survey (with all previously provided data saved). Other functionalities to ensure data consistency and minimize respondent burden include:

- Validation and logic checking, such as real-time geocoding of addresses, intersections, businesses, and utilizing points on a Google map; and
- "Copy-trips" functionality, allowing HH members to report other HH members on a trip and "copy" the trip details to that member's diary to reduce respondent burden of repeating trip details.

In addition, administrative data (also known as metadata) are collected by rSurvey, including browser language, browser type, use of a mobile device, and survey duration. A majority of HHs (89%) took the entire survey online. The median time spent on the recruit survey was 10 minutes, and the median time spent on the diary survey was 15 minutes. These numbers were quite similar to 2014.

PHONE SURVEY METHODS

The toll-free phone number was listed on all the invitation materials to allow HHs to participate over the phone. ETC fielded incoming calls and made outbound calls to HHs with a known phone number. Eleven percent of cross-sectional and panel HHs (same proportion in both groups) took the recruit or retrieval survey over the phone, down from 14% in 2014. The reduction in phone participation is partially explained by the call center placing fewer recruit calls than in 2014.

5.4 | COMMUNICATION PROTOCOL

PHONE RECRUITMENT

The address-based sample included a landline telephone number associated with the address for 24% of invited cross-sectional HHs, similar to the 27% phone match in 2014. In addition to the printed invitation materials, cross-sectional HHs with a phone match received telephone calls encouraging them to participate in the study. Contacted HHs could complete the recruit survey over the telephone or through the survey website.

RSG sent a prioritized recruit call list to ETC each weekday during data collection. The recruitment phone calls prioritized HHs based on their designation as a "target" or hard-to-reach HH. Recruitment phone calls began once HHs received their prenotice postcard and continued until two days prior to the travel date. "Target" recruitment HHs were designated based on estimated income and geography. The sample provider included income estimates for 87% of cross-sectional HHs. HHs in Kitsap, Pierce, and Snohomish counties with an estimated income lower than $25,000 were given first recruitment call priority, followed by HHs in King County with an estimated income lower than $25,000.

Recruit calls were not made to panel HHs, because unlike cross-sectional HHs, panel HHs already been contacted for recruitment via e-mail before the mailings arrived.

E-MAIL AND PHONE REMINDERS

Once recruited, cross-sectional and panel HHs received telephone and e-mail reminders encouraging them to complete the steps to finish the study. Reminders to HHs were conducted based on the HH's indicated communication preference (provided in the recruit

survey). Reminder e-mails were sent to the 82% of HHs that indicated a preference for e-mail reminders and to the 9% of HHs that preferred text reminders. Similarly, the 15% of HHs that indicated a preference for phone calls reminders received phone calls. A small number (1.6%) of HHs received both phone call and e-mail reminders after indicating a preference for receiving both.

Telephone Reminders

For HHs that preferred receiving reminders via telephone, ETC conducted reminders through the following process:

- A telephone call was placed to the HH on the day before their travel date to remind the HH to track their travel the following day.
- Additional calls were placed (for up to seven days after the travel day) to the HHs to remind them to complete the survey online or over the telephone. The timing and frequency of telephone calls varied based on the HHs' previously expressed preference for a "call back" and the ease of reaching the HH.
- After seven days from the travel date passed, no additional phone calls were placed to that HH.

ETC ensured that all reminder phone calls were placed on time and that scripted messages were left on voicemail if a voice mailbox was available. Approximately 15% of recruited HHs received telephone reminders.

E-mail Reminders

RSG sent e-mail reminders to HHs that preferred e-mail contact requesting that they log and report trips on their assigned travel date and describing the reporting process. Reminders included a link to the survey website, the HH password, and the toll-free telephone number had the HH preferred to report travel over the telephone, or had difficulty completing the survey online.

Reminder e-mails were sent to HHs:

- The day before the assigned travel date (reminder to log travel the following day);
- The morning after the assigned travel date (reminder to report travel from the previous day);
- Three days after the travel date (only if travel had not yet been reported); and
- Five days after the travel date (only if travel had not yet been reported).

If a HH had not reported travel after seven days past the assigned travel date, no additional e-mail reminders were sent to the HH. Examples of the e-mail reminders are included as an appendix item.

E-MAIL AND PHONE INQUIRIES

RSG monitored and maintained the study e-mail account hosted by PSRC (help@psrc.org). RSG responded to e-mails within 24 hours of receiving the message or on the next business day. Inquiries sent by e-mail typically involved HHs asking for their password before they

received the invitation letter, questions about the gift card, and questions about the survey. Occasionally, HHs also e-mailed with comments about regional transportation issues, which were forwarded to PSRC.

ETC operators responded to questions over the phone. If an operator did not know the answer to a question or needed more information, then the ETC supervisor contacted RSG for guidance. ETC kept a record of all interactions with respondents, and received multiple inquiries during the course of the survey effort, in addition to calls to take the survey. In cases where a participant was having trouble completing the survey, ETC would help them complete the survey over the phone. Calls from HHs who wanted to report their travel on their travel date (rather than on the day after) were scheduled for callback. Calls to ask about the HH's gift card were forwarded to RSG for resolution.

PSRC also received a handful of phone calls about the project from the public and participating HHs. The PSRC contact information was provided on the project website and it is suspected that this was the source of most of the incoming inquiries.

MAILINGS

Undeliverable mail was returned to the project's PO Box and subsequently forwarded to RSG. In total, 2,435 invitation letters, or approximately 13% of invites, were returned. This number includes returned smartphone GPS in addition to cross-sectional and panel returns. The proportion of returned addresses (13%) can be included or excluded when calculating final RRs. This report provides RRs based on both methods in Section 7.0.

5.5 | SURVEY INCENTIVES

As in 2014, incentives were offered as encouragement and compensation for HHs that completed the survey. The printed survey invitation materials and survey reminders notified HHs that they would receive their choice of a $10 Amazon.com or Starbucks gift card upon completion of the travel diary.

Incentives were sent approximately once per week for HHs that had completed their travel diaries the previous week. Respondents who chose to receive survey reminders by e-mail during the recruit survey were e-mailed an Amazon or Starbucks gift card (depending on their card preference). Respondents who only chose phone call reminders were given the option of receiving an e-mailed gift card or a physical mailed gift card.

Some "hard-to-reach" HHs were selected for a higher incentive ($20) to encourage a higher completion rate. Initially, higher incentives were offered to HHs with more than four adults or income under $25,000. In 2014, zero-vehicle HHs were also offered the higher incentive, but this criterion was dropped in 2015 based on the strong participation by these HHs in 2014.

After the survey administration assessment at the two-week mark of data collection (approximately halfway through), incentive amounts were lowered because of high panel RRs. Twenty percent of participating cross-sectional and panel HHs in the first half of the study qualified for the $20 incentive. To accommodate continued high panel response and

manage costs, only the $10 incentive was offered to all cross-sectional and panel HHs for the last three weeks of travel dates.

In total, 13% of HHs received the $20 gift card. Table 10 shows the number of gift cards sent by type and amount. The total number of gift cards sent includes every household who completed the study (regardless of whether they are included in the final dataset) as well as some cases where exceptions were made (e.g., if a panel household had not received their mailed gift card from 2014, an exception was sometimes made to send a new gift card.)

TABLE 10: GIFT CARD TYPE AND AMOUNT

AMOUNT	AMAZON		STARBUCKS		TOTAL	
	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
$10	1,149	86.0%	990	88.1%	**2,139**	**87.0%**
$20	186	14.0%	134	11.9%	**320**	**13.0%**
Total	**1,335**	**100.0%**	**1,124**	**100.0%**	**2,455**	**100%**

6.0 2015 HTS DATA PREPARATION

RSG performed data quality assurance and quality checks during all stages of the project—from questionnaire and sample design to final deliverables. This section summarizes steps taken to prepare the data deliverables.

RSG's dataset preparation focuses on review of frequency tabulations and mapping of location data, flags for potential issues, quality checks of the prepared core datasets, and deriving key variables for downstream data uses. RSG excludes a small number of HHs based on issues with home location or self-reported serious data issues, but is otherwise conservative with editing reported data, such as trip records. As in 2014, RSG understands that at the time of writing this document, PSRC planned to continue to make edits to the dataset.

The data deliverable includes four distinct datasets, which can be joined using a combination of household ID, person number, and trip number:

1. Household level data
2. Person-level data
3. Trip-level data
4. Vehicle-level data

6.1 | rSURVEY DATA CHECKS

rSurvey includes built-in data and consistency checks that facilitate dataset preparation and reduce the amount of data cleaning and up-coding required. A few examples include:

- Web respondents and ETC telephone operators both use rSurvey to ensure that all data undergo the same logic, validation, and real-time checks.
- Validation logic to ensure respondents answer all questions.
- Logic checking, such as real-time geocoding of addresses, intersections, businesses, and utilizing points on a Google map.
- Filters to automatically determine which questions were shown to each person based on their previous responses (e.g., nonemployed persons were not asked commuting questions).
- Predefined acceptable ranges for text entry questions.
- Metadata collection permitted passive collection of data such as survey duration (in total and by each question), browser type, default language of web-browser, and more. These metadata are used to troubleshoot survey errors and to assist a household that calls or e-mails asking for help.
- The copy-trips feature in rSurvey allows a household member to select and copy information already reported by another household member if that household member reported joint travel. This "copy-trips" feature, described in more detail in Section 3.0, ensures that jointly made household trips were reported with the same geocodes and trip times.

- Reported trip sequences were required to be logical, so that one trip's end location matched the next trip's starting location.
- A trip's end time had to be later than that trip's start time, and the next trip's start time was required to occur after the previous trip ended.

6.2 | HTS 2015 DATASET PREPARATION

The goal of the 2015 HTS data preparation was to deliver datasets as similar as possible to the 2014 HTS datasets, in terms of variable names, value coding, data processing steps, and derived variables. Keeping the two datasets similar helped PSRC reuse processes developed for the 2014 data, and facilitated combining the two years of HTS data with the college data.

RSG delivered the unweighted 2015 HTS data to PSRC in early July 2015. PSRC then reviewed and excluded several HHs based on more in-depth data review. After PSRC's data edits, RSG developed HH-level weights in August 2015.

EXCLUSION CRITERIA

RSG removed 12 previously "complete" cross-sectional households (~1% of households) from the final dataset for the following reasons:

- Households who reported a home address at an intersection more than 0.25 miles from their sample address, and whereupon review it was determined that the cross-street was not a valid home or residential location: 11 HHs.
- Households who reported a home location as an organization or institution rather than a valid home address, likely due to privacy concerns: 1 HH.

HH records were also checked to ensure all reported home locations were in the four-county study area and that no HHs participated more than once (e.g., no duplicate e-mail addresses).

Panel HHs with notable discrepancies between sample provider and reported home location were flagged for PSRC inspection and possible exclusion, but unlike cross-sectional HHs, all panel HHs were retained in the dataset to allow for comparison with 2014 data.

GEOGRAPHIC DATA CHECKS

Finalizing Home Location

Every household has two sources of home location data: 1) the sample provider (MSG) home latitude/longitude provided with the address file; and 2) the survey self-reported home latitude/longitude from the Google Maps API. Home location is an essential variable for the analysis of HTS datasets, but the two sources of addresses do not always match perfectly. For this reason, data preparation included comparing the two sources and recommending the "final" home location for each HH (coordinates and address). This final home location was used in all downstream data tasks, such as deriving geographic variables based on home location.

The self-reported address was used as the final address for 90% of cross-sectional HHs (same percentage as in 2014). In the panel sample, the 2014 RSG-assigned final home address was retained for 93% of households.

For completeness, three sets of home address variables have been provided with the HH-level dataset:

1. The sample provider (MSG) address and coordinates used for mailing of the invitation materials.
2. The home address (and coordinates) self-reported by the HH in the recruit survey.
3. The final home address, which is either the reported address or the sample provider address.

Estimating Travel Time and Duration

Estimated travel time and trip duration between a trip's origin and destination points were passively recorded and calculated by the Google Maps API Distance Matrix Service embedded in rSurvey; these are included in the data deliverable. These estimates indicate the distance and duration of a trip under "standard driving directions using the road network"[2] and do not account for traffic, thus representing "free flow" conditions on the roadway. These values were collected in addition to the user-reported travel time and allow for comparison between the two values. All but a few ferry and airplane trips were coded and provided and could be used for future trip validation to detect trip records with potential issues.

DERIVED AND CALCULATED VARIABLES

Deriving Trips for Children Under Five

Children under the age of five were not required to complete a diary, but could be reported on trips made by household members age five or older. After deriving all other trip-level variables, trip records were created for the children under five by copying trip records from other household members and editing relevant details. Edits included identifying and removing duplicate trips, such as all trip records that were copy-trips, sorting the remaining trips in ascending order, creating unique trip IDs, and recoding instances of "driver" to "passenger" for vehicle trips. This exercise added 770 records to the trip dataset, or 4% more trips, which is the same percentage added in 2014. A flag to identify these derived records, and the original trip ID (from the HH member from whom the trip record was derived) were attached to each record to ensure the ability for tracing back.

[2] https://developers.google.com/maps/documentation/javascript/distancematrix

7.0 2015 HTS RESPONSE RATES

The RRs presented in this section are based on the final number of completes after RSG excluded 12 cross-sectional HHs. Cross-sectional and panel RRs are presented separately; this is because their targets and selection criteria differed from one another.

7.1 | CROSS-SECTIONAL FINAL RESPONSE RATES

Starting with a high-level overview, Table 11 has the target number of complete survey households, final number of invited households, and final RRs by the four counties, with the supplemental sample purchases by the City of Tacoma listed separately. As described in Section 2.0, the 2015 survey adjusted the number of invites based on 2014 RRs. With 619 final HHs, the cross-sectional sample closely matched the target of 600 HHs. Retention rates were around 80% in all counties, and King, Kitsap, and Snohomish all moderately exceeded their targets. Snohomish County, which fell short of its target in 2014, recovered in 2015. At 84%, Pierce County came in below target, unlike in 2014 when the target was exceeded by purchasing additional sample midway through survey administration. The shortfall in Pierce County is compensated for by the higher-than-expected response rate in the City of Tacoma supplemental sample.

TABLE 11: SPRING 2015 SURVEY COMPLETION—CROSS-SECTIONAL HHs

SAMPLE AREA	RECRUITED	RETRIEVED	RETENTION PERCENT	TARGET HHs	PERCENT TARGET	RESPONSE RATE
King County	455	371	81.5%	351	106%	7.9%
Kitsap County	61	47	77.0%	39	121%	6.6%
Pierce County	122	97	79.5%	115	84%	4.2%
Snohomish County	133	104	78.2%	95	109%	5.9%
PSRC Subtotal	771	619	80.3%	600	103%	6.5%
City of Tacoma Supplement	291	202	69.4%	125	162%	4.9%
Total	**1,062**	**821**	**77.3%**	**725**	**113%**	**6.0%**

Table 12 details the target and actual sampling rates and RRs for the six sampling segments described in the sampling plan. The City of Tacoma add-on sample is not included. Recall that the "regular" sampling segments were sampled proportional to population, whereas the oversample (higher sampling rates) segments were either in PSRC's RGCs, or contained high proportions of household types or behaviors of interest (i.e., low-income, 0-vehicle, young nonfamily, or noncar commuting). The finer resolution shows the differences in expected and actual RRs between groups. For example, the expected RRs in the oversample segments had been adjusted upward based on 2014 performance; as a result, the oversample segments

closely matched targets. The regular medium-income segment performed stronger than in 2014 (5.9% RR in 2014). The regular lower-income segment came in under target; however, the target was initially small (14 HHs).

TABLE 12: CROSS-SECTIONAL COMPLETES BY SAMPLE SEGMENT

SAMPLE SEGMENT	ACS HHs	TARGET SAMPLING RATE	TARGET COMPLETE HHs	EXPECTED RESPONSE RATE	RETRIEVED	RESPONSE RATE	SAMPLING RATE
Regular Higher Income	729,827	0.0299%	218	7.1%	213	6.9%	0.0292%
Regular Medium Income	333,550	0.0299%	100	5.7%	120	6.9%	0.0360%
Regular Lower Income	47,928	0.0299%	14	4.5%	10	3.2%	0.0209%
Oversample Higher Income	86,190	0.0762%	66	7.7%	74	8.7%	0.0859%
Oversample Medium Income	102,945	0.0762%	78	7.5%	80	7.7%	0.0777%
Oversample Lower Income	161,663	0.0762%	123	5.0%	122	5.0%	0.0755%
Total	**1,462,103**	**0.0410%**	**600**	**6.3%**	**619**	**6.5%**	**0.0423%**

(1) HHs in Census block groups from the ACS 2008–2012 5-year data.

(2) Target Sampling Rate = % of total HHs in sampling area desired in the final dataset.

*(3) Target Complete HHs = Target sampling rate * Total # HHs.*

The RRs presented in this section do not account for the 13% of total mailings (cross-sectional and panel) that were returned undeliverable; thus, the actual RRs are somewhat higher.

7.2 | PANEL FINAL RESPONSE RATES

As described in Section 2.0, the original goal of the 2015 HTS panel was to achieve a final sample of 600 HHs, with four targeted groups of interest based on observed travel behavior and home locations in 2014, and random sampling among willing participants in the four-county area for the remainder. As a result, the panel sample plan was not population proportional, unlike the cross-sectional sample plan. The initial estimate of 20% response rate proved overly conservative for the PSRC region; as previously described, RSG and PSRC made adjustments to accommodate a final sample size of 1,600 HHs.

Table 13 shows retention and RRs for each of the five types of panel HHs. The 55% response rate is instructive for future panel surveys in the PSRC region, and the 90% retention rate is also worth noting.

TABLE 13: PANEL RRs BY PANEL TYPE

PANEL TYPE	RECRUITED	RETRIEVED	RETENTION PERCENT	RESPONSE RATE
Rode revised bus routes	88	78	88.6%	57.4%
In block group of revised bus route riders	376	333	88.6%	54.9%
Commutes to downtown Seattle	230	206	89.6%	55.8%
Lives in downtown Seattle	118	110	93.2%	53.4%
Randomly sampled	970	882	90.9%	55.5%
Total	**1,782**	**1,609**	**90.3%**	**55.4%**

Although the panel sample did not have targets by county, Table 14 shows panel retention and RRs were nearly uniform across the four counties.

TABLE 14: PANEL RRs BY COUNTY

COUNTY	RECRUITED	RETRIEVED	RETENTION PERCENT	RESPONSE RATE
King	1,205	1,085	90.0%	54.9%
Kitsap	88	82	93.2%	55.0%
Pierce	271	248	91.5%	57.3%
Snohomish	218	194	89.0%	56.1%
Total	**1,782**	**1,609**	**90.3%**	**55.4%**

8.0 2015 HTS DATA EXPANSION & WEIGHTING

8.1 | THE ROLE OF WEIGHTING

HTSs cover a fraction of the population, yet the resultant datasets are used to analyze and make inferences about the population at large. Weighting is the process of comparing selected demographics in the survey to external controls such as Census or ACS data, and adjusting the profile of the survey dataset to improve its representativeness of the study area population.

The final demographic and geographic distribution of households and persons in a survey dataset is a result of several factors:

- **The sampling plan:** The study area is divided into geographies with separate targets or expected numbers of completed surveys. Geographies with certain demographic characteristics may be oversampled, either because the area is of special interest (e.g., a growth area), or because low RRs are expected (e.g., low-income areas).
- **Pilot survey findings:** Adjustments made after administration of the pilot survey (or in this case, also the previous year study) and throughout survey administration to reach sampling targets.
- **Final sampling rates:** Some households are more or less likely than others to participate, despite efforts in sampling planning and adjustments during administration. For example, a dataset may have a larger proportion of senior households and a lower proportion of young households than the true study area population. Typical "hard-to-reach" groups include young households, very low-income households, and zero-vehicle households.

Depending on the outcomes of the three factors above, the resultant data are not necessarily fully representative of the target population in terms of demographic or geographic characteristics—there is some bias related to nonresponse. By assigning lower weights to households that were over-represented in the survey, and higher weights to those that were under-represented, these differences are mitigated.

8.2 | 2015 HOUSEHOLD DATASET

Two weights were developed for the 2015 household dataset: 1) a cross-sectional weight for households who only participated in the 2015 study (w_1); and 2) a combined cross-sectional and panel weight that includes households who participated in both the 2014 and 2015 studies (w_2). However, before any weighting could be done, values for household income were imputed for those who did not provide a response.

INCOME IMPUTATION

Households had the option of reporting income in 10 detailed categories or selecting "prefer not to answer." A follow-up question offered respondents the option of reporting income in five broader categories for those selecting the latter (Table 15). The more-detailed income

data is key for weighting. Thus, household income was imputed for the 232 (9.6%) households that preferred not to report detailed income. Seventy households opted to report their income with the broader follow-up survey question. This information supplemented the imputation of income for these households.

TABLE 15: HOUSEHOLD INCOME CATEGORIES

TEN CATEGORY CLASSIFICATION (DETAILED)	FIVE CATEGORY CLASSIFICATION (BROAD)
Under $10,000	Under $25,000
$10,000–$24,999	
$25,000–$34,999	$25,000–$49,999
$35,000–$49,999	
$50,000–$74,999	$50,000–$74,999
$75,000–$99,999	$75,000–$99,999
$100,000–149,999	$100,000 or more
$150,000–$199,999	
$200,000–$249,999	
$250,000 or more	

The income imputation model development process covered a number of modeling techniques and variables hypothesized to predict household income. Models were estimated using data from the 2,196 households where the detailed income data was known and were evaluated not in regards to model fit, but in regards to predictive accuracy, a subtle but key difference. This limits the chance of producing an "over-fit" model that is excellent at predicting income categories for households, where it is known, but poor at predicting for households where it is not known.

Predictive accuracy was determined by employing a 25-fold bootstrap cross-validation procedure, effectively estimating each model 25 times on a bootstrapped sample of households and applying the model to the remaining households. Predictive accuracy was then quantified with two metrics: 1) percent correct; and 2) Cohen's Weighted Kappa (κ_w). The latter metric accounts for correct predictions occurring by chance alone and also applies a penalty for predictions that are far away from the observed value. For instance, a simple percent correct measure may not be useful if, for the observations the model incorrectly predicts, it predicts them as very different values. For example, if a household has a true income of less than $10,000, but the model predicts its income as $250,000 or more.

A variety of modeling techniques were tested: Linear/Quadratic Discriminant Analysis, Nearest Neighbors, Multinomial Logit, Ordered Logit, and Random Forest. The best performing imputation model was found to be an Ordered Logit model. The model includes attributes of the household and the income distribution in the residence block group, based

on the 2009–2013 five-year ACS. Because a logit model is probabilistic and not deterministic, a "Monte Carlo" simulation of predicted income categories is the most appropriate application. The final income variable was created as follows:

- If a household answered the detailed income question, the reported detailed category was used.
- If a household did not answer the detailed income question but did answer the broad income follow-up question, the Monte Carlo method was used to impute a choice among only the associated detailed subcategories.
- If a household neither answered the detailed nor the broad category income questions, the Monte Carlo method was used to impute a choice from among all ten income categories.

The resulting final income categories are shown in Table 16. These categorizations were used for all weighting steps described in the following sections.

TABLE 16: INCOME IMPUTATION RESULTS

INCOME CATEGORY	REPORTED	IMPUTED	COMBINED	PERCENT COMBINED
Under $10,000	85	9	94	4%
$10,000–$24,999	245	35	280	12%
$25,000–$34,999	183	21	204	8%
$35,000–$49,999	276	32	308	13%
$50,000–$74,999	368	23	391	16%
$75,000–$99,999	335	29	364	15%
$100,000–$149,999	406	49	455	19%
$150,000–$199,999	146	16	162	7%
$200,000–$249,999	78	8	86	4%
$250,000 or more	74	10	84	3%
Total	**2,196**	**232**	**2,428**	**100%**

SAMPLING SEGMENT EXPANSION FACTORS

The first weight (w_1) applies to only the cross-sectional households (820 households) in the study (i.e., households that did not participate in the 2014 study). The second (w_2) applies to all households in the 2015 study, including panel households who participated in both the 2014 and 2015 studies. Both weights were developed using a two-step process.

In the first step, the number of survey households was expanded to the actual number of households in each sampling segment by assigning an expansion factor to each household based on the sampling rate. This step is based only on the calculated sampling rates for the

different sampling groups. These are groups that had equal sampling probabilities for all households within each group. The groups used in this step were the six original sampling segments, but with the households located in Tacoma broken out separately. These initial expansion factors are then used in the second step (Demographic R) as initial weight seeds.

For panel households (1,608), the initial expansion factors were set to the household weights from the 2014 study. For cross-sectional households, the initial expansion factors were calculated from the most recent estimates of the number of households at the block group level from the 2009–2013 five-year ACS. The ratio of the estimated number of households to the number of households in the cross-sectional sample is the initial expansion factor (Table 17). The low- and medium-income regular Tacoma sample groups, and the medium- and high-income Tacoma oversample groups, were combined due to small cross-sectional sample sizes, forming 10 groups.

TABLE 17: 2015 CROSS-SECTIONAL SAMPLE EXPANSION FACTORS

BLOCK GROUP TYPE	EXPANSION FACTOR	SAMPLE HOUSEHOLDS	PERCENT	TOTAL HOUSEHOLDS (ACS 2009-2013)
Regular–Low income	4,844	9	1.1%	43,592
Regular–Medium income	2,593	119	14.6%	311,138
Regular–High income	3,337	216	26.0%	710,702
Oversample–Low income	1,158	121	14.9%	141,329
Oversample–Medium income	1,252	81	9.8%	100,184
Oversample–High income	1,154	72	9.0%	85,370
Tacoma Regular–Low/Medium income	699	40	4.8%	27,249
Tacoma Regular–High income	669	35	4.1%	22,743
Tacoma Oversample–Low income	230	92	11.5%	21,605
Tacoma Oversample–Medium/High income	162	35	4.3%	5,665
Total	**--**	**820**	**100.0%**	**1,469,577**

ESTABLISHING DEMOGRAPHIC TARGETS

In the second step, target demographic variables and weighting geographies were established. The initial expansion weights were adjusted to match control data targets from the 2009–2013 five-year ACS PUMS (Public Use Microdata Sample) for the following target dimensions, which were intentionally kept similar to those used in PSRC 2014 weighting:

- County (King, Kitsap, Pierce, Snohomish)
- 2010 PUMA geography (16 PUMAs in King County, 2 in Kitsap, 7 in Pierce and 6 in Snohomish)
- Household size (1, 2, 3, 4, 5+)

- Number of workers (0, 1, 2, 3+)
- Income (10 categories)
- Number of vehicles (0, 1, 2, 3+)
- Lifecycle (eight categories)

Household lifecycle was defined as a combination of the presence of children (ages 0–4 or ages 5–17), number of adults (1 or 2+), and householder age (under 35, 35–64, 65 or older).

The final question for setting targets is which ACS sample to use. The two best options were the 2009–2013 five-year ACS PUMS or the 2014 one-year ACS PUMS. The latter is more recent, but based on a relatively small sample size. Therefore, targets based on one year of data will have quite a bit of measurement error compared to the five-year ACS PUMS. For these reasons, targets were established using the 2009–2013 five-year ACS PUMS.

Comparisons between the 2009–2013 five-year ACS PUMS data and the initial expanded cross-sectional sample were made for the five demographic household dimensions (Table 18 to Table 22). For example, after initial expansion, there were 16% fewer four-person households than the ACS target for four-person households. Summarizing these five tables, the groups that appear to be under-represented due to lower RRs were:

- Larger households;
- 3+ worker households;
- Low-income households;
- Zero-vehicle and 3+ vehicle households; and
- Households with children and single households.

TABLE 18: SURVEY DIFFERENCE FROM ACS TARGETS AFTER INITIAL EXPANSION—HOUSEHOLD SIZE

HOUSEHOLD SIZE	ACS TARGET	INITIAL EXPANSION	DIFFERENCE	PERCENT DIFFERENCE
1 person	420,824	457,020	36,181	8.6%
2 people	497,094	614,374	117,288	23.6%
3 people	232,449	190,128	-42,317	-18.2%
4 people	195,168	163,925	-31,231	-16.0%
5 or more people	124,042	44,117	-79,924	-64.4%
Total	**1,469,577**	**1,469,577**	**0**	**0.0%**

TABLE 19: SURVEY DIFFERENCE FROM ACS TARGETS AFTER INITIAL EXPANSION—HOUSEHOLD WORKERS

HOUSEHOLD WORKERS	ACS TARGET	INITIAL EXPANSION	DIFFERENCE	PERCENT DIFFERENCE
0 workers	293,567	470,318	176,751	60.2%
1 worker	594,742	517,745	-76,997	-12.9%
2 workers	479,598	437,097	-42,501	-8.9%
3 or more workers	101,670	44,417	-57,253	-56.3%
Total	**1,469,577**	**1,469,577**	**0**	**0.0%**

TABLE 20: SURVEY DIFFERENCE FROM ACS TARGETS AFTER INITIAL EXPANSION—HOUSEHOLD INCOME

HOUSEHOLD INCOME	ACS TARGET	INITIAL EXPANSION	DIFFERENCE	PERCENT DIFFERENCE
Under $10,000	86,955	47,337	-39,618	-45.6%
$10,000-$24,999	175,046	144,648	-30,398	-17.4%
$25,000-$34,999	124,966	115,599	-9,367	-7.5%
$35,000-$49,999	192,542	167,903	-24,639	-12.8%
$50,000-$74,999	268,772	234,562	-34,210	-12.7%
$75,000-$99,999	203,593	248,191	44,598	21.9%
$100,000-$149,999	233,262	284,276	51,014	21.9%
$150,000-$199,999	95,192	116,248	21,056	22.1%
$200,000-$249,999	36,327	60,577	24,250	66.8%
$250,000 or more	52,922	50,237	-2,685	-5.1%
Total	**1,469,577**	**1,469,577**	**0**	**0.0%**

TABLE 21: SURVEY DIFFERENCE FROM ACS TARGETS AFTER INITIAL EXPANSION—HOUSEHOLD VEHICLES

HOUSEHOLD VEHICLES	ACS TARGET	INITIAL EXPANSION	DIFFERENCE	PERCENT DIFFERENCE
0 vehicles	109,334	89,237	-20,097	-18.4%
1 vehicle	479,225	480,437	1,212	0.3%
2 vehicles	558,397	640,786	82,389	14.8%
3 or more vehicles	322,621	259,117	-63,504	-19.7%
Total	**1,469,577**	**1,469,577**	**0**	**0.0%**

TABLE 22: SURVEY DIFFERENCE FROM ACS TARGETS AFTER INITIAL EXPANSION—HOUSEHOLD LIFECYCLE

HOUSEHOLD LIFECYCLE	ACS TARGET	INITIAL EXPANSION	DIFFERENCE	PERCENT DIFFERENCE
Children age 0-4	86,955	47,337	-39,618	-45.6%
Children age 5-17 only	175,046	144,648	-30,398	-17.4%
No children, hhsize 1, householder under 35	124,966	115,599	-9,367	-7.5%
No children, hhsize 1, householder 35-64	192,542	167,903	-24,639	-12.8%
No children, hhsize 1, householder 65 or older	268,772	234,562	-34,210	-12.7%
No children, hhsize 2, householder under 35	203,593	248,191	44,598	21.9%
No children, hhsize 2, householder 35-64	233,262	284,276	51,014	21.9%
No children, hhsize 2, householder 65 or older	95,192	116,248	21,056	22.1%
Total	**1,469,577**	**1,469,577**	**0**	**0.0%**

DEMOGRAPHIC REWEIGHTING

The second step in weighting employed an iterative proportional fitting (IPF) procedure that looped over the five demographic target dimensions and the two geographic target dimensions (County and PUMA). The procedure was seeded with the initial expansion weights from the first weighting step, and gradually adjusted the weights to match the target values. At each iteration, household weights were constrained to between 25% and 400% of their initial value to avoid extreme weight values. The procedure was applied to the 2015 cross-sectional data to produce w_1, and to the cross-sectional and panel HHs jointly to produce w_2.

For cross-sectional HHs, the resulting expansion weights are between 180 and 12,000, but with the large majority remaining in the range of the initial expansion weights. Table 23 shows the resulting median and standard deviation of the final expansion weights by

sampling group. The median within each group tends to stay fairly close to the initial expansion weight, with the exception of the Tacoma oversample. Similar results for the joint cross-sectional and panel household weights (w_2) are shown in Table 23.

TABLE 23: FINAL EXPANSION WEIGHTS—2015 CROSS-SECTIONAL HOUSEHOLDS (w_1)

BLOCK GROUP TYPE	SAMPLE HOUSEHOLDS	MEDIAN INITIAL EXPANSION FACTOR	MEDIAN FINAL EXPANSION FACTOR	FINAL EXPANSION FACTOR STANDARD DEVIATION
Regular–Low income	9	4,014	3,359	3,963
Regular–Medium income	119	2,140	1,621	1,794
Regular–High income	216	2,969	2,478	2,843
Oversample–Low income	121	754	708	838
Oversample–Medium income	81	944	934	948
Oversample–High income	72	1,108	924	932
Tacoma Regular–Low/Medium income	40	2,140	535	1,340
Tacoma Regular–High income	35	2,969	1,017	1,521
Tacoma Oversample–Low income	92	754	189	326
Tacoma Oversample–Medium/High income	35	944	236	143
Total	**820**	**2,140**	**1,012**	**2,137**

TABLE 24: FINAL EXPANSION WEIGHTS—2015 CROSS-SECTIONAL AND PANEL HOUSEHOLDS (w_2)

BLOCK GROUP TYPE	SAMPLE HOUSEHOLDS	MEDIAN INITIAL EXPANSION FACTOR	MEDIAN FINAL EXPANSION FACTOR	FINAL EXPANSION FACTOR STANDARD DEVIATION
Regular–Low income	44	313	231	2,099
Regular–Medium income	353	327	327	1,175
Regular–High income	695	333	351	1,606
Oversample–Low income	501	148	100	900
Oversample–Medium income	356	90	62	849
Oversample–High income	277	103	74	812
Tacoma Regular–Low/Medium income	40	1,919	602	535
Tacoma Regular–High income	35	1,332	737	938
Tacoma Oversample–Low income	92	1,537	436	840

BLOCK GROUP TYPE	SAMPLE HOUSEHOLDS	MEDIAN INITIAL EXPANSION FACTOR	MEDIAN FINAL EXPANSION FACTOR	FINAL EXPANSION FACTOR STANDARD DEVIATION
Tacoma Oversample–Medium/High income	35	1,168	321	496
Total	**2,428**	**242**	**190**	**1,211**

8.3 | 2014 COMBINED HOUSEHOLD AND UNIVERSITY DATASET

A third joint weight was also developed for the 2014 household and university datasets (w_3) following the same aforementioned weighting procedure.

COMBINING DATASETS

In October-November 2015, RSG combined data for selected variables from the 2014, 2015, and college surveys. The motivation for combining the data was to facilitate weighting across survey years and DaySim modeling work. Prior to combining the data, RSG and PSRC established the list of relevant variables to include from each of the three datasets.

The combined dataset uses files PSRC provided in September–October 2015. PSRC has edited all datasets to varying extents, e.g. removing HHs, editing home locations, appending geographic variables, editing trip details and linking trip records.

Table 25 shows the records from each survey that contributed to the combined dataset. See the dataset guide accompanying the combined dataset for details.

TABLE 25: COMBINED DATASET OVERVIEW

DATA TYPE	2014 HTS	2015 HTS	COLLEGE	COMBINED DATASET
HH	6,036	2,428	4,382	12,846
Person	12,198	4,812	4,382	21,392
Trip	47,918	19,630	19,161	86,709
Vehicle	9,453	3,704	-	13,157

A THIRD JOINT WEIGHT

The joint weight applies to all 2014 households and university samples within King, Kitsap, Pierce, or Snohomish counties. University responses outside of the four counties of interest (41 responses) were excluded. Additionally, university respondents who indicated that they live off-campus with family members (35 responses) were removed, as these households are better represented by the 2014 household dataset. A total of 526 university respondents indicated that they live on-campus. This type of shared-quarters household represents

additional households not captured by the ACS. For this reason, these responses were not included in the reweighting IPF procedure, and their weight was set equal to their 2014 weight. A total of 6,035 households and 1,510 university respondents were included in the weighting.

Households and university respondents entered the IPF procedure with initial weights equal to their final weight from the 2014 weighting. The target values for the demographic reweighting were the same as for the 2015 cross-sectional and joint weights. Intuitively, the median final expansion factor decreases as more records are included in the joint dataset.

TABLE 26: FINAL EXPANSION WEIGHTS—2014 HOUSEHOLD AND UNIVERSITY SAMPLE (w_3)

BLOCK GROUP TYPE	SAMPLE HOUSEHOLDS	MEDIAN INITIAL EXPANSION FACTOR	MEDIAN FINAL EXPANSION FACTOR	FINAL EXPANSION FACTOR STANDARD DEVIATION
Household Sample	6,035	16	4	26
University Sample	1,510	179	179	218
Total	**7,545**	**126**	**108**	**214**

9.0 2015 GPS OVERVIEW

9.1 | SMARTPHONE-BASED GPS SAMPLE PURPOSE

Traditional HTSs, such as those conducted by PSRC in 2014 and 2015, typically collect a single day's worth of travel from a sample of residents in an area. A growing body of work[3] suggests that data collection periods longer than one day would better fulfill data needs for modeling and understanding trends. However, longer periods of reporting travel are thought to increase household burden if typical approaches to data collection (e.g., travel diary web sites, call centers, or paper surveys) continue as the primary means of reporting travel. Additionally, the data collected through these means often suffers from inaccuracies due to misreported and missed trips, further warranting an alternative method of data collection.

Data collection through a smartphone app using Wi-Fi, GPS, and other sensors has the potential to reduce burden and attrition while still collecting required HTS data elements through features like in-app questions and pattern recognition. The accuracy of GPS data will reduce the number of "missed stops" during the travel period, and the ability to prompt respondent to answer travel details close to "real-time" will help to improve data quality. These benefits will facilitate conducting travel diary studies over longer household travel periods instead of just a single day.

The GPS data collection component of the 2015 Puget Sound Regional Travel Study used RSG's smartphone app, rMove™. The goal was to successfully collect a sample of households in order to allow PSRC to evaluate the process and data for future travel survey planning purposes.

9.2 | rMOVE SMARTPHONE APP

After several iterations of testing and improvements, rMove became available in the Google Play store (for Android devices) and the iTunes App Store (for iOS devices) in April 2015. A support website with FAQs, instructions, and terms and conditions accompanied the app release (Figure 2).

[3] http://www.brookings.edu/research/papers/2015/04/17-driving-in-the-21st-century-dutzik-tomer-baxandall-puentes

FIGURE 2: rMOVE USER SUPPORT WEBSITE

The April 2015 version of rMove included the following features.

TABLE 27: rMOVE FEATURE LIST

FEATURE
Fully compatible with both Android and iOS operating systems (estimated as 96% of total smartphone market share at the time)
Automatic trip start and end /stop detection—no user intervention was necessary
Automatic recording of trip path, duration, and speed
Multiple smartphone sensor utilization (i.e., GPS, compass, Wi-Fi, accelerometer)
Automatic loading and running—app ran in the background and on device power-up
Automatic monitoring of smartphone hardware—issued alert/message if user turned off GPS/Wi-Fi asking to turn back on
Proprietary adaptive GPS collection technology to optimize battery life and minimize need to recharge phone on a typical day
Automatic transfer of collected data to a central server immediately after each trip is complete (assuming a connection)
Encryption of all personally identifiable information when transferring location and trip survey data to server
Companion rMove support website with FAQs and additional study information
Customizable in-app trip survey triggered automatically by trip stop—no user intervention was necessary
In-app customization by household where each household selects specific household members and household vehicles on a given trip
Ability, in the event the user obtained a new/different smartphone, to retain the household password and participate via the new/different smartphone
In-app trip survey had validation and real-time logic based on user response (e.g., a transit trip was asked a question about transit fare payment, but other travel modes were not shown this question)
In-app trip survey allows reporting of feedback and any details about trips (e.g., situations where user reports wanting to merge two trips)
Adaptive activity sampling where app integrated learning or inference based on previously answered trip surveys and the user was asked to simply confirm the prepopulated answer (lower burden) or change the

FEATURE
inference for a given trip
An “end-of-day” summary survey to obtain overall behavior such as reasons why no trips were made and to obtain any trips missed that day

9.3 | GPS SAMPLE TIMELINE

Data were collected for the Puget Sound GPS study in spring 2015 (see Table 28). A recruitment effort preceded the smartphone portion of the study in March, and in April, participants began to download the smartphone app prior to the travel period dates in early May. The last travel date was May 11, 2015. A week after the last travel date, a follow-up survey was sent to those who participated, those who recruited but did not download, and those who did not recruit to determine user experience and reasons why people did not participate in the study.

TABLE 28: 2015 STUDY TIMELINE

DATE	EVENT
March–June 2014	2015 Puget Sound Regional Travel Study conducted online and by telephone (a subset of these households become the 2015 invite pool)
September 2014–March 2015	rMove smartphone app feature development period
Monday, April 6, 2015	rMove submitted to Apple & Android stores for approval
Monday, April 6, 2015	Android Store approves and publishes rMove smartphone app
Wednesday, April 8, 2015	Household information survey open to response
Wednesday, April 22, 2015	Apple Store approves and publishes rMove smartphone app
Wednesday, May 13, 2015	Participants invited to begin downloading rMove smartphone app by mail and e-mail
Tuesday, May 19, 2015	First rMove travel date (Day #1)
Thursday, May 21, 2015	Last rMove travel date (Day #3)
Friday, May 22, 2015	Participants sent reminders to finish any incomplete surveys, instructions to uninstall rMove smartphone app
Monday, May 25, 2015	Final day that reminders and uninstall instructions were sent
Monday, June 1, 2015	Participants invited to optional follow-up feedback survey
Wednesday, June 9, 2015	Optional follow-up feedback survey was closed to response
June–July 2015	Data preparation and documentation efforts

10.0 GPS SAMPLE RECRUITMENT

10.1 | INITIAL INVITATION AND SCREENING

The sample for the 2015 Puget Sound GPS study was drawn from households who completed the 2014 HTS study and met the following criteria:

- Agreed to participate in future studies
- Provided an e-mail address
- All members age 16 or over reported owning an Android or iOS device in 2014

A total of 1,730 households matched this criterion and were invited to participate. Participants initially took a recruitment questionnaire to collect household demographics and smartphone information. This recruitment questionnaire closely resembled the 2015 Puget Sound HTS questionnaire, with the addition of person-level smartphone ownership details and person-level contact information. For a full list of recruit survey variables, refer to the above sections of this report.

Although all invited households provided smartphone ownership details in 2014, these details were not necessarily the same in 2015. Participants were re-asked for smartphone details in the recruit survey, and eligibility to participate in the GPS study was based on these updated details. If all household members over age 16 reported having an eligible smartphone (Android or iPhone 4S or higher), then that household was invited to participate. Household members younger than 16 were not considered participants, though their person-level information was retained in the recruit dataset.

Table 29 shows the smartphone ownership status reported at the person level in the recruit survey.

TABLE 29: 2015 RECRUIT SURVEY—TYPE OF SMARTPHONE OWNED (BY PERSONS)

TYPE OF SMARTPHONE OWNED (AGE 16 OR OLDER)	PERSONS	PERCENTAGE OF SMARTPHONE OWNERS	PERCENTAGE OF TOTAL
Android phone	398	41.7%	40.8%
iOS phone	538	56.3%	55.1%
Other type of smartphone (e.g., BlackBerry)	19	2.0%	1.9%
Total persons with smartphones	955	100%	--
Does not have a smartphone	21	--	2.2%
Total persons (age 16 or older)	**976**	**--**	**100%**

Among the 538 people with an iPhone were 51 people in 36 households with older phone models (iPhone 4 or earlier). These iPhones are from the mid-2010 or earlier and lack sensors that the rMove app utilizes, so they were not invited to the study. This resulted in a final tally of 487 people with Apple smartphones who were invited to participate for the assigned travel dates. Because there are numerous smartphones using the Android operating

system (particularly when compared to phones using iOS), the project team decided to invite all Android owners to download rMove and participate in the study for the three days of assigned travel.

After removal of households where not all members 16 or over had smartphones, the resulting pool of participants included 1,087 people (874 of whom were eligible participants) in 540 households. The final eligible pool of households was 31% of those initially invited to take the recruit survey.

10.2 | rMOVE INVITATION DISSEMINATION

The set of 1,087 people (874 eligible participants) in 540 households were loaded into the rMove database and assigned authentication codes. On May 13, six days before the first travel date, RSG sent an e-mail to the 874 eligible members inviting them to download rMove, with participation information (including authentication code and travel date) and download instructions for iOS and Android operating systems. At this time, RSG also mailed physical letters and instructions to all invited households. The combined e-mailed and mailed invitation effort was intended to achieve strong recruitment and provide convenient and accessible written instructions to all households. Following the initial invitation, e-mail reminders to download the rMove app were sent on May 15, May 17, and May 18. Additionally, on May 18, those who downloaded rMove received a brief reminder that surveys would start showing up the next day.

On the first travel date, 539 participants in 381 households had downloaded rMove by 3:00 a.m. (Pacific Time). During the travel study period, that number rose to 584 participants in 403 households, indicating that 45 participants downloaded rMove after the travel period began. Overall, the study saw 342 households (63% of those invited) in which every eligible member downloaded rMove, and 61 households in which some but not all household members downloaded rMove. Figure 3 shows the percentage of people and households invited who downloaded rMove, where a "full household" is a household in which every person invited downloaded rMove.

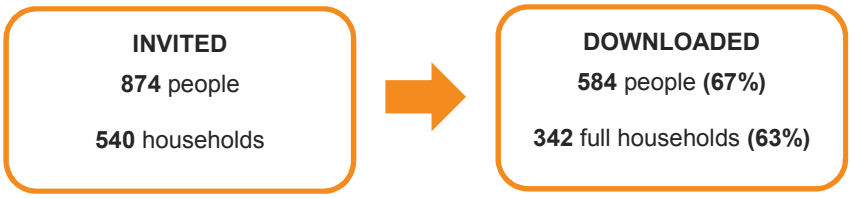


FIGURE 3: rMOVE DOWNLOAD RATE

Table 30 shows the device type of the 584 participants who downloaded rMove.

TABLE 30: PARTICIPANT SMARTPHONE TYPE

DEVICE TYPE	PARTICIPANTS	PERCENT

iOS	345	59.1%
Android	239	40.9%
Total	**584**	**100%**

10.3 | GPS SAMPLE RECRUITMENT DEMOGRAPHICS

Figure 4 through Figure 7 compare household demographics from the 2014 study ("2014 HTS") to the initial 2015 recruitment pool ("2015 Recruited") and to those who went on to download rMove ("2015 Downloaded"). The demographics for households who downloaded rMove represent households where at least one person downloaded the app, and is therefore based on the number of 821 total people (584 of which were eligible participants) in 403 households.

Two-person households represented a higher percentage of the sample in the 2014 HTS compared to the recruited sample in 2015 (see Figure 4), and one-person households represented a significantly lower percentage of the group who downloaded rMove. One possibility for this difference is that senior residents are more likely to live in a one- or two-person household and are less likely to own smartphones. Similarly, the person-level age results in Figure 6 show that people 25 to 44 years old make up a higher percentage of the sample in the rMove recruitment and download pools compared to the 2014 HTS sample. This is of interest because traditional approaches to HTSs 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 $25,000 comprised a larger portion of the sample than in 2015 (Figure 5), though households with incomes between $50,000 and $75,000 rose in the 2015 GPS recruitment and download samples. Additionally, people in households that recruited in 2015 or downloaded rMove are more likely to have a bachelor's degree than those in the 2014 HTS, and very slightly more likely to have a graduate degree (Figure 7).

These demographic differences between the 2014 HTS sample and the rMove pool reflect trends reported in the 2015 US Smartphone Use study conducted by Pew Research Center, which found that adults ages 18 to 50 with higher education and income levels have the highest smartphone ownership rates.[4]

[4] Smith, Aaron. "U.S. Smartphone Use." http://www.pewinternet.org/2015/04/01/chapter-one-a-portrait-of-smartphone-ownership/ April 2015.

FIGURE 4: NUMBER OF PEOPLE IN HOUSEHOLD 2014–2015

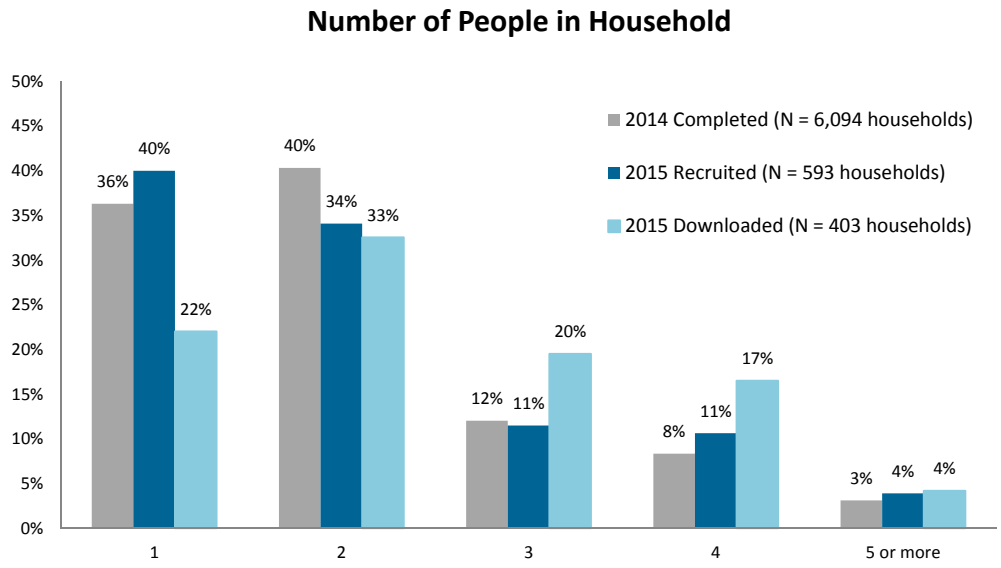


FIGURE 5: SELF-REPORTED HOUSEHOLD INCOME 2014–2015

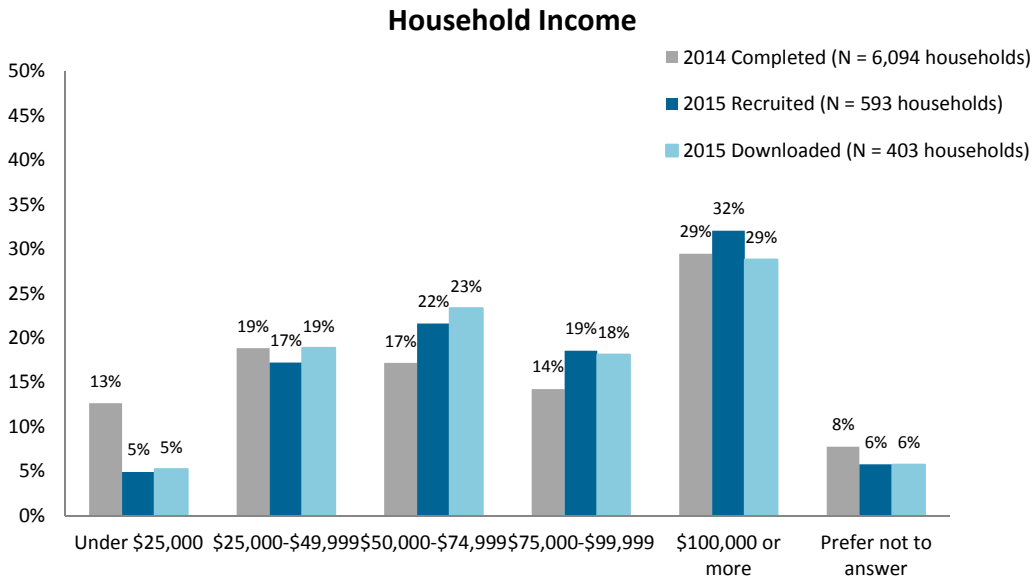


FIGURE 6: AGE OF HOUSEHOLD MEMBERS (AGE 16 OR OVER) 2014–2015

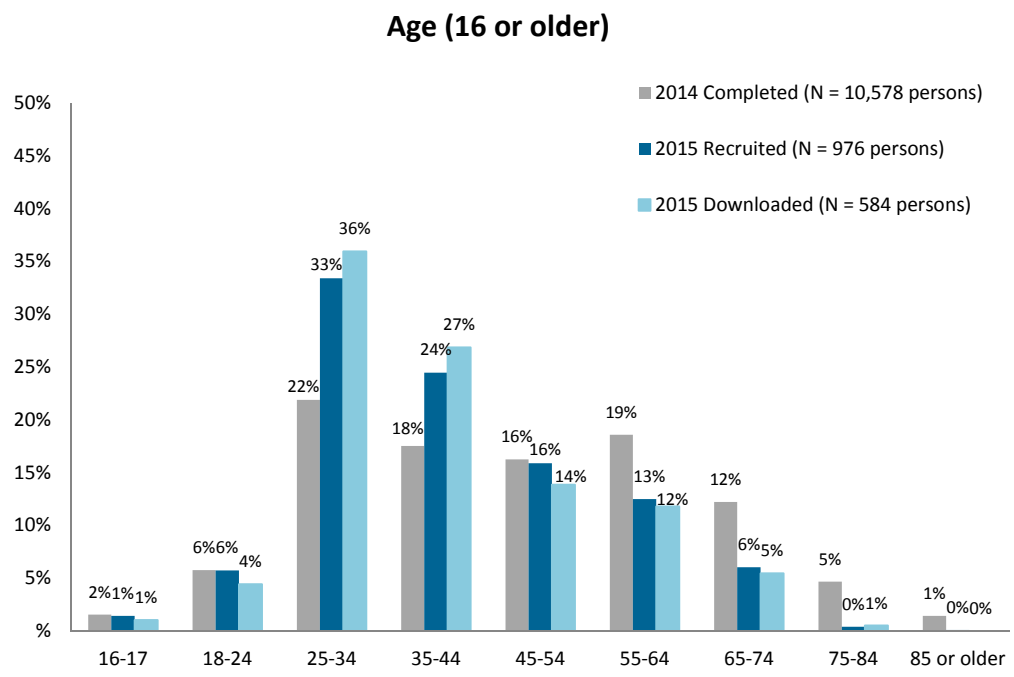
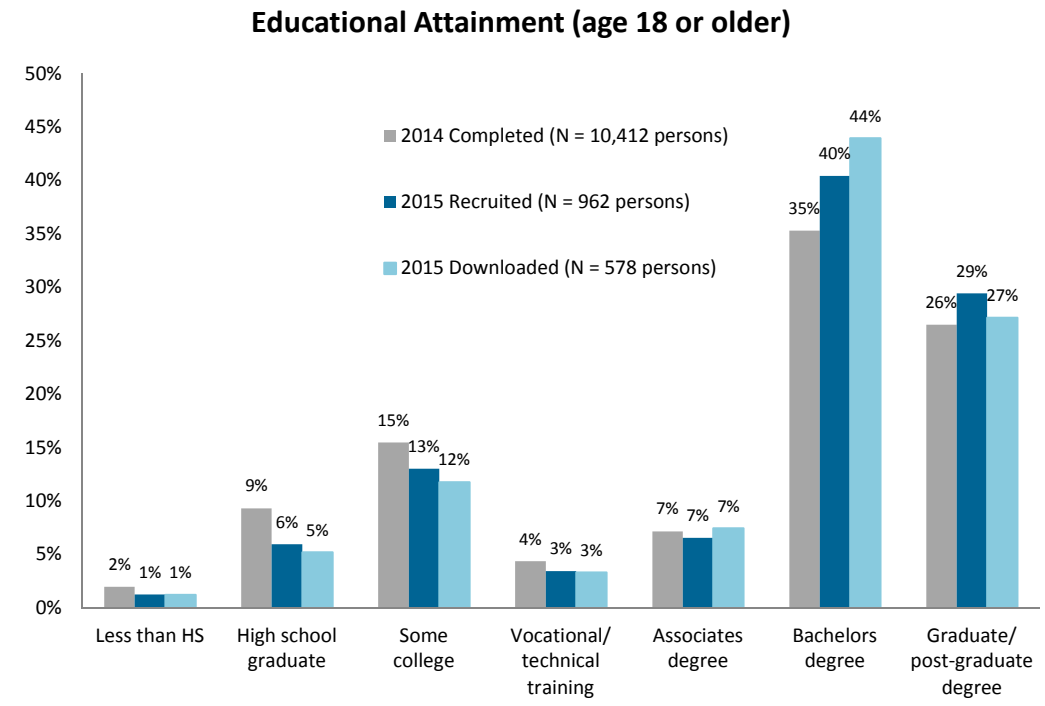


FIGURE 7: EDUCATION LEVEL (PERSONS AGE 18 OR OLDER) 2014–2015



11.0 GPS SAMPLE DATA COLLECTION

rMove collected travel survey data from participants' smartphones for three consecutive days: Tuesday, May 5 through Thursday, May 7, 2015. During this time, RSG monitored participation rates at the household and participant level through an internal web "dashboard," which displayed the number of trips and trip surveys per each participant device, device information, and other participation details needed for data monitoring and participant communication.

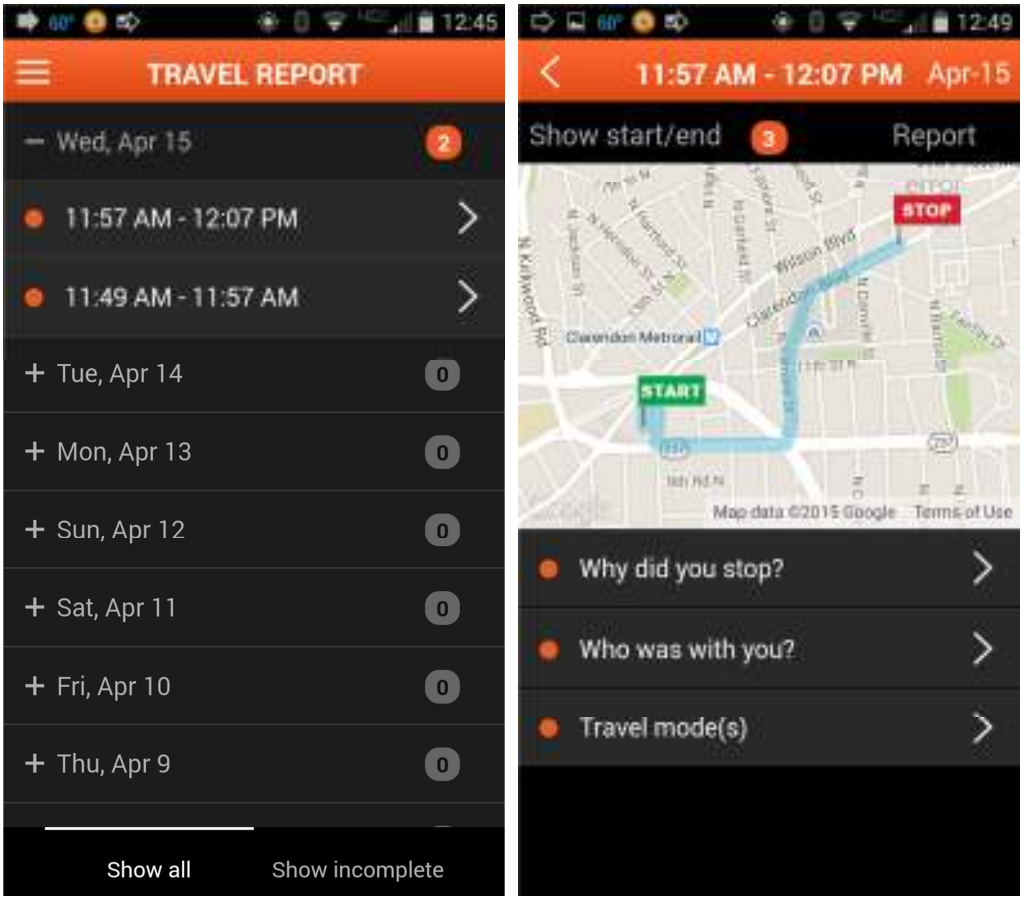
11.1 | DATA COLLECTED THROUGH rMOVE

In addition to collecting location data from devices, rMove collected user-provided responses through two types of surveys: trip surveys and daily summary surveys.

Trip surveys appear in rMove shortly after the app senses that a trip has been completed. A notification appears on the device letting the user know that surveys are ready in rMove. Surveys are labeled with the trip timestamp, and once the survey is selected, a map of the trip will appear, followed by questions about the trip.

Figure 8 shows an example of the rMove "home screen" with the list of surveys, and the trip survey page with the initial questions that show up in the trip survey. Once a mode is chosen, additional questions appear when relevant.

FIGURE 8: rMOVE INTERFACE



Trip survey questions include:

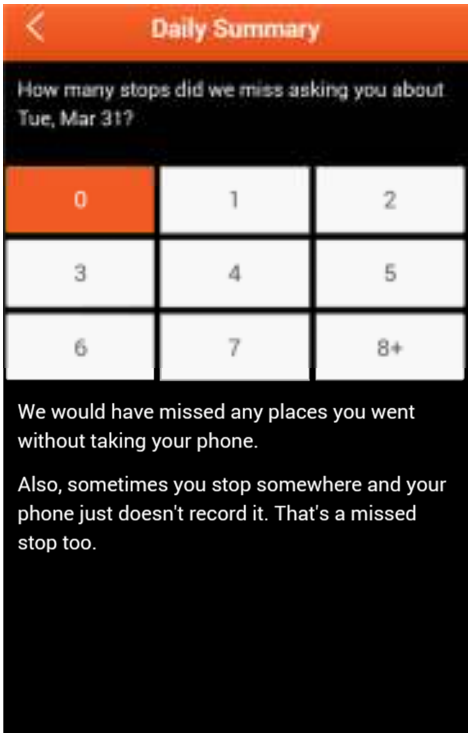
- Trip purpose
- Trip party
    - Household members listed by name
    - Number of non-household members
- Trip mode (can select more than one mode)
- Auto details, if auto mode:
    - Which vehicle, if personal vehicle
    - Where parked
    - Parking payment, if any
- Transit fare payment amount and method, if transit
- Taxi fare payment amount and method, if taxi

rMove recognized "repeat" trips, if the start and end location closely match the start and end location on a previous trip. When this type of trip was recognized, rMove inferred the trip details and asked the user to confirm or change the survey answers.

Daily summary surveys appeared in the app at midnight after the travel day was over. If the user traveled during the travel day, the daily summary asked one question about how many

trips rMove missed during the travel day (Figure 9). If rMove did not record any trips, 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.

FIGURE 9: rMOVE DAILY SUMMARY SURVEY



11.2 | INCOMING COMMUNICATION

Communication from participants through e-mail and in-app feedback is quantified by type in Table 31. Participants submitted 64 comments through the feedback button and sent 94 e-mails related to rMove or other aspects of the study. These numbers include cases where multiple comments and/or e-mails were submitted by the same participant, so they are not reflective of the total number of participants who submitted feedback or sent e-mails.

Questions about when to uninstall the app and whether the participant qualified for the gift card incentive ("Completion/Uninstalling" category) were the most common type of communication received, followed by general comments about app experience and participant eligibility questions. Technical issues included installation difficulties and GPS or Wi-Fi problems.

TABLE 31: INCOMING PARTICIPANT COMMUNICATION

CATEGORY	TOTAL	PERCENT
Completion/Uninstalling	45	28.5%
Comments	25	15.8%

Eligibility	19	12.0%
Technical issues	17	10.8%
Can't participate	15	9.5%
Missed trips	14	8.9%
Battery	9	5.7%
Spurious trips	9	5.7%
Trip questions	5	3.2%
Total	**158**	**100.0%**

11.3 | OUTGOING COMMUNICATION

Outbound communication with participants, other than responses to incoming communication, was conducted to encourage and retain participation levels. Outbound e-mails were sent to participants in the following situations:

- The device had not sent any trip data to the server
- Trip surveys had not been answered in several days
- Daily surveys had not all been answered after the end of the study period
- All surveys were complete and the participant could uninstall

A small number of devices did not send any data to the rMove server (and thus no data were observed via the dashboard) for various reasons, including:

- A person is believed to have legitimately made no trips during days with no trip data
- The device was a tablet and was not carried with the participant
- The device's GPS or Wi-Fi sensors were turned off
- The device had a custom operating system installed (an operating system not released by Apple or Android); and/or
- The app was uninstalled before the travel period began

If the device was a tablet or the participant was not making any trips, then this information could typically be determined through the dashboard, where the device type and "daily summary surveys" listing reasons for no travel could be viewed. Participants with tablet devices were asked to either install rMove on a smartphone instead or take their tablet with them on all travel. Participants who installed rMove on smartphones, but did not send any trip data to the server, were reminded to turn Wi-Fi and GPS on and turn "battery save" modes off. Thirty-three devices still did not send data to the server even after participants were reminded to ensure that GPS and Wi-Fi were enabled.

12.0 GPS SAMPLE RESULTS

The remainder of this section is based upon the 539 participants in 374 households whom RSG determined were active participants who answered at least one trip survey (whether they fully completed the study or not), out of the 584 people from 403 households that initially downloaded rMove. Forty-five respondents either did not answer any surveys or collected no trip data and are not included in the following evaluation.

12.1 | PARTICIPATION RESULTS

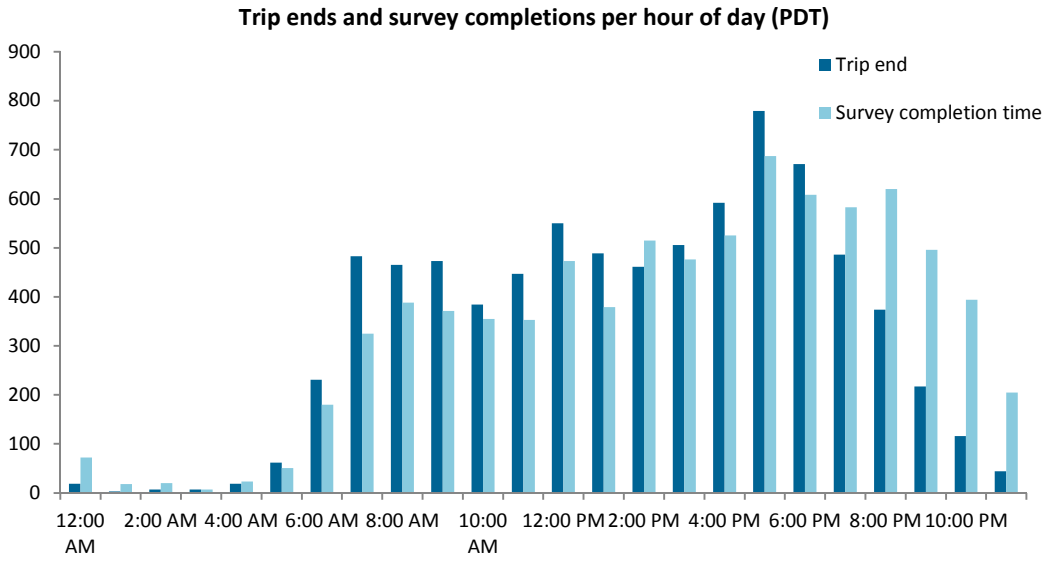
Table 32 lists the rate of survey completion for participants, excluding those whose devices did not send any data. The majority of participants completed all trip surveys in the app, and only a small percentage of participants completed less than two-thirds of their trip surveys.

TABLE 32: PARTICIPANT-LEVEL TRIP SURVEY COMPLETION RATE

PERCENTAGE OF TRIP SURVEYS COMPLETE	COUNT	PERCENT
0 to 33%	6	1.1%
34% to 66%	7	1.3%
66% to 99%	11	2.0%
100%	515	95.5%
Total	**539**	**100.0%**

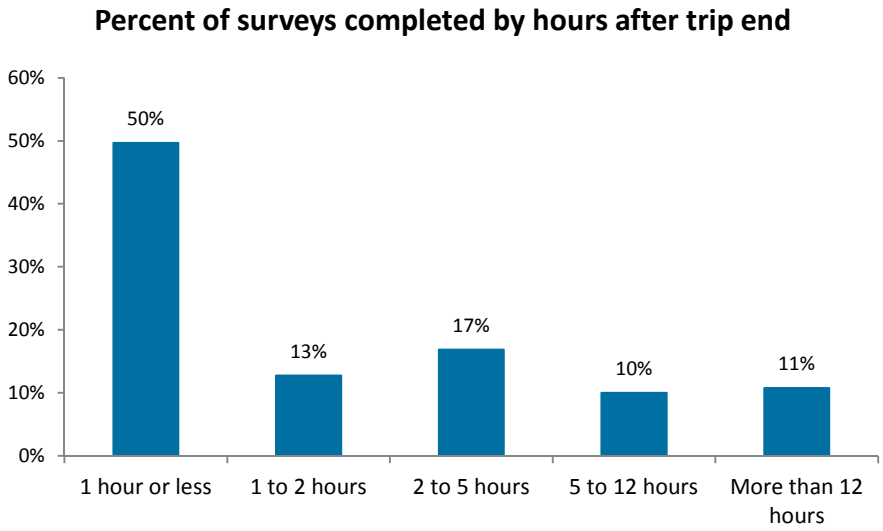
For trips where surveys were completed, surveys were generally submitted by the participant either within a few hours of the trip, or after travel was likely done for the day. Figure 10 shows the trip ends and survey completions per hour of day (PDT) for all trips that had surveys answered and were not reported as "not moving" errors. Trip totals peaked during the morning, noon, and evening rush hours; however, the highest rates of survey completion occurred between 5:00 p.m. and 9:00 p.m.

FIGURE 10: TRIP ENDS AND TRIP SURVEY COMPLETIONS PER HOUR



Although the survey completion peaked in the evening, most surveys were completed within one hour of the trip end. Figure 11 shows the time (in hours) between when trips ended and when surveys were completed. The median time between trips and surveys was one hour and 53 minutes (113 minutes). Twenty-five percent (25%) of surveys were completed within 10 minutes of the trip end.

FIGURE 11: TIME BETWEEN TRIP END AND TRIP SURVEY COMPLETION



In sum, the high retention rate and the short period of time that elapsed for most trips before survey completion indicate early success in achieving lower participant burden and higher reporting accuracy. The household retention rate of 87% is higher than the HTS retention rate of 83% in 2014. This indicates the potential for even further burden reduction in the future, as rMove functionality improves and as people adopt newer smartphones.

Additionally, the short period between most trips ending and trip survey completion compares favorably to the latency in traditional online and phone surveys, where the diary survey is usually completed one day or more after the travel date.

12.2 | rMOVE DATA PREPARATION

The trip and location data from rMove were cleaned and processed in two stages. First, all rMove data was first copied into a new database; this was done in order to preserve the raw rMove data in its original form. Second, this copied dataset was then loaded into an interface where RSG could review each participant's trips spatially on a map. The following processes were performed at this stage:

- All points with unrecorded speed and heading data were removed from the location data, except for points that were the origin or destination point of a trip.
- Based on spatial analysis and respondent error reporting, analysts removed trips that were false (spurious) trips, split trips with more than one clear stop, and merged trips where two or more trip traces were clearly part of the same trip.
- Trips were automatically derived when a gap of 250 meters or more existed in a person's trip record, using the previous destination and the next trip's origin as the origin and destination points of the derived trip.
- Distance along the GPS path was automatically derived.

In total, 1,370 trips resulted from splitting trips and 145 trips resulted from merging trips. Additionally, 463 trips were derived due to gaps in trip records. The dataset with the aforementioned edits was then exported, and further processes were performed on the dataset without manual spatial review of trips. These procedures included the following:

- Trips were derived for non-rMove participants in households based on whether non-rMove household members were reported as part of a trip party.
- Trip counts were added to person and household records.
- A "missing data" value was derived where trip or daily summary survey details were missing.
- Various other data correction and cleaning was done at this stage on a case-by-case basis.

12.3 | GPS SAMPLE TRIP-LEVEL RESULTS

The final sample includes 10,324 trips, of which 9,582 have complete trip survey data (92%). This total includes derived trips (described previously.)

TRIP ERROR REPORTING

When answering a survey for a trip, the respondent could report an error on that trip if they felt the need. Three of these error types were reviewed during the first stage of processing, as mentioned previously: 1) "more than one trip" errors; 2) "part of another trip" errors; and 3) "not actually moving" errors. The totals below are based on the cleaned data, so trips that were processed and corrected are not included in these counts. If the analyst could not

ascertain the error reported, then they did not attempt to correct the error. This was typically due to respondent mistakes in error reporting or missing information (e.g., if rMove missed the last piece of a trip, the respondent might report a "part of another trip" error that could not be fixed by the analyst due to the missing leg of the trip).

ERROR TYPE	COUNT
This was more than one trip (e.g., brief stop for gas during trip)	14
This was part of another trip (e.g., GPS cut out mid-trip)	51
This was not a trip	14
Other error	32
Was not actually moving (e.g. spurious trip)	48
Trip has the wrong time shown	28
Total	**187**

Another possibility for error is where a trip occurs but is not captured by rMove. This can happen due to user error (e.g. did not carry smartphone, did not have GPS/WiFi sensors on, etc.) or due to a technical error (e.g. poor cell coverage, a technical issue with rMove and/or the smartphone). Respondents reported in the daily summary surveys how many trips were missed per day (e.g. not captured by rMove). Of 1,604 daily summary surveys answered, 372 (23%) reported at least one trip missed by rMove. Table 33 shows the number of missed trips reported in each of the 372 daily summary surveys. Just over half of these have one missed trip reported, with a small number of days where respondents reported five or more missed trips.

TABLE 33: NUMBER OF MISSED TRIPS PER DAY REPORTED BY RESPONDENTS

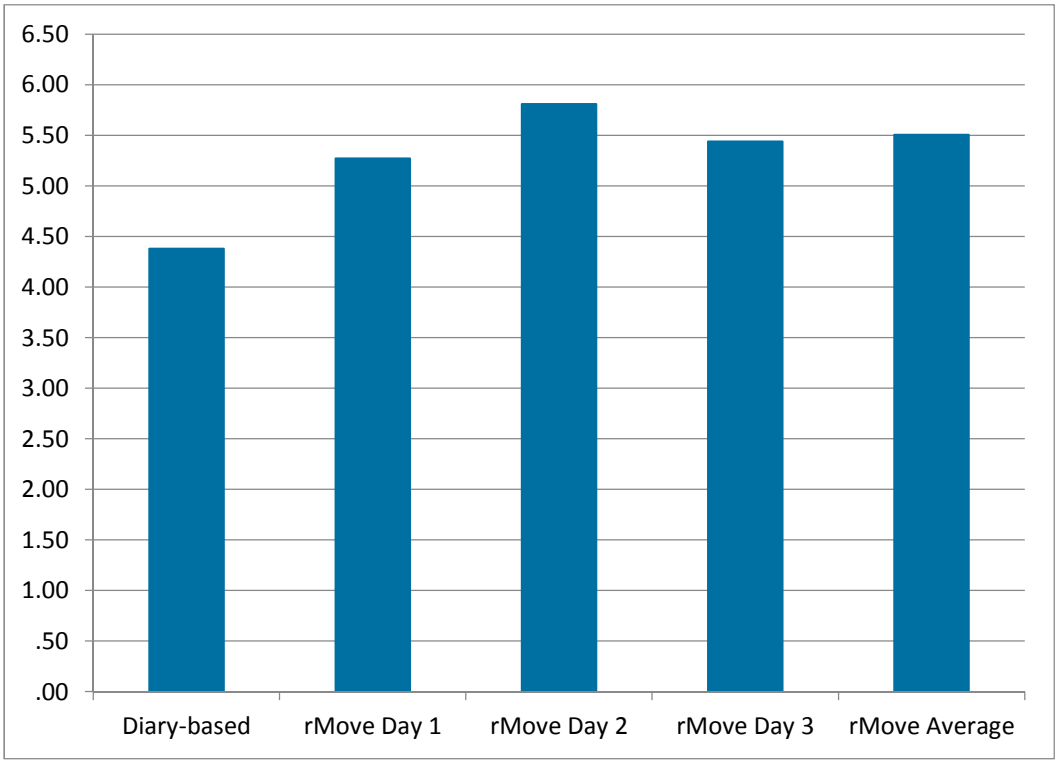
MISSED TRIPS PER DAY	COUNT
1	203
2	87
3	29
4	25
5	11
6	6
7	4
8	7
Total	**372**

TRIP RESULTS COMPARED TO 2015 WEB-BASED DIARY

As discussed earlier in this report, a combined panel and cross-sectional sample of households participated online/over the phone through the traditional diary conducted parallel to the 2015 rMove study effort. Although the 2015 diary-based participants and the rMove participants comprised a different set of households, the comparison of trip rates and other trip details between the two provides potential insight into how many and what type of trips are better captured through rMove compared to web-based diaries.

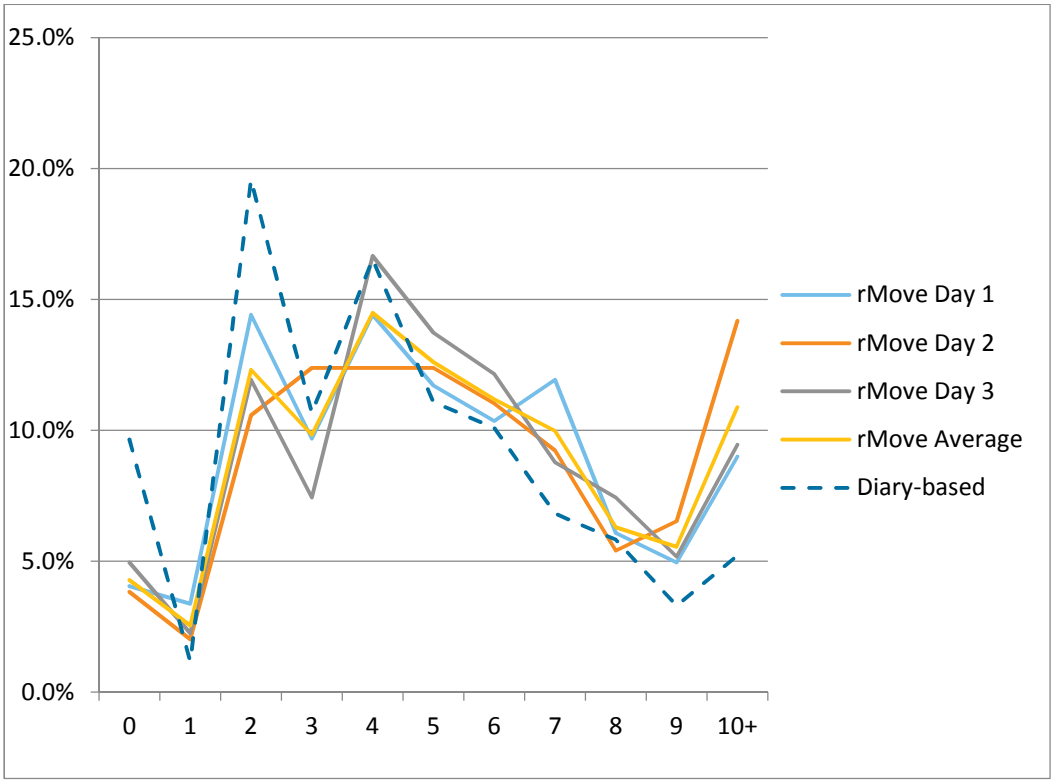
Figure 12 shows the average trip rate from the 2015 one-day diary-based survey (carried out on Tuesday, Wednesday, or Thursday), about 4.4 trips/person-day, compared to the rMove pilot survey average trip rates of 5.2 on Tuesday, 5.7 on Wednesday, and 5.4 on Thursday, for an overall average of 5.5 trips per day. These early results indicate that the smartphone-based method yields about 25% more trips per person-day compared to the diary-based trip rates.

FIGURE 12: COMPARISON OF AVERAGE TRIPS PER PERSON-DAY FROM 2015 WEB TRAVEL DIARY AND EACH DAY OF THE rMOVE STUDY



One reason for the higher trip rate is that fewer respondents neglect (or forget) to report any trips at all in any given survey day. Figure 13 shows that for 10% of person-days (for smartphone-owning adults) in the diary-based data, respondents did not report any trips at all. For each of the three travel days with rMove, only about 5% of respondents did not make any trips at all. This is an indication that the cases of non-trip-making in diary-based methods are at least in part due to nonresponse bias, where people make some trips but do not report them.

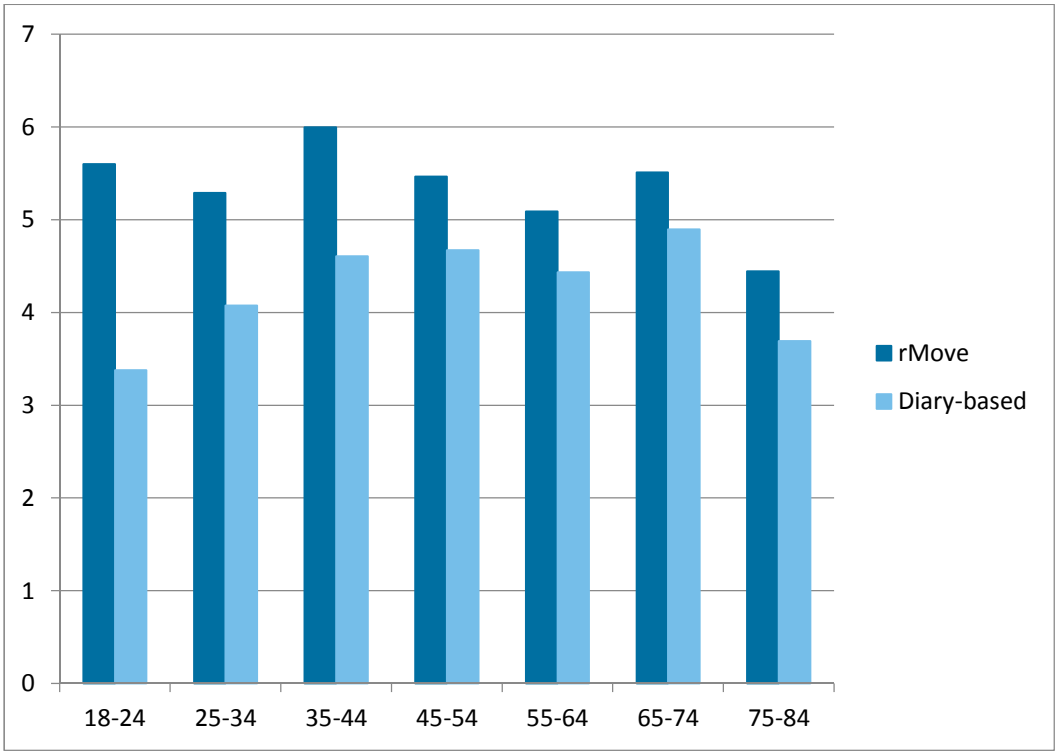
FIGURE 13: DISTRIBUTION OF SAMPLE BY PERSON-TRIPS/DAY



At the other end of the chart in Figure 13, we see that only about 5% of travel days in the diary-based data contain 10 or more trips, compared to the about 10% of rMove travel days. This indicates that the increased trips rates for the smartphone method are also due to capturing more trips during busy travel days, which respondents may overlook or find too burdensome to report using the diary recall method.

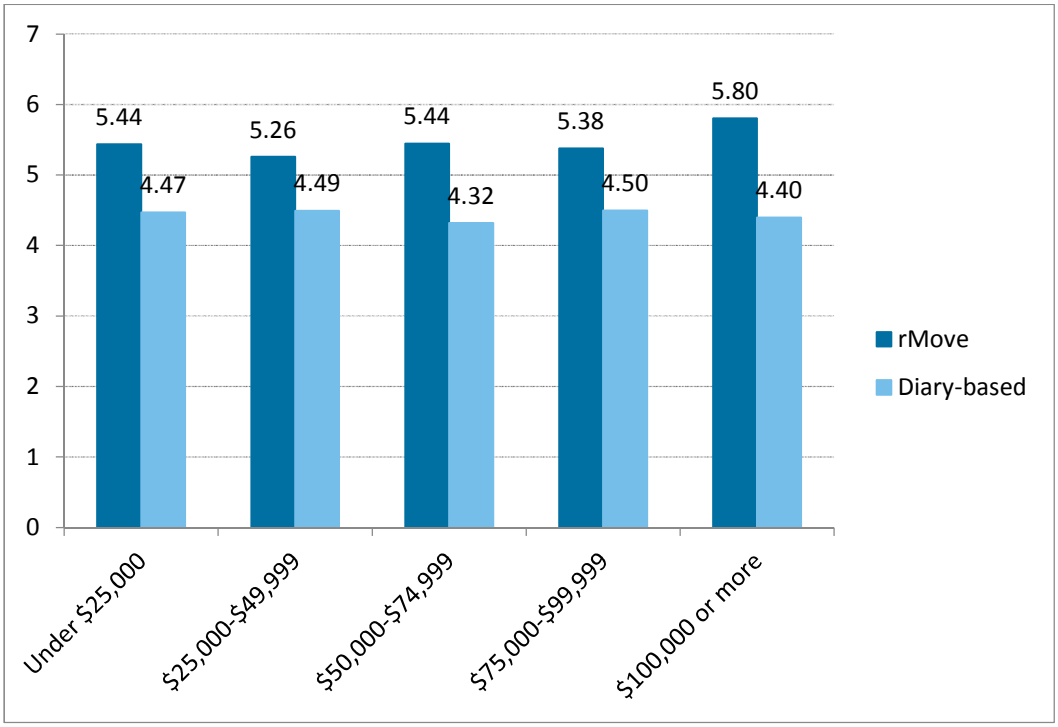
Another possible reason for higher trip rates with smartphone-based methods is a change in how self-selection bias may affect the data. With diary-based surveys, it has been suspected that even after accounting for demographic differences, those who are most busy and travel the most may be somewhat less likely to complete diary-based surveys due to respondent burden. There is at least some evidence that this type of self-selection bias is less pronounced for smartphone-based data collection, because of less perceived burden and/or the technological aspect being more appealing to certain types of people. For example, when analyzing the diary-based data across different age groups (including only smartphone-owning adults), we find that the 18 to 24 and 25 to 34 age groups report markedly fewer trips per day on average than other age groups—even the 65 to 74 age group (Figure 14). When analyzing the smartphone-based data, however, this age difference disappears, with no clear trend across the age groups from 18 to 74 years old. This finding suggests that: a) the younger age groups are less motivated when filling in diary-based surveys, but are more (ore equally) conscientious when using their phones; and/or b) the subset of younger people who are willing to complete smartphone-based surveys tend to travel more, on average, than the subset of younger people willing to complete diary-based surveys.

FIGURE 14: AVERAGE TRIPS PER RESPONDENT-DAY BY AGE GROUP



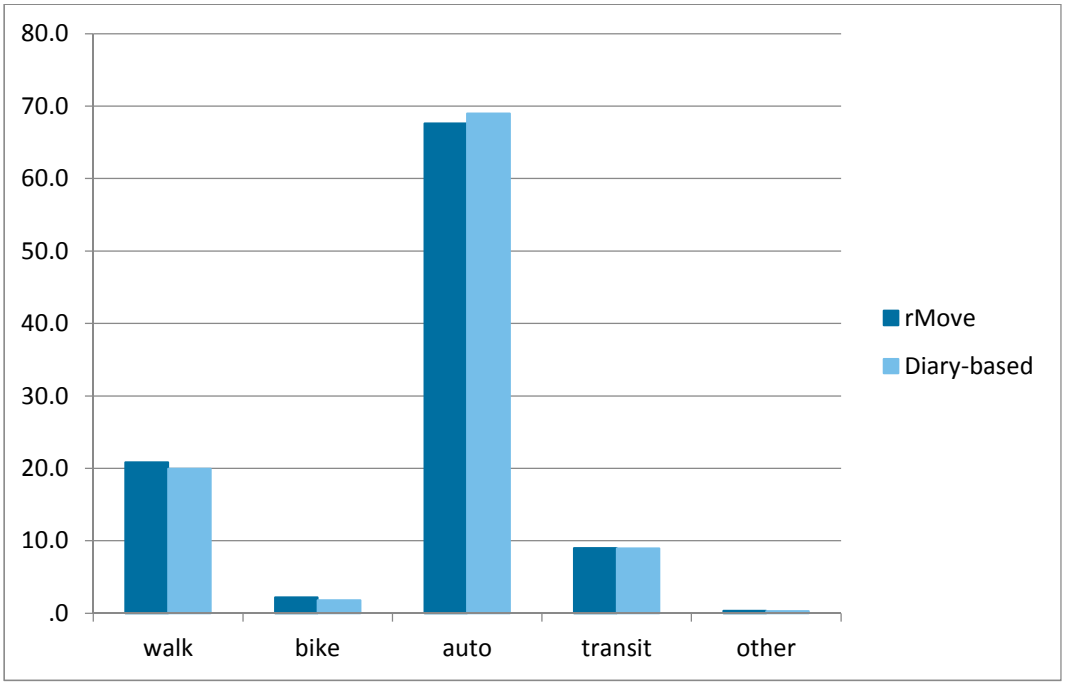
It is also interesting to look at trends in trips/day by household income level. In Figure 15, reported trip rates are similar across the different income groups for both the smartphone- and diary-based methods. The one exception is the higher-income households earning $100,000 or more, which reported a similar trip rate as other income groups in the diary-based study but have a higher relative trip rate in rMove. This provides some evidence in support of the supposition that the smartphone method may be more successful at capturing busier, higher-income households.

FIGURE 15: AVERAGE TRIPS PER RESPONDENT-DAY BY INCOME GROUP



It is also interesting to compare the distributions of the trip characteristics for the two survey methods. Figure 16 shows that the percentage of trips by each mode is very similar for the two methods, with a slight increase in the percentage of trips that are by walk and bike, and a slight decrease in the percent by auto.

FIGURE 16: PERCENTAGE OF TRIPS BY MODE



When comparing the trip distance distribution (Figure 17), the two methods are again similar, but with the smartphone method providing a somewhat larger fraction of trips under one mile. (For rMove, the distance is based on the distance between trace points along the trip; for rSurvey, it is based on the Google API road distance between the trip endpoints.) Table 34 further breaks down the distance distribution by mode, and it appears that the distance distributions for walk and bike are very similar for the two methods, although the smartphone-based method may be better at capturing the long bicycle trips make for exercise, which are rarely reported in diary-based data. The main difference, however, is that rMove has a higher percentage of short auto trips under one mile. These quick auto trips may often be left out of diary-based surveys because they are forgotten or not considered worth reporting.

FIGURE 17: PERCENTAGE OF TRIPS BY ONE-WAY DISTANCE

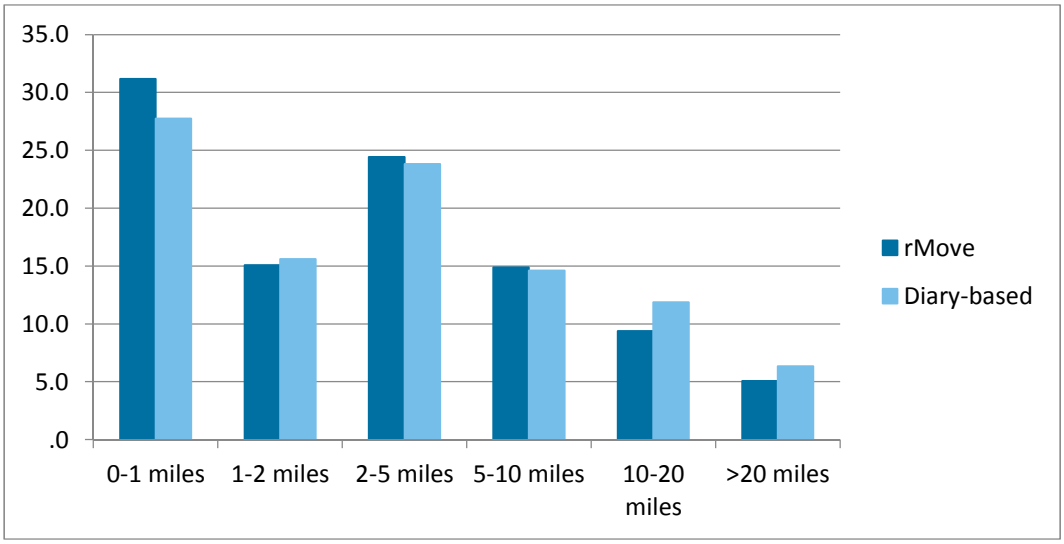


TABLE 34: TRIP DISTANCE DISTRIBUTION FOR rMOVE AND EACH MODE

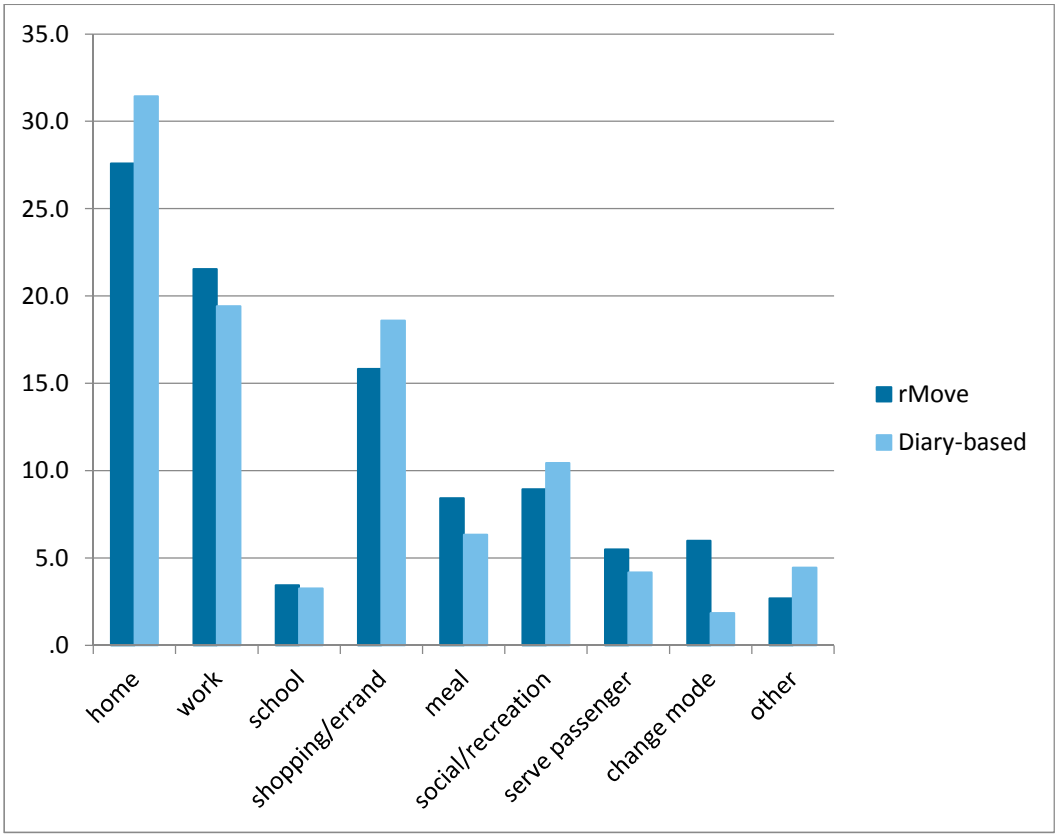
rMOVE	WALK	BIKE	AUTO	TRANSIT
0–1 miles	83.3%	18.6%	18.0%	12.5%
1–2 miles	12.5%	23.6%	15.8%	13.9%
2–5 miles	3.3%	33.6%	30.2%	27.4%
5–10 miles	0.3%	14.3%	18.3%	23.3%
10–20 miles	0.5%	6.4%	11.5%	14.1%
>20 miles	0.2%	3.6%	6.1%	8.7%

TABLE 35: TRIP DISTANCE DISTRIBUTION FOR DIARY-BASED AND EACH MODE

DIARY-BASED	WALK	BIKE	AUTO	TRANSIT
0–1 miles	82.4%	18.9%	14.6%	8.9%
1–2 miles	12.8%	22.0%	16.3%	15.4%
2–5 miles	3.9%	34.4%	29.0%	26.9%
5–10 miles	.4%	18.9%	17.8%	21.2%
10–20 miles	.2%	5.7%	14.5%	19.3%
>20 miles	.3%	—	7.7%	8.3%

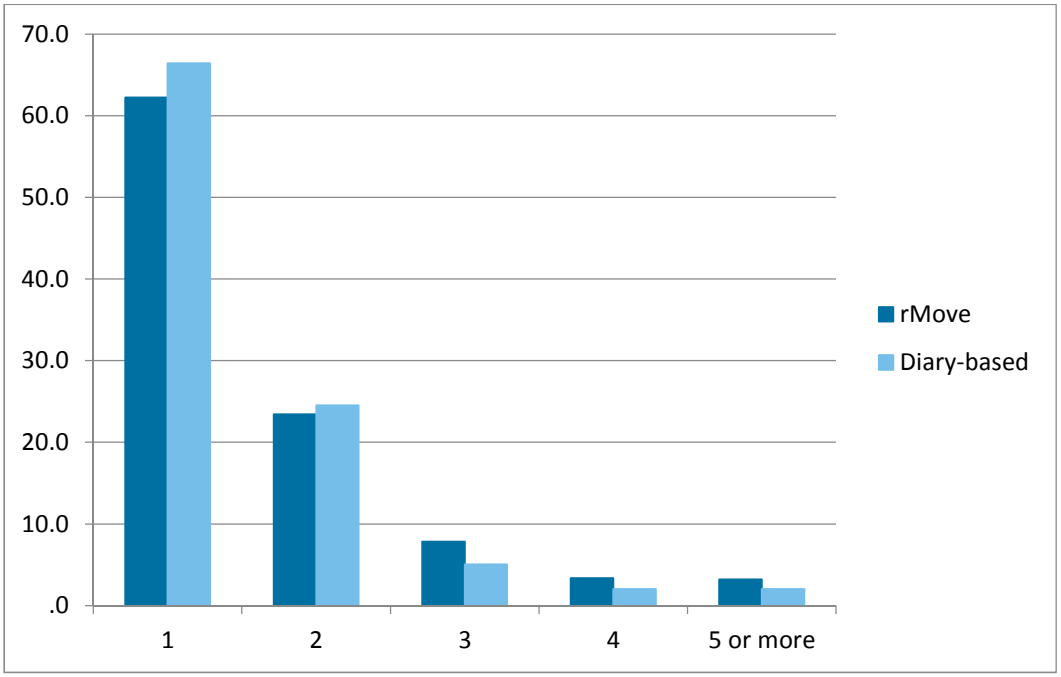
When comparing trips by destination purpose for the PSRC pilot data (Figure 18), the percentage of trips returning to home is lower for the smartphone-based method. The average number of trips per home-based tour is approximately the inverse of the percentage of trips going home, meaning that the rMove data has more trips per tour, and thus more intermediate stops and trip chaining along tours. One reason for that is the higher percentage of "change mode" tours. With the rMove survey, it appears that often multimode tours are broken into separate trips rather than grouped with the access and egress modes, so more trip linking needs to be done in post processing. (This linking has not been done yet, so the more detailed aspects of this difference are not yet known.) Otherwise, there are no major differences in the percentage of trips for different purposes.

FIGURE 18: PERCENTAGE OF TRIPS BY DESTINATION PURPOSE



Finally, Figure 19 details the percentage of trips by travel party size. The percentage of trips where the person traveled alone is about 65% with both methods, and there are no substantial differences across the other groups.

FIGURE 19: PERCENTAGE OF TRIPS BY TRAVEL GROUP SIZE (NUMBER OF PERSONS)



Overall, the trip characteristics are surprisingly consistent across the two survey methods. rMove appears to capture about 25% more trips—with the greatest increase for the youngest age groups and highest income groups—but with no substantial shift in the types of trips that are captured.

13.0 SMARTPHONE-BASED GPS FOLLOW-UP SURVEY

13.1 | OVERVIEW

The project team also issued a follow-up survey to invited participants on June 1, 2015, ten days after the travel period ended. Participants in three groups were invited to take the follow-up survey:

- People who downloaded rMove.
- People who were invited to download rMove but did not download.
- People who were invited to the recruit survey but did not recruit.

The follow-up survey solicited feedback on user experience with rMove, and sought 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. Participants who downloaded rMove were asked about their use habits, experience, and satisfaction with rMove. Survey questions asked participants to indicate when they answered surveys, rank questions on user experience, provide an account of the experience among household members, provide comparisons to the 2014 study, and provide open-ended statements about rMove's features.

The survey was closed to response on June 10, 2015. Table 36 shows the response rate by respondent type.

TABLE 36: FOLLOW-UP SURVEY RESPONSE RATE

RESPONDENT TYPE	COMPLETED	INVITED	RESPONSE RATE
Downloaded rMove	230	582	39.5%
Did not download rMove	40	292	13.7%
Did not recruit	86	1,081	8.0%
Total	**356**	**1955**	**18.2%**

13.2 | RESULTS

SURVEY EXPERIENCE COMPARED TO 2014

When comparing the survey experience in 2015 using rMove to the online/phone-based survey experience in 2014, respondents generally favored the experience of participating via rMove, as shown in Table 37. Because all questions were optional, the number of people responding to each question is slightly different, and these counts are detailed in the table.

Ninety percent (90%) of respondents agreed that participating in 2015 was easy, compared to 67% of respondents who agreed that participating in 2014 was easy. Similarly, 67% agreed that participating in 2015 was more fun than in 2014. While a majority of respondents (60%) agreed that they spent less time participating this year than last year, 12% disagreed that they spent less time, which was the highest overall disagreement in any category. However, this may be partially attributed to the fact that 2015 encompassed a three-day travel period, compared to a one-day travel period in 2014.

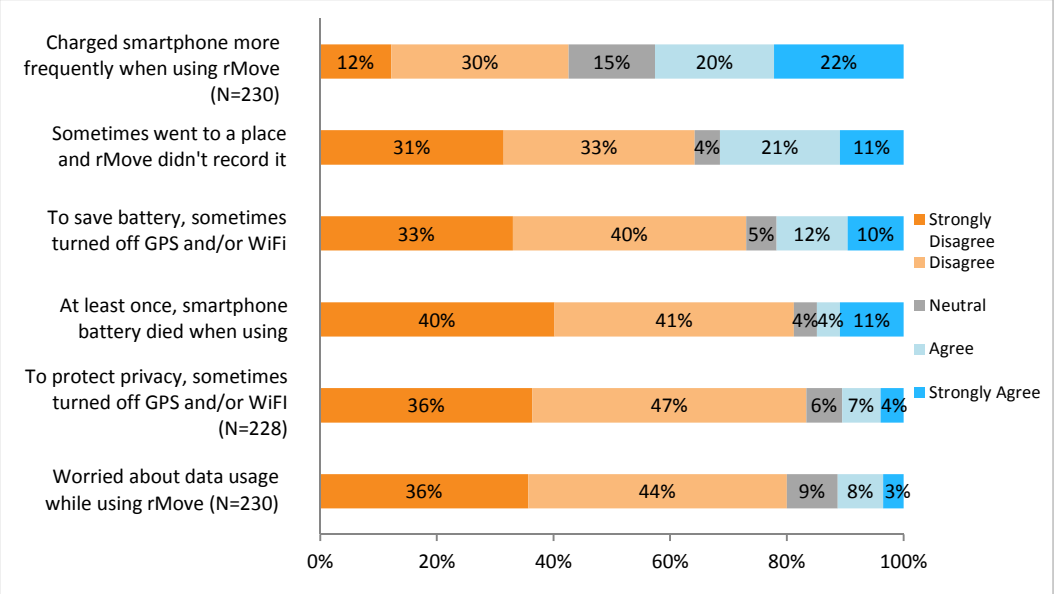
TABLE 37: PARTICIPANT COMPARISON BETWEEN 2014 AND 2015

	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
Participating was easy in 2014 (N = 227)	1.8%	4.4%	26.9%	54.2%	12.8%
Participating was easy in 2015 (N = 228)	1.3%	3.1%	5.3%	42.5%	47.8%
Spent less time in 2015 participating than 2014 (N = 228)	5.3%	7.0%	27.2%	30.7%	29.8%
More fun to participate in 2015 compared to 2014 (N=227)	1.3%	3.1%	28.2%	30.0%	37.4%

USER EXPERIENCE

The follow-up survey asked agree/disagree questions about various aspects of user experience, the results of which are shown in Figure 20. Battery-related issues were the most-often agreed with or strongly agreed with statements—42% of participants agreed that they charged their smartphone more frequently when using rMove, and 22% agreed that they occasionally turned off GPS or Wi-Fi to save battery. Just over 30% of respondents reported that they sometimes went to a place and rMove did not record it.

FIGURE 20: AGREEMENT/DISAGREEMENT WITH USER EXPERIENCE STATEMENTS



The follow-up survey also asked participants when they answered trip and daily summary surveys, in "select all that apply" questions. As shown in Table 38, the majority of respondents (60%) said that they answered trip surveys right after they appeared in the app, and nearly 50% of respondents said they answered several surveys at once. Only 1% of respondents said they answered trip surveys after several days. Responses to this question match the trip completion vs. survey completion trends observed in the data.

TABLE 38: WHEN RESPONDENTS ANSWERED TRIP SURVEYS (SELECT ALL THAT APPLY)

	COUNT	PERCENT
Right after they appeared in the app	137	59.6%
Answered several trip surveys at once	110	47.8%
All at once at the end of the day	55	23.9%
When waiting somewhere for something (e.g. waiting in line)	51	22.2%
After several days	2	0.9%
At other times	2	0.9%
Total	**230**	**--**

With regard to daily summary surveys, the vast majority (95%) reported answering these surveys in the morning on the following day when they saw the survey in the app.

REASONS FOR NONPARTICIPATION

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. The reasons why these respondents chose not to participate are shown in Table 39. The most-often selected reason for not participating is "other reason," which respondents were required to clarify in a text box. Many "other" reasons were related to being out of town on the travel date, or not having time to participate. Similarly, "too busy" received the next highest number of responses.

TABLE 39: REASONS RESPONDENTS DID NOT RECRUIT OR DID NOT DOWNLOAD rMOVE

REASON(S) DID NOT PARTICIPATE	DID NOT RECRUIT		DID NOT DOWNLOAD		TOTAL	
	COUNT	PERCENT	COUNT	PERCENT	COUNT	PERCENT
Other reason	30	35%	15	37%	45	35.4%
Too busy	21	24%	11	27%	32	25.2%
Did not see e-mails	22	26%	3	7%	25	19.7%
Privacy concerns	13	15%	12	29%	25	19.7%
Tried but had problems	4	5%	8	20%	12	9.4%
Doesn't use smartphone frequently	8	9%	3	7%	11	8.7%
Battery concerns	5	6%	3	7%	8	6.3%
Did not understand how to participate	1	1%	0	0%	1	0.8%
Does not own smartphone	1	1%	0	0%	1	0.8%
Total	**85**	**—**	**41**	**—**	**126**	**—**

14.0 GPS SAMPLE CONCLUSION & NEXT STEPS

14.1 | ADMINISTRATIVE

Once participants downloaded rMove, their retention rate was very high, with 95% of people completing every single survey in rMove. The primary challenge in retaining participants is encouraging all adult members of a household to download rMove—63% of households invited had every eligible member download rMove. Additionally, while the rMove sample was not vastly different from the 2014 diary sample in demographic composition, the potential for self-selection bias is prevalent due to the smartphone focus—households with higher incomes and education levels are more prevalent in the rMove sample. It should also be noted this was partly due to purposeful sampling – with a limited budget the project team only invited households that were known to have smartphones. Achieving a higher and more representative retention rate is a priority from an administrative standpoint.

Potential steps toward these administrative goals include:

- Sending smartphones to households where all or some adults do not own smartphones;
- Offering a higher incentive for under-represented households;
- Offering more flexibility in travel dates or a rolling period over which households can participate (many households did not participate because they were busy or out of town during the travel period); and
- Addressing privacy concerns more clearly in invitation materials.

Several of these steps have since been accomplished on projects in other regions.

14.2 | DATA COLLECTION

Steps can be taken in rMove to improve the quality of data collected, increase the overall number of trips captured, and reduce the time spent postprocessing the trip data. These steps include:

- Allowing users to "split" and "merge" trips within rMove;
- Allowing users to add trips in rMove when the app misses trips; and
- Allowing users to add trips that their children take within rMove.

The first of these functionalities is under development in rMove, and further improvements are planned in the coming year.

14.3 | MODELING IMPLICATIONS

The main implications for travel demand modeling include a number of issues:

- Compared to more-traditional methods, smartphone-based surveys can provide a more complete "inventory" of household trip-making, with particular benefits for shorter trips such as walk and bike trips, including "loop trips" for exercise or recreation.

- It appears possible to complete smartphone-based surveys for up to seven or more days per respondent with no apparent drop-off in survey participation or completion rates. Furthermore, all travel days have full trip details and can be used in modeling. This not only provides more useful data per respondent, but can enable new types of models, such as the allocation and substitution of activities across days of the week.
- Initial evidence suggests that smartphone-based surveys are less prone to some of the types of nonresponse bias and self-selection bias that have been prevalent in past diary-based travel surveys—particularly the biases toward older households and less "active" respondents.
- Smartphone-based location and time-of-day data are inherently more accurate than the data reported by respondents. This is even more true for smartphones, which people tend to carry with them almost everywhere, than it is for the GPS devices used in previous travel surveys, which people often forget or leave in their vehicles.
- Smartphone-based surveys also provide trace data, from which respondents' travel routes and speed profiles can be derived. (Here, there is a careful tradeoff between accuracy of the data and the amount of drain on the phone battery, which should become less of an issue in the future as smartphone sensors continue to improve.)

In 2015, about 70% of adults in the United States own smartphones, with the percentage of smartphone users increasing rapidly. However, the approximate 30% of adults who do not own smartphones is significant, and our experience has shown that some of them are not willing or able to complete surveys by smartphone even if one is provided to them for free.

Given this impediment, the foreseeable future we may need to rely on mixed methods, with some respondents providing data via smartphone and others using more-traditional diary-based methods. Using mixed methods need not adversely impact modeling, however, as long as the survey is designed so that the different methods provide the same data items, meaning that the data can be merged and used jointly in analysis. When that is the case, one can estimate "bias parameters" on the non-smartphone data cases in order to identify and adjust for any method-specific differences. In a sense, this is the reverse of the way GPS data has been used in the past for trip-rate correction, and is much more powerful in this case because both types of data can be used jointly in modeling. Thus, bias parameters can be estimated not only for trip or tour generation rates, but also for other variables such as mode choice constants and time-of-day choice constants.