MEMORANDUM

TO: TPB Technical Committee

FROM: Ken Joh, Principal Statistical Survey Analyst
Yu Gao, Transportation Engineer
Zhuo Yang, Transportation Data Analyst
Nicole McCall, Manager, Planning Research and Assistance

SUBJECT: 2017-2018 Regional Travel Survey 7-Day Panel Evaluation

DATE: January 6, 2023

PURPOSE

The purpose of this memorandum is to share the results and summary of overall findings from TPB staff's evaluation of the smartphone app-based survey methodology. The 7-Day Regional Travel Survey (RTS) Follow-On Smartphone Panel Survey (SPS) served as the primary source for this evaluation.
In the summer and fall of 2021, TPB staff performed a comprehensive review of the SPS data files and all data items contained in those files. Data editing and imputation were performed, followed by trip logic and consistency checks which were completed in December 2021. After the data processing was completed, TPB staff conducted an evaluation to assess the effectiveness of the smartphone app-based survey methodology.

This memo evaluates the effectiveness of the smartphone app-based survey methodology based on the findings from the comprehensive review, reflecting on the degree of data cleaning and imputation as well as issues found during the trip logic and consistency checks. As part of the SPS evaluation, user comments providing feedback on the survey experience were reviewed and analyzed. The memo concludes with a summary of key findings and next steps.

BACKGROUND

In 2019, the Metropolitan Washington Council of Governments/Transportation Planning Board (COG/TPB) conducted a follow-on survey to the 2017/2018 Regional Travel Survey (RTS) based on a smartphone app-based methodology. The RTS Follow-On Smartphone Panel Survey (SPS) sampled a panel of respondents from the RTS. The primary objectives of the SPS were to evaluate the effectiveness of the smartphone app-based survey methodology, to assess the quality of the data collected from a smartphone-app based survey, and to determine the feasibility of smartphone surveys for future survey efforts by COG/TPB. Furthermore, the SPS collected detailed travel information for multiple days (the RTS was a one-day travel diary) so the SPS can provide insights on day-to-day variability of travel behavior in the region. The SPS collected demographic information and travel diary information with a survey instrument based on a proprietary smartphone app called *rMove* developed by RSG, the survey contractor for the RTS and the SPS.

SPS Survey Design and Methodology

The survey design and methodology for the SPS differed from the RTS, which employed a more traditional travel survey methodology. Unlike the RTS, which was primarily a web survey that consisted of a one-day travel diary, the SPS was a smartphone-only survey which asked participants to answer travel diary questions for up

to seven days using *rMove™*[1]. In addition, the SPS was conducted at the person-level and the RTS was conducted at the household-level. The SPS was also a considerably smaller-scale survey compared with the RTS since SPS participants comprised a small sample of RTS participants. The sample addresses within the SPS survey region were selected from RTS households who resided in COG/TPB Activity Centers. In total, 1,039 residents completed the SPS while 15,976 households completed the RTS.

Key methodological differences are outlined in Table 1 below.

Table 1: Comparison of RTS and SPS

Type of Survey	RTS	SPS
Who Participated	Every member of household required to complete the travel diary	One person in household
Period Recorded	1 Weekday	Up to 7-Days
Completed Responses	15,976 (households)*	1,039 (persons)
Period Conducted	October 2017 to December 2018	October and November 2019
Geographic Area	TPB Modeled Region	Activity Centers in TPB Region
Status of Internal QA/QC	Complete and extensive	Complete

*Through collaboration with the Baltimore Metropolitan Council (BMC), TPB staff added information collected by the 2018/2019 Maryland Travel Survey for Anne Arundel, Carroll, and Howard Counties. There was also an oversample conducted for Arlington County. These two efforts added another 2,039 households and brought the total number of households reported in the final RTS data files to 18,015.

The SPS was conducted in October and November 2019, while the RTS data was still being processed. Data processing for the RTS was completed in mid-2020 and key findings from the RTS were shared with the TPB and regional stakeholders. The data processing for the SPS started in mid-2021 and completed in Spring 2022.

OVERVIEW OF THE PROJECT

The evaluation includes the following key objectives:

1. Conduct a comprehensive review of the SPS data files and all of the data items contained in those files.
2. Perform data editing and imputation of the household, person, trip, and vehicle files based on the review of the SPS data files.
3. Conduct logic and consistency checks of the SPS trip file which include speed checks, loop trip checks, missing/incomplete trip checks, and activity purpose checks.
4. Conduct an evaluation of the efficacy of the smartphone app-based survey by reviewing user feedback and comments on the smartphone app survey (*rMove*).

[1] *rMove* was developed by Resource Systems Group, Inc (RSG, Inc) in 2014. A revised version of the rMove app is released annually to improve data collection and the user experience. More information on updates to *rMove* can be found in the consultation with RSG section of this memo.

TPB staff began the project by reviewing the SPS data files and identifying data items that required data editing and imputation. There are seven data files in the SPS dataset:

- Household-Level Data File
- Person-Level Data File
- Trip-Level Data File
- Vehicle-Level Data File
- Day-Level Data File
- Location-Level Data File
- Sample-Level Data File

TPB staff reviewed the data files in the SPS dataset that were provided by RSG and identified key variables of interest and assessed the level of data cleaning/imputation effort required based on the review of the data files (see Table 2).

Household File

The household-level data file provided information about the participant's household. This file included a unique identifier for each household, home location variables, travel period start and end times, and household income variables. Unlike the RTS, the household-level data did not contain any detailed information about other household members since the SPS was a person-based survey.

Person File

The person-level data file provided demographic information about the participant, in addition to school and work location variables, number of complete days during the travel period, and number of trips made during the travel period by travel mode (e.g., total trips, walk trips, transit trips, bike trips, taxi trips, TNC trips, scooter trips).

Trip File

The trip-level data file included the detailed trip records captured from each participant during the 7-day travel period, with one record for each trip captured by *rMove*. The trip file contained the primary detailed trip information from the survey, including origin and destination trip purpose, departure and arrival times, trip duration, distance, travel mode, transit access and egress, and trip purpose imputation variables. RSG recommended using the imputed origin and destination purposes for all trip purpose analysis performed. The trip file contained unlinked trips only.

Vehicle File

The vehicle-level data file contained detailed information about vehicles in the participant's household.

Day File

The day-level data file consisted of records for each day of the participant's assigned 7-day travel period.

Location File

The location-level data file consisted of passively recorded trip location data captured by *rMove*.

Sample File

The sample-level data file contained information about the sample (participant address, letter date, XY coordinates, recruitment/complete status).

Table 2: SPS Data Files

File	*Observations*	*Key Variables of Interest*	*Data Cleaning/Imputation Effort*
Household File	*1,039*	home location geography, travel period start and end times, household income, no. of vehicles, no. of bicycles, housing type, housing tenure, household size	**low/moderate** (variables with missing/non-responses, coded '9998').
Person File	*2,185*	numerous variables of interest including number of trips by mode, demographic variables (e.g., age, employment status, race/ethnicity, gender, etc.), school mode, work mode, telework frequency, bicycles and bikeshare, TNCs, EVs, scooters, etc.	**moderate** (variables with missing/non-responses, coded '9998', there are also some open response data items that may require recoding).
Trip File	37,797	origin and destination trip purpose, departure and arrival times, trip duration, distance, travel mode, transit access and egress	**high** (trip records reviewed for logic and consistency and led to modal edits, trip records need to be linked using a modal hierarchy, missing responses need to be imputed for several variables). *Note: RSG analysts performed data imputation on the following variables: location type, origin and destination trip purpose and trip purpose categories.*
Vehicle File	1,372	vehicle year, make, and model	**low** (variables with missing/non-responses, coded '9998').
Day File	7,273	reason for no travel, home deliveries (food, package, service), online shopping	**low/moderate** (variables with missing/non-responses, coded '9998').
Location File	730,315	N/A	**none** (passively collected mobile device location data)
Sample File	6,494	XY coordinates for geocoding of participants	**low/moderate** (geocoded addresses checked for accuracy/reasonableness).

After completing the data cleaning and imputation, the SPS trip file was checked for logic/consistency. Consistency checks included speed/distance checks, loop trip checks, and missing/incomplete trip checks. Trip records in the SPS trip file were also checked for geocoding errors. Speed and distance checks were performed to determine reasonableness by travel mode, which is important for reported non-motorized trips, including bike, walk, and scooter trips. Loop trip checks were performed for trips that begin and end at the

same location with no intermediate stops. Finally, the SPS trip file was checked for missing or incomplete trips. The results of the data cleaning and imputation as well as consistency checks were used to evaluate the effectiveness of the smartphone app-based survey methodology based on the degree of data cleaning and imputation as well as any issues found during the trip logic and consistency checks. TPB staff also conducted an analysis of user feedback and comments on the smartphone app survey summarizing the comments into categories based on topic and attitudes (positive, neutral/constructive, negative).

DATA EDITING AND IMPUTATION

Approach

To prepare the data for the SPS evaluation, TPB staff reviewed the data files provided by RSG to evaluate the quality and consistency of the data files, which were provided in .csv format. The data files are described in detail in the previous section and are located in 7-Day Panel (SPS) Files for RSG.
These files were converted to SAS files (.sas7bdat) for the SPS evaluation. SAS programs were written to develop tabulations and frequency tables for the review of the data files. TPB staff also reviewed the RTS Smartphone Panel Dataset Guide (2019_RTS_SPS_Dataset_Guide.docx) and the RTS SPS Questionnaire (2019_RTS_SPS_Questionnaire.pdf).

After reviewing the data files and codebook, TPB staff determined the data items that required data editing, including variable recoding and imputation. The codebook was annotated to indicate which variables required recoding; the annotated codebook is located in 7-Day Panel (SPS) Files for RSG in the SPS Documentation folder ("2019_RTS_SPS_Codebook_KJ.xlsx").

Recoding "Other, Please Specify" Variables

TPB staff focused on recoding the "other, please specify" responses. These included several questions in the household, person, trip, and vehicle files. These open-ended responses were recoded to other categories; responses that did not correspond with any categories were aggregated as "other". For example, there were many open responses for race/ethnicity, which required careful editing and recoding given the complexity of personal identity.

The list of questions and variables that were recoded in the household, person, trip, and vehicle files are shown in Table 3 below.

Table 3: Recoded "Other, Please Specify" Variables

Question	Variable Name	Data File
Which factors influenced your decision to reduce the number of vehicles in your household? Select all that apply.	reduced_vehicle_other_specify	Household
Which factors influenced your decision to increase the number of vehicles in your household? Select all that apply.	increased_vehicle_other_specify	Household
Which of the following best describes the type of organization you work in?	industry_specify	Person
Why do you ride your bicycle? Select all that apply.	bike_purpose_specify	Person

Question	Variable Name	Data File
Why don't you ride a bicycle? Select all that apply	no_bike_specify	Person
Why don't you use a bike share service? Select all that apply.	no_bike_share_specify	Person
When using smartphone-app ride services, what is the most common purpose of your trips?	tnc_purpose_specify	Person
Please specify your race/ethnicity.	ethnicity_specify	Person
Can you tell us more about why you stopped here (at destination)?	trip_o_purpose_specify	Trip
Can you tell us more about why you stopped here (at destination)?	trip_d_purpose_specify	Trip
How did you travel? Select all that apply.	trip_mode_type_specify	Trip
How did you get to the transit stop?	trip_transit_access_specify	Trip
How did you get from the transit stop to your destination?	trip_transit_egress_specify	Trip
Where did you park?	home_park_specify	Vehicle

Recoding "Missing: Non-Response" Variables

There were many variables in the household, person, vehicle, and trip files with missing data or cells. Based on TPB staff's review, these missing values appeared to be reasonable and consistent. There are several reasons for why a cell may have missing data:

- A respondent did not select answers that are logically consistent.
  - Coded as: 994 (Response inconsistency)
- A value or response was not required under the circumstances.
  - Coded as: 995 (Skip logic)
- A respondent indicated that they didn't know the answer and skipped that question.
  - Coded as: 998 (Don't know)
- A respondent indicated that they preferred not to answer a question and skipped that question.
  - Coded as: 999 (Prefer not to answer)
- A respondent did not answer part of a survey that was required.
  - Coded as: -9998 (Non-response)
- A technological error occurred.
  - Coded as: -9999 (Technical error).
- In data processing, there was not enough information for RSG to derive a variable.
  - Coded as: -1 (Non-imputable)

Most variables with missing cells were records labeled as "missing: non-response" (coded '-9998') and "missing: skip logic" (coded '995'). Some variables had missing cells with records labeled as "prefer not to answer" (coded '999'); these cases include questions about household income and race/ethnicity which had a "prefer not to answer" option.

Origin and Destination Trip Purpose Category Codes

The open responses for trip origin purpose (trip_o_purpose_specify) and trip destination purpose (trip_d_purpose_specify) were recoded into the existing trip origin purpose (o_purpose) and trip destination purpose (d_purpose). The origin purpose is derived from the destination purpose of the previous trip, except for the first trip in the travel period or when a trip falls after a trip with item non-response. The SPS trip file also included broader trip purpose categories. A purpose category crosswalk was created to assign the "o_purpose_category" and "d_purpose_category" codes for the recoded open response records (see Table 4).

Table 4: Origin and Destination Trip Purpose

Trip Purpose	Trip Purpose Category
Go home	Home
My other home (second home, etc.)	Home
Other type of home	Home
Someone else's home	Home
Primary workplace	Work
Work-related activity (e.g., meeting, delivery, worksite)	Work-Related
Travel for work (e.g., going to airport)	Work-Related
Volunteering	Work-Related
Other work-related	Work-Related
Daycare or preschool	School
K-12 school	School
College/university	School
Vocational/technical education	School
Other education-related	School
Grocery shopping	Shop
Get gas	Shop
Shopping for major item (e.g., furniture, car)	Shop
Other routine shopping (e.g., pharmacy)	Shop
A stop on the way home	Errand/Other
Errand with appointment (e.g., haircut, accountant)	Errand/Other
Errand without appointment (e.g., post office, dry cleaning)	Errand/Other
Medical visit (e.g., doctor, dentist)	Errand/Other
Other errand	Errand/Other
Split loop trip	Errand/Other
To/from childcare/preschool/adult care	Escort

Trip Purpose	Trip Purpose Category
To/from K-12 school or college	Escort
To/from other person's home	Escort
To/from other person's workplace	Escort
To/from other person's scheduled activity (e.g., lesson, appointment)	Escort
Other place to pick-up/drop-off	Escort
Dine out/get coffee or take-out	Meal
Exercise (e.g. gym, jog, bike, walk dog)	Social/Recreation
Social (e.g., visit friends/relatives)	Social/Recreation
Leisure/entertain/cultural (e.g., cinema, museum)	Social/Recreation
Religious/civic/volunteer activity	Social/Recreation
Vacation/traveling	Social/Recreation
Family activity (e.g., watch child's game)	Social/Recreation
Other leisure	Social/Recreation
Change/transfer travel mode (e.g. wait for bus, change planes)	Change mode
Other	Other (Unknown)
Other (Unknown)	Other (Unknown)
Missing: Skip logic	Missing: Skip logic

In sum, data editing and imputation, including the recoding of open response variables, were performed to evaluate the efficacy of the smartphone app survey *rMove*. These steps are customary for survey data preparation and similar data editing and imputation steps were performed on the RTS. The next section describes some findings from the data editing and imputation process for the trip file.

Key Findings

Erroneous Trips

There were a few cases where open responses for trip origin purpose (trip_o_purpose_specify) and trip destination purpose (trip_d_purpose_specify) did not reflect actual trips. Based on TPB staff's review, the following open responses were coded as "erroneous trips" because they did not include an actual stop at a destination:

- "I did not stop here. I am just beginning my trip."
- "Drove around, did not stop"
- "Stuck in traffic as a result of a major car crash"
- "Waiting at traffic light."
- "I don't think I stopped anywhere. It just shows a minute so I'm guessing my husband pulled up on the curb."
- "Didn't stop, intermittent wifi coverage"
- "I did not make this trip. I was not out at 8:32 PM"
- "*rMove* added this trip. FYI: It looks like I was still home. Therefore, *rMove* probably recorded me going

outside briefly to take out the trash/put out the rolling trash can."
- "I put the trash out. I do not understand. I did not drive."
- "I haven't left my house. Maybe you detected me going across the alley to dump leaves in the trash bin?"
- "Train was holding in Germantown"
- "Still on train"

Based on these comments, the most common reasons for these erroneous trips include unintended stops on the way to a destination (due to a traffic incident, waiting at a long traffic light, or a train holding), movement within the confines of a home such as taking out the trash, and an interruption due to a lack of Wi-Fi coverage. Given that the r*Move* app passively records trips taken by the respondent based on movement, it is probable that these intermittent stops exceeded the threshold based on *rMove*'s algorithm. However, for these cases, the *rMove* app allows the user to edit these erroneous trips, although some users may not have performed these edits on the app because they did not know how to perform the edits or did not want to expend the extra effort to edit the trips.

Fortunately, the share of trips that were identified by TPB staff as erroneous was relatively small; only 19 out of 390 open response records (4.9 percent) for trip origin purpose and 19 out of 393 open response records (4.8 percent) for trip destination purpose were flagged as an "erroneous trip" (coded '866' by TPB staff).

CONSISTENCY CHECKS

Approach

Upon completing the data cleaning and imputation tasks, TPB staff reviewed the SPS trip file for trip logic and consistency. TPB staff began this process by reviewing the consistency checks that were performed on the RTS main survey to determine the most relevant and necessary consistency checks that are needed for the SPS. The consistency checks that were performed on the RTS were considerably more extensive than the SPS, given that it is a much larger dataset and more rigorous checks were required since the RTS dataset is to be used as input for developing TPB's regional travel demand forecasting model. Based on the evaluation of the RTS consistency checks, TPB staff determined that the following consistency checks would be most important for testing the efficacy of the smartphone app instrument *rMove*:

- Speed and distance checks by travel mode
- Trip logic and consistency checks for subway and commuter rail trips (including missing/incomplete trip checks)
- Trip purpose checks for loop trips (home to home trips and work to work trips)

Similar to the RTS main survey, speed and distance checks were performed on the SPS data to ensure that trips were accurately recorded by the smartphone app. TPB staff performed the speed and distance checks by reviewing trip records for each of the following travel modes: 1) bike; 2) bikeshare; 3) bus; 4) ferry; 5) household vehicle; 6) other vehicle; 7) micromobility; 8) rail; 9) ridehailing; 10) taxi; 11) walk; 12) other mode. For each travel mode, trip records with unreasonably low and high speeds and distances were flagged for review, and TPB staff carefully reviewed those records to determine the type of issue identified in the speed/distance checks.

In addition to speed and distance checks by travel mode and trip logic and consistency checks for subway and commuter rail trips, TPB staff performed trip purpose checks for loop trips. Loop trips are defined as trips that begin and end at the exact same location with no intermediate stops. Examples of loop trips include someone walking their dog or taking a walk, a jog or bike ride for exercise or pleasure. Most loop trips begin and end at home, but not all. A lunch-time walk or jog that starts and ends at a person's place of employment would also be considered a loop trip. The main purpose for checking loop trips is to determine if the origin and destination locations are accurately coded. To determine the accurate coding of home and work locations, XY coordinates of home and work locations were used to determine if the origin and destination locations are correctly identified as "home" or "work". Similar loop trip checks were performed for the RTS main survey but they were for walk and bike trips only.

Two different types of loop trips were checked for consistency:

- Home to home loop trip
- Work to work loop trip

To perform this check, TPB staff reviewed daily trips taken by a person which included a home-to-home loop trip or a work-to-work loop trip. Two excel files were created to conduct the review, one for daily trip records which included a home-to-home loop trip and one for daily trip records which included a work-to-work loop trip. There was a total of 1,934 trip records in the home-to-home loop trip file, and a total of 1,881 trip records in the work-to-work loop trip file. Due to the large number of trip records, only the first 400 trip records from each file were checked for consistency. Loop trips that appeared to be questionable were flagged and further reviewed

Key Findings

Speed and Distance Checks by Travel Mode

Table 5 summarizes the speed and distance check issues by travel mode. For all modes, the top five common issues identified include the following:

- Short trip distance over extremely long duration (n = 263)
- Speed is too high for this mode (n = 70)
- Extremely long trip distance over a short duration (n = 49)
- Extremely short trip distance (n = 33)
- Extremely long trip duration (n = 29)

In addition to these issues, there were several other issues listed, such as "both short distance and duration", "extremely high speed", "extremely short trip duration", "no trip distance", "not a ferry trip", "outside region", "possible short trip distance", "trip duration is too long for change mode", "trip duration is too short", and "wrong mode".

When ranked by number of flagged issues by travel mode, the top five modes include the following:

- Household vehicle trips (n = 227)
- Walk trips (n = 112)
- Rail (n = 78)
- Other vehicle (n = 19)
- Bus (n = 18)

For household vehicle trips, the most common issues were "short trip distance over extremely long duration",

followed by “extremely long trip distance over a short duration”, and “extremely short trip distance”. For walk trips, the most common issues were “speed is too high for this mode” and “short trip distance over extremely long duration”. For rail trips, the most common issues were “extremely long trip duration”, followed by “extremely short trip distance” and “extremely long trip distance over a short duration”. For other vehicle trips and bus trips, the most common issues were “short trip distance over extremely long duration” and “extremely long trip distance over a short duration.”

However, when the share of flagged trip records is considered, the travel modes with the highest share of flagged records include the following (travel modes with under 100 trip records and “other” are excluded):

- **Rail (2.4 percent of rail trip records flagged)**
- Ridehailing (1.6 percent of ridehailing trip records flagged)
- Bus (1.3 percent of bus trip records flagged)
- Household vehicle (1.2 percent of household vehicle trip records flagged)
- Bike (1.1 percent of bike trip records flagged)
- Walk (1.1 percent of walk trip records flagged)
- Other vehicle (1.0 percent of other trips flagged)
- Bikeshare (0.6 percent of bikeshare trip records flagged)

Based on the review of SPS trip records, rail trips had the highest share of flagged trips (2.4 percent), nearly twice as high as bus trips (1.3 percent) and higher than ridehailing trips (1.6 percent). Household vehicle (1.2 percent), bike (1.1 percent), and walk trips (1.1 percent) had a lower share of flagged trips and bikeshare trips had the smallest share of flagged trip records (0.6 percent). The major causes for these flagged trip records include the wrong mode selected by the respondent and recording error by the app (e.g., late detection or early termination of the trip) which may be due to a GPS signal issue, particularly for subway trips.

Trip Logic and Consistency Checks for Subway and Commuter Rail Trips

TPB staff found that rail trips had a notably higher share of flagged trips than other travel modes, except for travel modes with a small number of trip records such as ferry, micromobility, and taxi. Based on previous experience with the *rMove* smartphone app during the RTS pretest in the spring of 2017, the app had some difficulty capturing underground rail trips such as Metrorail (subway). Therefore, additional consistency checks were performed for rail trips that involved the use of a subway or a commuter rail. TPB staff reviewed the trip logic and consistency for the following trips:

- All daily trips taken by a person who used **subway** for any trip
- All daily trips taken by a person who used **subway** for any trip, *with questionable speed for the rail trip*
- All daily trips taken by a person who used **commuter rail** for any trip
- All daily trips taken by a person who used **commuter rail** for any trip, *with questionable speed for the rail trip*

For all daily trips taken by a person who used subway for any trip, subway trips with questionable speeds were flagged and reviewed. A total of 85 subway trip records were flagged. Similarly, for all daily trips taken by a person who used commuter rail for any trip, commuter trips with questionable speeds were flagged and reviewed. A total of 11 commuter rail trip records were flagged. Due to the small number of flagged commuter rail trip records, these were combined with flagged subway trips.

Based on the review of 85 subway and 11 commuter rail trips with questionable speeds, the issues identified can be categorized into the following types:

- **Trip start or end time wrong (33.3 percent of trip records flagged)**
- **Travel mode wrong (27.1 percent of trip records flagged)**
- Trip duration wrong (17.7 percent of trip records flagged)
- Trip purpose wrong (11.5 percent of trip records flagged)
- Incomplete/missing trip (4.2 percent of trip records flagged)
- Geocoding error (3.1 percent of trip records flagged)
- Too many trip modes for distance (2.1 percent of trip records flagged)
- Mode type and purpose wrong (1.0 percent of trip records flagged)

One-third of flagged trip records were cases where the trip start or end time was not recorded correctly, which resulted in a questionable speed. This suggests that the smartphone app started recording the trip after the trip started and/or ended the trip before or after the trip ended. In many such cases, the start time of the trip appeared to be delayed, suggesting that the app started recording the trip late. In other cases, the app continued to record the trip after the trip already ended.

Over one-quarter of flagged trips appear to have the wrong travel mode. There were several cases where the distance was too short to be a transit trip, and therefore incorrectly coded. It is possible for these cases that the app user did not select the correct travel mode. There were a few cases where a subway trip was reported but there were no subway stations near the trip origin and destination locations, suggesting that the travel mode selected is incorrect.

Other issues that were identified include wrong trip duration based on origin and destination locations and travel mode, incorrect origin or destination purpose selected, incomplete and missing trips, geocoding error, too many trip modes for distance traveled, and incorrect travel mode and trip purpose.

Table 5: Speed and Distance Check Issues by Travel Mode

Type of issues	HH Vehicle	Walk	Rail	Other Vehicle	Bus	Other	Ride Hailing	Bike	Ferry	Taxi	Bike Share	Micro-Mobility	Total
Short trip distance over extremely long duration	189	39		12	13	2	5			1	1	1	263
Speed is too high for this mode		68	1		1								70
Extremely long trip distance over a short duration	20		10	7	4		2	6					49
Extremely short trip distance	15		12				2	1	2	1			33
Extremely long trip duration		2	27										29
Extremely high speed						11							11
Possible short trip distance			9										9
Trip duration is too long for change mode			7										7
Trip duration is too short			7										7
Not a ferry trip									4				4
Wrong mode			4										4
Both short distance and duration	3												3
Extremely short trip duration		2											2
No trip distance		1											1
Outside region			1										1
Total Number of Trip Records	18,385	10,257	3,192	1,951	1,391	129	571	628	18	65	173	35	36,795
Total Flagged Issues	227	112	78	19	18	13	9	7	6	2	1	1	493
Share of Trip Records Flagged (%)	1.2	1.1	2.4	1	1.3	10.1	1.6	1.1	33.3	3.1	0.6	2.9	1.3

Trip Purpose Checks for Loop Trips (Home to Home Trips and Work to Work Trips)

There was a total of 1,934 trip records in the home-to-home loop trip file, and a total of 1,881 trip records in the work-to-work loop trip file. Due to the large number of trip records, only the first 400 trip records from each file were checked for consistency. Loop trips that appeared to be questionable were flagged and further reviewed. A total of 111 home-to-home loop trips were flagged, and a total of 91 work-to-work loop trips were flagged. Table 6 summarizes the type of issues for home-to-home and work-to-work loop trips.

For the 111 home-to-home loop trips, the top issues identified can be categorized into the following types:

- **Destination purpose wrong (53.2 percent of 111 trip records flagged)**
- **Origin purpose wrong (19.8 percent of 111 trip records flagged)**
- Too short to be a trip (12.6 percent of 111 trip records flagged)
- Origin and destination purpose wrong (11.7 percent of 111 trip records flagged)

For the 91 work-to-work loop trips, the top issues identified can be categorized into the following types:

- **Destination purpose wrong (46.2 percent of 91 trip records flagged)**
- **Origin purpose wrong (25.3 percent of 91 trip records flagged)**
- Too short to be a trip (6.6 percent of 91 trip records flagged)
- Dual work trip (i.e., trip from one workplace to another workplace) (6.6 percent of 91 trip records flagged)

For home-to-home loop trips, the majority of the 111 trip records that were flagged was due to the wrong destination purpose (53.2 percent), followed by wrong origin purpose (19.8 percent), too short to be a trip (12.6 percent), and origin and destination purpose wrong (11.7 percent). For work-to-work loop trips, nearly half of 91 trip records that were flagged was due to wrong destination purpose (46.2 percent), followed by wrong origin purpose (25.3 percent), too short to be a trip (6.6 percent), and dual work trip (6.6 percent). With the exception of dual work trip, where the trip purpose was correctly coded, the other flagged issues indicate an issue with the trip file data.

For the vast majority of flagged trip records, loop trips that were flagged were not actually loop trips because the trip purpose was incorrectly coded as “work” or “home”. This was verified by confirming the XY coordinates for the home and work locations. For example:

- A destination trip purpose was coded as “home” but the XY coordinates did not match the home address. (Incorrect destination purpose)
- Both the origin and destination do not match the XY coordinates of the home address (incorrect origin and destination purpose)
- Both origin and destination are home but the dwell time is 0 minutes (too short to be a trip).

Other issues that were identified include trip not continuous, data not reliable, duplicate trip, partial/incomplete trip, and wrong travel mode.

Table 6: Trip Purpose Checks for Loop Trips

Type of issues	Home-to-Home	Work-to-Work	Total
Wrong D purpose	59	42	101
Wrong O purpose	22	23	45
Too short to be a trip	14	6	20
Wrong OD purpose	13	4	17
Data not reliable	2	6	8
Dual work trip		6	6
Trip not continuous	1	1	2
Duplicate trip		1	1
Partial/incomplete trip		1	1
Wrong mode		1	1
Total	**111**	**91**	**202**
Total trips reviewed	**400**	**400**	**800**

USER COMMENTS

Approach

The SPS provided an opportunity for survey participants to provide feedback on the survey experience. This was an open response question that was asked at the conclusion of the survey. Nearly one-half of all survey respondents (46.8 percent) provided feedback on the user experience (486 out of 1,039 respondents), which provided valuable information for evaluating the SPS data from the users' perspective.

TPB staff conducted a detailed analysis of user feedback and comments on the smartphone app survey summarizing the comments into broad topic categories and key words/themes, based on topics and attitudes (positive, neutral/constructive, negative).

TPB staff reviewed all user feedback and comments from the SPS, and placed them into the following broad topic categories:

- **App Interface/Functionality.** These comments focused on the interface and functionality of the *rMove* app.
- **General Experience.** These comments focused on general experience with the survey.
- **Survey Questionnaire.** These comments focused on the survey questionnaire, instructions, and question options.
- **Tech/Accuracy.** These comments focused on technical issues pertaining to accurate recording of trips such as GPS.
- **Tech/Battery.** These comments focused on technical issues pertaining to battery usage.
- **Other.** These comments did not fall into the categories listed above.

The comments were also placed into attitudinal categories (positive, neutral/constructive, and negative).

In addition to summarizing comments by attitude and broad topic categories, TPB staff took a deeper dive into the comments by searching key words and developing themes. This allows for greater insight into specific comments that were shared by SPS participants. Unlike the tabulations for attitude and broad topic categories

above, the tabulation of key words/themes was not mutually exclusive since a comment may include multiple themes/key words.

Key Findings

Broad Topic Categories

From a total of 486 comments, the number of user comments by broad topic categories are listed below in descending order:

- **General Experience** (200 comments)
- **App Interface/Functionality** (111 comments)
- **Other** (79 comments)
- **Tech/Accuracy** (49 comments)
- **Survey Questionnaire** (36 comments)
- **Tech/Battery** (11 comments)

The largest number of user comments focused on general experience with the survey, followed by app interface and functionality. These two categories comprise nearly two-thirds of user comments received on the survey. Other comments focused on technical issues pertaining to accuracy and battery use and the survey questionnaire.

For attitudinal categories (positive, neutral/constructive, and negative) of all user comments, the breakdown by attitude is as follows:

- **Positive** - 277 comments
- **Neutral/Constructive** - 102 comments
- **Negative** - 107 comments

The majority of user comments on the survey experience was positive, and combined with neutral/constructive comments, they comprise over three-quarters of all user comments. Less than one-quarter of user comments were negative comments.

Table 7 provides a summary of user comments by attitude and topic. Broad topic categories were cross tabulated by attitude to show the breakdown of positive, neutral/constructive, and negative comments by broad topic categories. For comments focusing on general experience, which comprised the largest number of comments, nearly all comments were positive with very few negative and neutral/constructive comments. For comments focusing on app interface/functionality, there were more positive comments than negative comments. For other broad topic categories such as survey questionnaire, tech/accuracy, and tech/battery, there were more negative comments than positive comments. While the majority of comments were negative for these categories, it should be noted that the overall share of respondents who reported an issue with the survey questionnaire, tech/accuracy, and tech/battery was small compared with the total number of survey participants (e.g., 10 of 1,039 participants) or total number of commenters (10 of 486 commenters).

Table 7: Summary of User Comments by Attitude and Topic

	Negative	Neutral/Constructive	Positive	Total
General Experience	2 comments	8 comments	190 comments	200 comments
App Interface/Functionality	38 comments	15 comments	58 comments	111 comments
Other	1 comment	59 comments	19 comments	79 comments
Tech/Accuracy	26 comments	17 comments	6 comments	49 comments
Survey Questionnaire	30 comments	2 comments	4 comments	36 comments
Tech/Battery	10 comments	1 comment	0 comments	11 comments

Note: Darker shade indicates more user comments.

Deep Dive Analysis Using Key Words/Themes

Comments focusing on general experience were grouped into the following types based on key words/themes, with selected verbatim comments. Note that a comment may include multiple themes/key words so the tabulation of key words/themes was not mutually exclusive.

Positive Comments about General Experience

- Simple and easy (84 comments)
  - "This was a very easy, intelligent survey. The company behind the app is amazing!"
  - "Survey was easy to do. I enjoyed it."
  - "It was very simple and straightforward."
- Fun and great (53 comments)
  - "It was a fun and interesting experience. I'd do it again, anytime!"
  - "It was fun!"
  - "Everything was great!"
- Good experience (35 comments)
  - "Great user experience!"
  - "It was great to be a part of this!"
- Worked well (16 comments)
  - "Everything worked very well."
  - "It worked well. Straightforward."
- Thank you (13 comments)
  - "Thank you for the great effort and planning that went into launching the survey and tool. It was a pleasure to participate."

    - "Thanks for asking. Keep me in mind for other surveys."
- Useful (4 comments)
- Better (3 comments)
- Accurate (3 comments)

Negative Comments about General Experience

- Don't like it (1 comment)
- Too much work (1 comment)

Many participants commented that the smartphone survey app was simple and easy to complete, it was fun to do and a great survey overall, in addition to the survey being a good experience. Other positive comments focused on how well the app worked and expressed thanks for the opportunity to take the survey. Only two comments about general experience were negative.

Comments focusing on app interface/functionality were grouped into the following types based on key words/themes, with selected verbatim comments:

Positive Comments about App Interface/Functionality

- Simple and easy (31 comments)
    - "It was really easy with the technology tracking each trip automatically and guessing the commuting trip details."
    - "It was very easy to fill out the forms during my day to day."
- Auto-fill/smart (14 comments)
    - "The surveys are very easy to follow and the auto-fill feature for repeated trips is useful."
- Fun/love it (10 comments)
    - "I love it! Was totally clear on how to handle trip chaining."
- Well designed (10 comments)
    - "Well designed and easy interface with smart features."

Negative Comments about App Interface/Functionality

- Difficult to modify/delete trip (11 comments)
    - "Hard to edit or add trips"
- Too many questions/burdensome (8 comments)
    - "It's terrible. So many prompts."
- Inaccurate trip recording/GPS issues (8 comments)
    - "It mostly missed when recording my trips, and editing them/adding trip to your app missed was far too difficult."
- Interface hard to use (7 comments)
    - "Manually editing locations was not easy."
- Other (6 comments)

Many participants commented that the survey was simple and easy due to the app interface and that the auto-fill feature for repeated trips was useful and convenient. Others commented that the survey was fun and

enjoyable to complete and that it was well designed. Negative comments focused on difficulty of modifying trips on the app (e.g., adding or deleting trips), too many questions/prompts, inaccurate trip recording and other GPS signal issues, and a cumbersome, hard to use interface.

Comments focusing on survey questionnaire were grouped into the following types based on key words/themes, with selected verbatim comments:

Positive Comments about Survey Questionnaire

- Good/interesting (2 comments)
- Well-constructed (2 comments)

Negative Comments about Survey Questionnaire

- Too many questions/choices (16 comments)
    - "Too many questions and improve the auto-fill feature."
    - "The survey is way too long."
- Confusing/need more instructions (10 comments)
    - "More specific instructions on how best to fill out the survey would have been helpful."
    - "Purpose of trip categories could have been clearer."
- Choices need to be improved (5 comments)
    - "Some of the categories could have been more refined."

The majority of comments focusing on the survey questionnaire was negative. Several respondents commented on the length of the survey and the number of questions, and a few indicated that the survey was confusing and that more specific instructions would have been helpful.

Comments focusing on tech/accuracy were grouped into the following types based on key words/themes, with selected verbatim comments:

Positive Comments about Tech/Accuracy

- Easy/great/surprisingly accurate (6 comments)
    - "Really great! Very easy and generally accurate in its tracking."

Negative Comments about Tech/Accuracy

- Wrong GPS captured (14 comments)
    - "Issues with false trips need to be fixed for future surveys"
    - "This app doesn't collect trips properly."
- Missing or loss of GPS signal (11 comments)
    - "Sometimes the survey would lose reception in certain areas."
    - "App seemed to miss the beginning of several trips."
- Not accurate (2 comments)

More comments focusing on tech/accuracy were negative than positive. Some of the issues reported by users include inaccurate trip recording, missed trips, late recording of trips, premature ending of trips, and false trips.

Comments focusing on tech/battery were not broken down further due to the small number of responses. Most of these comments were negative and the main issue was that the survey app was battery draining.

SUMMARY OF KEY FINDINGS

The following summarizes the key findings from the 7-Day RTS Follow-On Smartphone Panel Survey (SPS) Evaluation:

Data Editing and Imputation

- Based on the review of the data files provided by RSG, several items required data editing and imputation. These include the recoding of "other, please specify" variables in the household, person, trip, and vehicle files. There were many open responses for certain data items, such as race/ethnicity, which required careful editing and recoding. Recoding of open response variables is customary to prepare the survey data for analysis and similar data editing and imputation steps were performed on the RTS.
- There were many variables with missing data or cells, but most of these missing values were reasonable and consistent. There are several reasons for why a cell may have missing data, such as skip logic, don't know, prefer not to answer, or nonresponse. There were a few cases where a cell was coded as "response inconsistency", "technical error", or "non-imputable" but these were fortunately not very common.
- Open responses for trip origin and trip destination purposes in the SPS trip file required recoding, and these needed to be recoded to the origin purpose and destination purpose categories. The purpose categories in the SPS were more detailed than the RTS, and therefore did not exactly match. The SPS trip file also included broader trip purpose categories and a crosswalk was created to assign the recoded origin and destination trip purpose into the broader trip purpose categories.
- There were a few cases where open responses for trip origin purpose and trip destination purpose did not reflect actual trips. Based on the review of these cases, these trips were coded as "erroneous trips" because they did not include an actual stop at a destination. The most common reasons for these erroneous trips include unintended stops on the way to a destination (due to a traffic incident, waiting at a long traffic light, or a train holding), movement within the confines of a home such as taking out the trash, and an interruption due to a lack of Wi-Fi coverage. It is likely that the sensitivity of the smartphone app was the cause of these erroneous trips where a temporary interruption or stop may have triggered the app to prematurely terminate the trip.

Consistency Checks

- There were several consistency checks that were performed on the SPS trip file. The purpose of the consistency checks was to determine the accuracy and validity of trips captured by the smartphone app *rMove*. Based on the evaluation of consistency checks performed for the RTS, TPB staff determined that the most relevant and important consistency checks for evaluating the efficacy of the smartphone app were: 1) speed and distance checks by travel mode; 2) trip logic and consistency checks for subway and commuter rail trips (including missing and incomplete trip checks); 3) trip purpose checks for loop trips (home-to-home and work-to-work trips).
- When speed and distance checks were performed by travel mode, the most common issues identified include: 1) short trip distance over extremely long duration; 2) speed is too high for this mode; 3) extremely long trip distance over a short duration; 4) extremely short trip distance; 5) extremely long trip duration. Among travel modes with more than 100 trip records, rail trips had the highest share of flagged records.
- Based on the finding above, further consistency checks were performed on subway and commuter rail trips, which found that trip start or end times were incorrect in about one-third of all flagged trip records. Other common issues included wrong travel mode, wrong trip duration, and wrong trip purpose. This suggests that the app may have not accurately recorded the start and end times of subway and commuter rail trips, which resulted in a questionable speed. In some cases, the start time of the trip was delayed which indicate that the app started recording the trip late, while in other cases the app continued to record the trip after the trip already ended.

- Trip purpose checks for loop trips were performed for the first 400 daily trip records containing a home-to-home loop trip and the first 400 daily trip records containing a work-to-work loop trip. Based on this review, 111 home-to-home loop trips and 91 work-to-work loop trips were flagged. For home-to-home loop trips, over one-half of 111 trip records flagged had the wrong destination purpose; for work-to-work loop trips, nearly half of 91 trip records flagged had the wrong destination purpose. This was verified by confirming the XY coordinates for the home and work locations.

User Comments

- User feedback and comments offered insight on users' perspective on the smartphone app survey. The largest number of comments focused on general experience, followed by app interface and functionality. Many user comments were positive or neutral/constructive, suggesting that the app worked well and that the user experience was positive for the majority of SPS participants. Comments that focused on the survey questionnaire and technical issues such as accuracy and battery were more negative than positive, but the overall share of respondents who reported an issue on the survey questionnaire and technical issues was small compared with the total number of survey participants or total number of commenters.
- Deep dive analysis using key words and themes revealed that many respondents had similar comments and feedback about their experience taking the smartphone app survey. Many positive comments about the general experience described the survey as "simple and easy" and "fun and great. Positive comments about the app interface and functionality noted that it was easy to complete, well-designed, and had smart features such as auto-fill which made the survey easier to complete. Comments about the survey questionnaire tended to be more negative, with some respondents complaining about the length of the survey and the large number of questions, while others desired more specific instructions and improved question choices. Similarly, comments about tech/accuracy and tech/battery were generally negative with some respondents reporting issues with false and inaccurate trips, loss of GPS signal and reception, and issues with battery drain using the app.

CONSULTATION WITH RSG

RSG performed the data collection for the SPS. As part of this evaluation TPB staff invited RSG to provide input on the memorandum. A draft memorandum was shared with RSG on July 5, 2022, comments were received from RSG on August 2, 2022, and a meeting was held on August 18, 2022. This version of the memorandum reflects updates after taking RSG's comments into consideration.

RSG noted that the following enhancements were made to *rMove* since the seven-day panel:

- *rMove* provides more accurate departure times through a speed and distance-based algorithm that corrects for lag in location collection.
- *rMove* allows users to edit departure and arrival times for all trips, which supplements raw trip times and algorithm-adjusted times.
- *rMove* utilizes an algorithm to analyze trip paths and identify where a user may have made a brief stop that was not initially recognized. The potential missed stops are displayed to the user who can keep or reject them. This functionality is particularly useful in splitting a single loop trip into two constituent trips when a brief activity was conducted along the way (e.g., dropping someone at school or picking up food).
- *rMove* uses a two-step authentication process for accessing the application to improve data security.
- *rMove* includes a re-designed interface that includes a dashboard and a trip roster. The dashboard itemizes all tasks required of the user, including daily summary survey and surveys collecting general

travel behavior of household children. A separate trip roster allows all trip collection and modification to occur in a standalone interface.

- *rMove* requires users to verify each trip they make, where they can add or remove stops, and edit trip times.
- *rMove* has an improved survey flow, particularly for trip verification.
- *rMove* assigns travel dates dynamically to shorten the between recruit and survey start.
- *rMove* reviews previous trips and previous trip survey responses to prepopulate survey answers and reduce user burden.

NEXT STEPS

TPB staff will consider the results of this evaluation as it considers methods and approach for future household travel surveys.