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UTAH MOVES
TRANSPORTATION SURVEY

2023 UTAH MOVES TRANSPORTATION SURVEY: WEIGHTING METHODOLOGY

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Prepared for UDOT, UTA, CMPO, Dixie MPO, MAG, and WFRC

Report Title:

2023 Utah Moves Transportation Survey: Weighting Methodology

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Report Prepared for:

The Utah Department of Transportation (UDOT), the Utah Transit Authority (UTA), and Utah's four metropolitan planning organizations: Cache Metropolitan Planning Organization (CMPO), Dixie Metropolitan Planning Organization (Dixie MPO), Mountainland Association of Governments (MAG), and Wasatch Front Regional Council (WFRC)

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EXECUTIVE SUMMARY

RSG conducted the Utah Moves Transportation Survey in spring 2023 on behalf of the Utah Department of Transportation (UDOT), the Utah Transit Authority (UTA), and Utah's four metropolitan planning organizations: Cache Metropolitan Planning Organization (CMPO), Dixie Metropolitan Planning Organization (Dixie MPO), Mountainland Association of Governments (MAG), and Wasatch Front Regional Council (WFRC).

This document describes the approach to generate weights to expand the survey data to represent Utah's residents across key metrics, such as geography and demographics, that impact travel behavior. The weighting process also corrects for biases related to data collection methods: for example, differences in response due to completing the survey over the phone or on a smartphone app.

The weighting process generates four types of weights:

- **A household-level weight.** The sum of these weights reflects the total households in the survey region.
- **A person-level weight.** The sum of these weights reflects the total persons in the survey region.
- **A day-level weight.** The sum of these weights also reflects the total persons in the survey region (and matches the sum of the person-level weights). The person weights are spread evenly across the number of complete weekdays, so the table represents the sum of one average weekday for each person in the study.
- **A trip-level weight.** The sum of these weights reflects the total trips in the survey region on a typical weekday (i.e., Tuesday, Wednesday, and Thursday).

The survey weighting process includes four primary steps that are covered in more detail throughout this memo:

1. **Initial expansion:** Each household is assigned an initial weight based on its probability of being invited to the survey. For example, if 5 households responded in a geography with 100 total households, each of the 5 households would receive an initial weight of 20 (100 / 5 = 20).
2. **Reweighting for non-response bias:** After the initial expansion, household weights are adjusted to better fit selected household- and person-level targets. For example, if 20% of households in the state are one-person households, but 25% of the sample households are one-person households, RSG adjusts the weights to better match the household size distribution of the population. This process leverages an open-source application, PopulationSim.[1] This step is performed twice in the weighting routine: once

[1] https://activitysim.github.io/populationsim

after the initial expansion (step 1) and again using new targets made from the day-pattern adjustment (step 3).

3. **Creating day-level weights to account for multi-day survey data:** Some survey respondents provided data for one travel day while others provided data for two or more days. To ensure multi-day respondents are not overrepresented in the final data, RSG creates a day-level weight to align each respondent's and household's representation in the dataset. For example, if two people each have a person weight of 100, a person with one reported travel day would retain a day-level weight of 100 while a person with two reported travel days would have a day-level weight of 50 on each travel day.
4. **Adjusting for non-response bias in day-pattern and trip rates:** During this final step, RSG adjusts the day- and trip-level weights to account for survey biases based on the method respondents used to report their travel. For example, if respondents who reported their travel over the phone reported fewer non-home-based-work trips compared to respondents who reported their travel in the smartphone app (after correcting for differences in demographics), the day- and trip-level weights for respondents who reported their travel over the phone are adjusted to more closely align with the smartphone app respondents. Travel reported by respondents who used the smartphone app is considered more accurate because respondents were not required to recall their travel and were therefore less likely to underreport trips.

Table 1 shows how each weight is impacted at each stage in the weighting process.

TABLE 1: WEIGHTS IMPACTED AT EACH STAGE OF WEIGHTING

	Household	Person	Day	Trip
Initial expansion	x			
Re-weighting for non-response bias	x			
Creating day-level weights to account for multi-day survey data	x	x	x	
Adjusting for non-response bias in day-pattern and trip rates	x	x	x	x

The remainder of this memo expands on the concepts above with specific, practical examples. The outputs from the 2023 Utah Moves Transportation Survey weighting process are in Appendix A.

1.0 INITIAL EXPANSION

The first step of the weighting process is to calculate an initial weight for each household based on their geographic and demographic sampling segment and probability of being sampled. In essence, this step reverses the initial sampling plan for the survey. The purpose of the weighting process is to expand the sample to represent the entire demographic segment across key dimensions, like total households and population.

The weighting process was performed only for completed household surveys. RSG considered a household complete and eligible for weighting if the household provided complete data on at least one Tuesday, Wednesday, or Thursday. The process described in this memo does not include Friday–Monday because:

- The survey only collected data from smartphone app (rMove) households on Friday - Monday.
- Travel behavior on Friday–Monday is not assumed to be interchangeable with behavior on Tuesday–Thursday.
- The data will be primarily used to analyze and model typical weekday travel behavior. RSG will develop separate weekend weights to facilitate other data uses (described separately).

The Utah Moves Transportation Survey used three methods to sample households for data collection:

Probability-based (Primary)

1. Traditional address-based sampling (ABS) whereby households are invited by mailed invitation.

Non-probability-based

2. University sampling (UNI) whereby students were invited by email (either from RSG or their college/university).
3. Convenience-based sampling (CBS) whereby residents were invited by email using contact lists from Community Health Workers and UTA.

University Sample

For each school in the university sample, RSG calculated the initial weight as **the school student enrollment divided by the average household size among university respondents divided again by the number of surveyed students.**

$$University\ Initial\ Weight_{school} = \frac{Enrollment_{school} / HH\ Size_{school}}{Responses_{school}}.$$

For example, if a university has an enrollment of 1,000 students, and the survey collected responses from 100 students from that university, and the students from that university reported an average household size of 2, then each sample for that university would have an initial weight of 5 (1,000 / 2 / 100 = 5).

Convenience Sample

For each household in the convenience sample, RSG calculated the initial weight **as the share of convenience sampling households for a segment multiplied by the number of actual households in a sample segment divided by the number of surveyed convenience households in the same sample segment.**

$$\boldsymbol{Convenience\ Share} = \frac{(\boldsymbol{Convenience\ Sample})_{\boldsymbol{segment}}}{(\boldsymbol{Total\ Sample})_{\boldsymbol{segment}}}$$

$$\boldsymbol{Convenience\ Intial\ Weight} = \frac{(\boldsymbol{Convenience\ Share})_{\boldsymbol{segment}} * \boldsymbol{Households}_{\boldsymbol{segment}}}{\boldsymbol{Convenience\ Responses}_{\boldsymbol{segment}}}$$

For example, if a segment contains 100 households, and the survey has 50 respondents from that segment, and 5 of the surveyed respondents are from the convenience sample, then the convenience survey share is 10% (5 / 50 = 0.10) and the segment would have an initial weight of 2 (10% * 100 / 5 = 2) .

ABS Sample

Finally, RSG adjusted the ABS household target to account for the off-campus university and convenience sample then calculated the initial weight for the address-based sample. The university sample adjustment was calculated by first summing the total off-campus student households in each geography determined in the University Initial Weight calculation. All off-campus students were assumed to belong to the same demographic segment within the geography regardless of the school they attended. The off-campus student households were then subtracted from the total households for the demographic segment in the specified geography. The convenience sample adjustment was calculated by further reducing the adjusted target in each geography based on the share of convenience sample collected in the geography.

$$\boldsymbol{ABS\ Target\ Households} = (\boldsymbol{Households}_{\boldsymbol{segment}} - \boldsymbol{Households}_{\boldsymbol{off-campus\ students}}) * (\mathbf{1} - \boldsymbol{Convenience\ Share})$$

For example, if geography A has 1,000 households and 100 off-campus student households, and 10% of the surveyed responses in that geography came from convenience sampling, the final ABS household target in that geography would be 810 ((1,000 – 100) * (1 – 10%) = 810).

From this point, RSG applied the original initial weight calculation to generate initial weights for the ABS sample.

In a survey that uses *only* probability-based sampling methods, the initial weight calculation for a given segment can be calculated as **the total households in a segment (e.g., based on Census estimates) divided by the number of ABS responses in the same segment.**

$$\boldsymbol{ABS\ Initial\ Weight}_{\boldsymbol{segment}} = \frac{\boldsymbol{Total\ Households}_{\boldsymbol{segment}}}{\boldsymbol{ABS\ Responses}_{\boldsymbol{segment}}}$$

For example, if the survey collected 81 responses in a geography with 810 households, each household would have an initial weight of 10.

Table 12 in Appendix A includes the initial weights RSG developed for each sampling segment.

After RSG calculated initial weights for each sampling approach, the combined sample was treated as a single group for the remainder of the weighting process.

2.0 REWEIGHTING FOR NON-RESPONSE BIAS

After creating the initial weights to account for each household's likelihood of being sampled, RSG conducted a reweighting process to adjust for non-response bias across geographies and demographics. Non-response bias refers to biases in the unweighted data that occur because different types of people respond to surveys at different rates.

Geographic Groups

RSG weighted the data to groups of Public Use Microdata Areas (PUMAs). PUMAs have populations in the range of 100,000 to 200,000 and tend to be smaller than urban counties but much larger than Census tracts and block groups. Although PUMAs are larger than block groups, survey data can still be sparse when split by PUMA. This can result in insufficient representation (i.e., missing person/household types) in the survey sample data that then need to be weighted to desired target totals, yielding poorly weighted data. For this reason, RSG aggregated PUMAs of similar characteristics until a sufficient sample and broader target totals yielded a satisfactory result. Table 7 in Appendix A includes the final PUMA groups RSG used for weighting, which are also shown in the map in Figure 1.

Demographic Targets

Different household and personal attributes affect survey response, which presents bias in unweighted survey data. For example, larger households may be less likely to respond due to the additional time needed to complete the survey questions and travel diaries for each member. To correct for these types of biases, RSG selected a variety of household- and person-level target categories.

RSG used the 2022 one-year American Community Survey (ACS) data to set total household and population targets for counties with populations over 65,000.[2] Counties with populations below 65,000 were not included in the one-year dataset, so RSG instead used the five-year 2015–2019 ACS data scaled to current county estimates[3] to set the total population targets in these cases.

Once RSG set the total population and household targets, the 2022 ACS Public Use Microdata Sample (ACS PUMS) was used to determine the target proportion of each weighting category. Table 2 and Table 3 show the weighting categories for each target. As part of this process, RSG also imputed missing data where applicable (described later in the memo). Note that some categories were combined in specific PUMA groups where sample size was insufficient.

RSG calculated separate targets for the university sample because data for these students were not available at the same level of detail as the PUMS data for ABS and CBS. The university sample targets treated each school as its own geography and set targets for undergraduate and

[2] Although the data was collected in 2023, the 2022 data was the most recently available at the time of weighting. The 2023 data will likely become available in late 2024.
[3] https://www.utah-demographics.com/counties_by_population

graduate students based on provided student enrollment figures. Section 1.0 describes the adjustment process to address on-campus vs. off campus students.

FIGURE 1: FINAL PUMA GROUPS

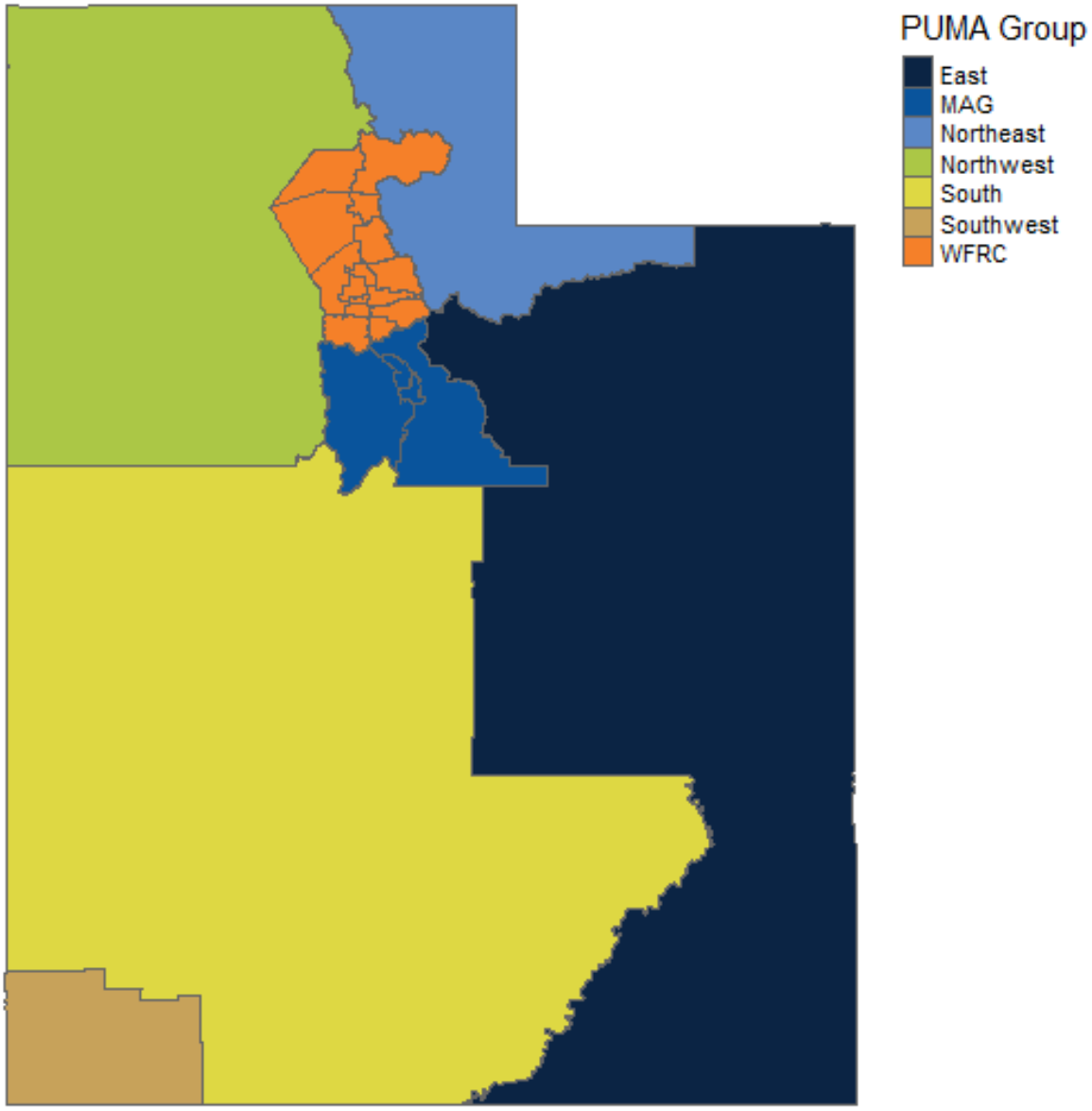

TABLE 2: HOUSEHOLD-LEVEL TARGETS

Variable	Categories
Household Size	1-person 2-person 3-person 4-person 5-person or more
Income ***(Imputed if non-response)***	Under $25,000 $25,000–$49,999 $50,000–$74,999 $75,000–$99,999 $100,000–$199,999 $200,000 or more
Workers[4]	0 workers 1 worker 2 workers 3 workers or more
Vehicles	No vehicles Fewer vehicles than drivers Vehicles greater than or equal to drivers
Presence of Children	0 children 1 or more children
Total Households per PUMA	*Not applicable*
Total Households	*Not applicable*

[4] Due to low sample sizes, the following PUMA groups used a top level of 2 or more workers: East, South.

TABLE 3: PERSON-LEVEL TARGETS

Variable	Categories
Gender ***(Imputed if non-response)***	Male Female
Age	Under 5 5–15 years 16–17 years 18–24 years 25–44 years 45–64 years 65 years or older
Worker Status	Full-time worker Part-time worker Non-worker
Commute Mode[5]	Telecommute Walk Bike Transit Other Not applicable
University Student Status[6]	University student (ABS) University student (UNI, undergraduate) University student (UNI, graduate) Not a university student
Educational Attainment	Some college education No college education
Race[7] ***(Imputed if non-response)***	African American Asian/Pacific White Other
Ethnicity ***(Imputed if non-response)***	Hispanic Non-Hispanic
Total Persons	*Not applicable*

[5] Due to low sample sizes, the following PUMA groups combined walk, bike, and transit with “other”: East, South, and Southwest.
[6] Due to low sample sizes, University students were combined into a single target for the South group.
[7] Due to low sample sizes, the following PUMA groups combined African American with Other: Northwest, East, and South.

Data Imputation

The income, gender, race, and ethnicity questions in the survey allowed participants to respond with "prefer not to answer." To facilitate data weighting, RSG imputed missing values for these variables when a participant selected "prefer not to answer."

Income Imputation

RSG imputed income using a model-based approach where missing income was predicted based on a set of independent variables including:

- Income distribution of the block group based on ACS 2021 5-year data.
- Number of non-working adults in the household.
- Number of children in the household.
- Employment status of household members.
- Educational attainment of household members.
- Age of the primary survey respondent.
- Whether the household is owned by the residents.
- Whether the household is a single-family home.

RSG has tested this model across many travel survey projects. The model adequately matches the income values that were reported by survey respondents who provided an answer to the income question, which indicates it is suitable for predicting the missing income values. Table 8 in Appendix A includes the model specification and coefficients.

Gender Imputation

RSG probabilistically assigned missing gender responses using a Monte Carlo procedure based on the sample data's gender distribution within the respondent's age category.

Race and Ethnicity Imputation

RSG probabilistically assigned missing race and ethnicity responses using a Monte Carlo procedure based on the ACS data's race and ethnicity distribution within the respondent's reported home block group.

Reweighting Process

Using the geographies and targets outlined earlier in the memo, RSG adjusted the initial weights using an entropy-maximization (EM)[8] algorithm using PopulationSim. This approach is beneficial because it reduces the variance in the final weights, which in turn reduces the margins of error when using the weighted data.

[8] For more information, see Multi-level Population Synthesis Using Entropy Maximization-Based Simultaneous List Balancing by Paul et al. (2018).

During the process, RSG constrained the ratio of the initial weight to final weight to be in a range of 0.125–5.0 for each household with a maximum final assigned weight of 10,000. RSG determined this range after testing alternative limits and judging the best tradeoff between accuracy and variability. Although removing these constraints would enable the process to match the targets more closely, keeping the constraints reduces variance in the final weights. Furthermore, the PUMS targets are based on census survey data, so it is best practice to not try to match the targets too precisely by allowing the weights to vary widely.

Although most of the final weighted categories were close to their targets, specific cases in some geographies were further from their targets than typically desired, even after grouping categories and geographies. These cases typically stem from very small sample sizes. Though these cases could be further grouped to improve the *apparent* fit to targets, RSG generally left these as they were for two primary reasons.

- No further grouping would be logical given the intended use of the data (e.g., it may not be useful to group “walk” with “transit”).
- Further grouping would not change the underlying weights and therefore could present a false impression of fit where data users should instead exercise caution (e.g., understanding the limitations of certain analyses).

Table 4 provides the distribution of the final weights RSG calculated for each PUMA group. Table 5 summarizes the ratio of the final weight to the initial weight. Note that RSG did not reweight the on-campus students in the UNI sample. Their final weight was set to their initial weight.

TABLE 4: SUMMARY OF FINAL WEIGHTS

PUMA Group	Sample Size	Min	Mean	Median	Max
Northwest	397	3.55	111.15	15.83	614.35
Northeast	1,154	1.51	55.98	8.51	471.55
WFRC	5,177	1.52	123.26	19.12	838.38
East	253	12.02	197.27	36.29	1,717.00
South	589	3.61	91.74	7.94	1,719.70
MAG	1,829	1.51	111.60	17.80	707.84
Southwest	550	5.17	131.71	18.45	713.05
Overall	**9,949**	**1.51**	**113.31**	**18.45**	**1,719.70**

TABLE 5: RATIO OF FINAL TO INITIAL WEIGHTS

Geography	Sample Size	Min	Mean	Median[9]	Max
Northwest	397	0.13	0.98	0.13	4.93
Northeast	1,154	0.13	0.98	0.13	5.01
WFRC	5,177	0.13	0.99	0.13	4.99
East	253	0.13	1.00	0.13	4.99
South	589	0.13	1.14	0.13	5.01
MAG	1,829	0.13	1.03	0.13	4.99
Southwest	550	0.13	1.02	0.13	5.00
Overall	**9,949**	**0.13**	**1.01**	**0.13**	**5.01**

[9] In many cases, the median ratio is extremely close to the minimum ratio because there is a significant skew toward a low ratio. This is ideal because it represents a lower variance in most weights.

Figure 2 through Figure 8 in Appendix A includes the final comparison of weighted counts to targets in each PUMA group.

To demonstrate how this step impacts the weights, consider the example in Table 6. If there were only a single weighting geography with only a single target (e.g., household size), this step would simply adjust the initial weights such that the distribution of the adjusted weights match the distribution of the targets.

In this example, assume each of 5 households has an initial weight of 20.0 and a distribution of household sizes as follows:

- 40% of households have 1 member
- 40% of households have 2 members
- 20% of households have 3 members

The distribution of household sizes in the target population is as follows:

- 20% of households have 1 member
- 40% of households have 2 members
- 40% of households have 3 members

The initial weight for households with a size of 1 would be scaled down to match the targets, and initial weights for households with a size of 3 would be scaled up to match the targets.

The maximum entropy method achieves a similar outcome but addresses multiple targets at once.

TABLE 6: EXAMPLE WEIGHTS AFTER REWEIGHTING

	Household Size	Initial Household Weight	Household Weight After Reweighting
Household 1	1	20.0	10.0
Household 2	2	20.0	20.0
Household 3	1	20.0	10.0
Household 4	2	20.0	20.0
Household 5	3	20.0	40.0

3.0 CREATING DAY-LEVEL WEIGHTS

The Utah Moves Transportation Survey collected multiple days of travel from smartphone households, while web and call center households only reported a single day of travel. For this reason, it was important to consider how to combine the multi-day and single-day data using a consistent method without overrepresenting smartphone households. RSG applied the following approach to develop the day-level weights.

First, RSG created person weights by copying the household weight to the associated person records. In households with unrelated members, each unrelated member receives a weight of zero and the value of their weight is split evenly among the remaining household members (see example in Table 7). This step ensures that the full person table still represents the total number of people in the region while avoiding downstream interference when analyzing household- and person-level trip rates.

TABLE 7: EXAMPLE RELATED AND NOT RELATED PERSON WEIGHTS

	Household Weight	Person Number & Relation	Person Weight
Household 3	10.0	1 (Related)	10.0
Household 4	20.0	1 (Related)	20.0
Household 4	20.0	2 (Related)	20.0
Household 5	30.0	1 (Related)	45.0
Household 5	30.0	2 (Related)	45.0
Household 5	30.0	3 (Not Related)	0.0

After creating person-level weights, RSG applied these weights to the day-level table. RSG assigned households with *only one complete day* the same day weight as person weight. RSG assigned households with *more than one complete day* a day weight that equaled their person weight divided by the number of complete days. For example, if a household had person weights of 30.0 and 3 complete days, each complete day would have a day weight of 10.0 (30 / 3 = 10). Table 8 shows an example.

TABLE 8: EXAMPLE DAY WEIGHTS BY NUMBER OF COMPLETE DAYS

	Household Weight	Person Number & Relation	Person Weight	Complete Household Days	Day Weight
Household 3	10.0	1 (Related)	40.0	1	10.0
Household 4	20.0	1 (Related)	20.0	2	10.0
Household 4	20.0	2 (Related)	20.0	2	10.0
Household 5	30.0	1 (Related)	45.0	3	15.0
Household 5	30.0	2 (Related)	45.0	3	15.0
Household 5	30.0	3 (Not Related)	0.0	N/A	0.0

4.0 ADJUSTING FOR NON-RESPONSE BIAS IN DAY-PATTERN AND TRIP WEIGHTS

RSG has found over many HTS projects that travel data collected via smartphone app typically exhibits higher trip rates compared to data collected via web or call center travel diary methods. There are three main reasons for this trend.

- Households that own smartphones have different socio-demographic characteristics than households that do not own smartphones. These characteristics can correspond to higher trip-making activity.
- Households that report their travel by smartphone tend to report fewer “stay at home” days. This may be due to the lower burden to recall trips when an app is tracking travel as it occurs.
- On days with reported trips, households that report by smartphone tend to report an average higher number of trips for the reasons previously stated.

These three factors are interrelated and therefore must be isolated in any analysis and weighting adjustments. RSG applied a two-stage approach to address differences in trip reporting across diary methods. First, RSG adjusted weights at the person-day level to account for biases in day-pattern types. Second, RSG adjusted weights at the trip level.

Day Pattern Adjustments

RSG developed a multinomial log-linear model to estimate the probability of each day type (no trips, made mandatory[10] trips, made non-mandatory trips) for each person-day. This model used household income, presence of household vehicles, worker status, student status, and age as independent variables. The model also included variables for diary type, which capture trip reporting bias after accounting for the variables listed previously.

First, RSG applied the model to each person-day to calculate the probability of each day type. To check that the model was applied correctly, RSG summed the probabilities across each diary type (smartphone and non-smartphone). If the aggregate model shares match the observed data shares, the model is applied correctly. Table 13 in Appendix A shows the model specifications.

Next, RSG applied the model again but set the diary type bias coefficients to zero. Because the bias coefficients do not apply to smartphone respondents, the new predictions represent the day

[10] Mandatory trips are trips to work or school.

type shares if non-smartphone respondents reported travel the way smartphone respondents did (after accounting for the same socio-demographic factors).

TABLE 9: DAY TYPE BY DIARY MODE (BEFORE AND AFTER ADJUSTMENT)

Day type	Call Center (Before Adjustment)	Call Center (After Adjustment)	Web (Before Adjustment)	Web (After Adjustment)	Smartphone
No trips	32%	21%	20%	15%	15%
Made mandatory trips	18%	16%	45%	28%	27%
Made non-mandatory trips	50%	64%	35%	58%	58%

RSG then applied these model choice predictions (segmented by weighting geography) as a new set of targets in the reweighting process described in Section 2. RSG reran the weighting process with these new targets to create the final household, person, and day weights. Adjusting the day pattern bias through additional weighting targets instead of simply adjusting the household weights ensures that weight sums are consistent within households and within the region

Trip Rate Adjustments

After finalizing the day-level weights, RSG applied these weights to the trip table to create the initial trip weights. Next, RSG adjusted the trip weights using a similar method as the day-pattern adjustment, now adjusting for four trip types:

- home-based work or school,
- home-based other,
- non-home-based work or school, and
- non-home-based other.

For each person-day in the sample, RSG counted the number of trips by type. For each trip type, RSG estimated a Poisson regression model where the dependent variable was the number of trips of that type on the person-day. The independent variables were the same as the day-pattern adjustment plus variables for non-smartphone person-days.

For each person-day and trip type, RSG applied the regression model with and without the diary type bias coefficients. The ratio of the two estimates represents a trip correction factor. For example, if the model predicted 1.10 trips with the bias coefficients and 1.32 without the bias coefficients, this represents a ratio of 1.20 (1.32 / 1.10 = 1.20). RSG applied this factor to the trip weight to get a final adjusted trip weight. RSG set bounds of 1.0 – 2.0 for all trip factors to avoid extreme weights. The factor was always 1.0 for smartphone respondents since the bias coefficients do not apply. Table 10 shows the final trip adjustment factors. Table 11 demonstrates how these factors could be applied to an example travel day for a respondent who reported their travel using the online diary. Table 16 through Table 19 in Appendix A show the specifications for each of the four models (corresponding to the four trip types).

TABLE 10: TRIP ADJUSTMENT FACTORS

Trip Type	Call Center	Online Diary
Home-based work (HBW)	2.000	1.641
Home-based other (HBO)	2.000	2.000
Non-home-based work (NHBW)	2.000	1.291
Non-home-based other (NHBO)	1.018	1.312

TABLE 11: EXAMPLE TRIP ADJUSTMENT APPLICATION (ONLINE DIARY)

	Day Weight	Trip Type	Trip Weight (Before Adjustment)	Adjustment Factor	Trip Weight (After Adjustment)
Person 1	15.0	HBO	15.0	2.000	30.0
Person 1	15.0	NHBW	15.0	1.291	19.4
Person 1	15.0	NHBO	15.0	1.312	19.7
Person 1	15.0	NHBO	15.0	1.312	19.7
Person 1	15.0	HBO	15.0	2.000	30.0

APPENDIX A. 2023 UTAH MOVES TRANSPORTATION SURVEY WEIGHTING OUTPUTS

TABLE 12: INITIAL WEIGHTS

Sample Stratum[11]	Invitation Type	1-C[12]	Sampled Households	Original Target	Adjusted Target[13]	Initial Expansion Factor
Supplemental	CBS	0.012	123	N/A	14,708	119.58
All other counties—General	ABS	0.988	121	42,266	41,671	344.39
All other counties—Hard-to-survey	ABS	0.988	56	15,744	15,523	277.19
All other counties—Walk/Bike/Transit	ABS	0.988	43	5,490	5,413	125.88
Box Elder, Tooele, and Juab—General	ABS	0.988	311	39,317	38,763	124.64
Box Elder, Tooele, and Juab—Hard-to-survey	ABS	0.988	36	3,243	3,197	88.81
Box Elder, Tooele, and Juab—Walk/Bike/Transit	ABS	0.988	55	3,699	3,647	66.30
Cache—General	ABS	0.988	405	27,705	27,315	67.44
Cache—Hard-to-survey	ABS	0.988	126	5,784	5,703	45.26
Cache—Walk/Bike/Transit	ABS	0.988	167	5,890	5,807	34.77
Davis—General	ABS	0.988	634	97,980	96,601	152.37
Davis—Hard-to-survey	ABS	0.988	33	4,634	4,569	138.45
Davis—Walk/Bike/Transit	ABS	0.988	89	8,052	7,939	89.20
Iron—General	ABS	0.988	219	11,033	10,878	49.67

[11] Sample stratum based on sampling plan. See the dataset user's guide or final report for sampling segment definitions.
[12] C = the share of non-university households coming from convenience sampling.
[13] This column includes adjustments to account for off-campus university students as well as the CBS sample. See Section 2.1 for details.

Sample Stratum[11]	Invitation Type	1-C[12]	Sampled Households	Original Target	Adjusted Target[13]	Initial Expansion Factor
Iron—Hard-to-survey	ABS	0.988	54	4,265	4,205	77.87
Iron—Walk/Bike/Transit	ABS	0.988	60	2,393	2,359	39.32
Morgan, Summit, and Wasatch—General	ABS	0.988	295	28,249	27,852	94.41
Morgan, Summit, and Wasatch—Hard-to-survey	ABS	0.988	17	987	973	57.23
Morgan, Summit, and Wasatch—Walk/Bike/Transit	ABS	0.988	16	1,110	1,094	68.40
Salt Lake—General	ABS	0.988	1,612	247,710	244,222	151.50
Salt Lake—Hard-to-survey	ABS	0.988	677	87,746	86,511	127.79
Salt Lake—Walk/Bike/Transit	ABS	0.988	990	65,874	64,946	65.60
Utah—General	ABS	0.988	1,041	149,902	147,792	141.97
Utah—Hard-to-survey	ABS	0.988	242	14,322	14,120	58.35
Utah—Walk/Bike/Transit	ABS	0.988	237	10,844	10,692	45.11
Washington—General	ABS	0.988	410	59,343	58,508	142.70
Washington—Hard-to-survey	ABS	0.988	58	6,826	6,730	116.04
Washington—Walk/Bike/Transit	ABS	0.988	75	5,335	5,260	70.14
Weber—General	ABS	0.988	384	65,624	64,700	168.49
Weber—Hard-to-survey	ABS	0.988	73	10,764	10,612	145.37
Weber—Walk/Bike/Transit	ABS	0.988	201	12,609	12,431	61.85
Brigham Young University__grad_offcampus	UNI	N/A	53	1,723	1,723	32.51
Brigham Young University__undergrad_offcampus	UNI	N/A	209	13,822	13,822	66.13
Brigham Young University__undergrad_oncampus	UNI	N/A	78	3,898	3,898	49.98

Sample Stratum[11]	Invitation Type	1-C[12]	Sampled Households	Original Target	Adjusted Target[13]	Initial Expansion Factor
Snow College__undergrad_offcampus	UNI	N/A	55	1,528	1,528	27.79
Snow College__undergrad_oncampus	UNI	N/A	23	270	270	11.73
Southern Utah University__grad_offcampus	UNI	N/A	14	949	949	67.76
Southern Utah University__undergrad_offcampus	UNI	N/A	114	6,849	6,849	60.08
Southern Utah University__undergrad_oncampus	UNI	N/A	5	289	289	57.79
University of Utah__grad_offcampus	UNI	N/A	132	5,369	5,369	40.67
University of Utah__grad_oncampus	UNI	N/A	5	286	286	57.22
University of Utah__undergrad_offcampus	UNI	N/A	184	17,766	17,766	96.55
University of Utah__undergrad_oncampus	UNI	N/A	43	2,576	2,576	59.90
Utah State University__grad_offcampus	UNI	N/A	71	856	856	12.05
Utah State University__grad_oncampus	UNI	N/A	9	151	151	16.80
Utah State University__undergrad_offcampus	UNI	N/A	202	7,054	7,054	34.92
Utah State University__undergrad_oncampus	UNI	N/A	92	1,688	1,688	18.35
Utah Valley University__grad_offcampus	UNI	N/A	2	440	440	220.09
Utah Valley University__undergrad_offcampus	UNI	N/A	8	14,347	14,347	1,793.43
Weber State University__grad_offcampus	UNI	N/A	3	530	530	176.82
Weber State University__undergrad_offcampus	UNI	N/A	35	7,467	7,467	213.33
Weber State University__undergrad_oncampus	UNI	N/A	3	538	538	179.27
Westminster University__grad_offcampus	UNI	N/A	1	158	158	158.01
Westminster University__undergrad_offcampus	UNI	N/A	6	333	333	55.49

Sample Stratum[11]	Invitation Type	1-C[12]	Sampled Households	Original Target	Adjusted Target[13]	Initial Expansion Factor
Westminster University__undergrad_oncampus	UNI	N/A	3	173	173	57.75
Total	**N/A**	**N/A**	**10,210**	**N/A**	**1,133,801**	**N/A**

TABLE 13: FINAL PUMA GROUPS FOR REWEIGHTING

Group	PUMA Name	PUMA ID	Sampled Households	ACS Households
East	Southeast Utah & Uintah Basin Region PUMA	13000	253	49,300
East	**Subtotal**	**N/A**	**253**	**49,300**
MAG	Utah County (West)--Saratoga Springs, Payson & Lehi (Southwest) Cities PUMA	49001	356	43,550
MAG	Utah County (Central)--Orem, Pleasant Grove, American Fork & Lindon Cities PUMA	49002	464	66,495
MAG	Utah County (Central)--Provo City PUMA	49003	680	40,681
MAG	Utah County (East)--Spanish Fork, Springville, Lehi (Northeast) & Highland Cities PUMA	49004	329	53,581
MAG	**Subtotal**	**N/A**	**1,829**	**204,307**
Northeast	Cache, Summit, Morgan & Rich Counties PUMA	05000	1,154	64,383
Northeast	**Subtotal**	**N/A**	**1.154**	**64,383**
Northwest	Tooele & Box Elder Counties PUMA	03000	397	43,901
Northwest	**Subtotal**	**N/A**	**397**	**43,901**
South	Southwest & South Central Utah (Outside Washington County)—Cedar City PUMA	21000	589	54,071
South	**Subtotal**	**N/A**	**589**	**54,071**
Southwest	Washington County—St. George City PUMA	53000	550	71,890

Group	PUMA Name	PUMA ID	Sampled Households	ACS Households
Southwest	**Subtotal**	**N/A**	**550**	**71,890**
WFRC	Davis County (South)—Bountiful, Farmington & North Salt Lake Cities PUMA	11002	326	43,652
WFRC	Davis County (Northwest)—Syracuse, Clearfield & West Point Cities PUMA	11003	213	29,491
WFRC	Davis County (Northeast)—Layton, Kaysville & South Weber Cities PUMA	11004	279	43,560
WFRC	Salt Lake County (Southeast)—Sandy (North), Cottonwood Heights & Midvale Cities PUMA	35008	289	43,492
WFRC	Salt Lake County (South & East Central)—Draper (Northwest) & Sandy (South) Cities PUMA	35009	243	38,508
WFRC	Salt Lake County—Salt Lake City (West) & Magna PUMA	35011	608	44,132
WFRC	Salt Lake County—Salt Lake City (East) & Emigration Canyon PUMA	35012	647	46,539
WFRC	Salt Lake County—West Valley City PUMA	35013	295	41,896
WFRC	Salt Lake County—Taylorsville, Kearns & Magna PUMA	35014	287	41,718
WFRC	Salt Lake County (East Central)—South Salt Lake, Murray, Holladay & Millcreek Cities PUMA	35015	614	71,526
WFRC	Salt Lake County—West Jordan City PUMA	35016	255	43,637
WFRC	Salt Lake County—South Jordan, Herriman, Bluffdale & Riverton cities PUMA	35017	397	52,827
WFRC	Weber County (West)—Roy, North Ogden, Ogden (Northwest) & West Haven Cities PUMA	57001	331	51,775
WRFC	Weber County (East)—Ogden (Southeast) & South Ogden Cities PUMA	57002	393	43,325
WFRC	**Subtotal**	**N/A**	**5,177**	**636,078**
Total	**N/A**	**N/A**	**9,949**	**1,123,931**[14]

[14] This total excludes on-campus university students.

TABLE 14: INCOME IMPUTATION MODEL SUMMARY

Parameter	Description	Estimate	std error	t-stat	P-value
finc_0k_25k	Fraction of people in block group with incomes under $25,000	-0.183	0.249	-0.74	0.463
finc_25k_50k	Fraction of people in block group with incomes $25,000–$50,000	-0.226	0.240	-0.94	0.346
finc_50k_75k	Fraction of people in block group with incomes $50,000–$75,000	0.356	0.278	1.28	0.2
finc_100k_200k	Fraction of people in block group with incomes $100,000–$200,000	1.405	0.254	5.53	<0.001
finc_200k_plus	Fraction of people in block group with incomes more than $200,000	4.382	0.295	14.86	<0.001
nonworking_adult_n	Number of non-working adults in household	0.299	0.034	8.86	<0.001
child_n	Number of children in household	0.054	0.018	2.98	0.003
full_time_graduate_degree_n	Number of full-time workers with graduate degrees in household	2.303	0.056	40.97	<0.001
part_time_graduate_degree_n	Number of part-time workers with graduate degrees in household	0.865	0.101	8.58	<0.001
full_time_bachelor_degree_n	Number of full-time workers with bachelor's degrees in household	1.738	0.048	35.93	<0.001
part_time_bachelor_degree_n	Number of part-time workers with bachelor's degrees in household	0.356	0.071	4.99	<0.001
full_time_no_college_n	Number of full-time workers with no advanced degrees in household	1.071	0.041	26.09	<0.001
part_time_no_college_n	Number of part-time workers with no advanced degrees in household	0.051	0.046	1.10	0.273
head_under_35	Head of household under 35	-0.407	0.047	-8.57	<0.001
head_65_plus	Head of household over 65	0.260	0.066	3.97	<0.001
own_home	Owns home (doesn’t rent)	1.272	0.059	21.69	<0.001
single_family_home	Lives in single family housing	0.451	0.058	7.78	<0.001

FIGURE 2: COMPARISON OF WEIGHTED COUNTS TO TARGETS (NORTHWEST)

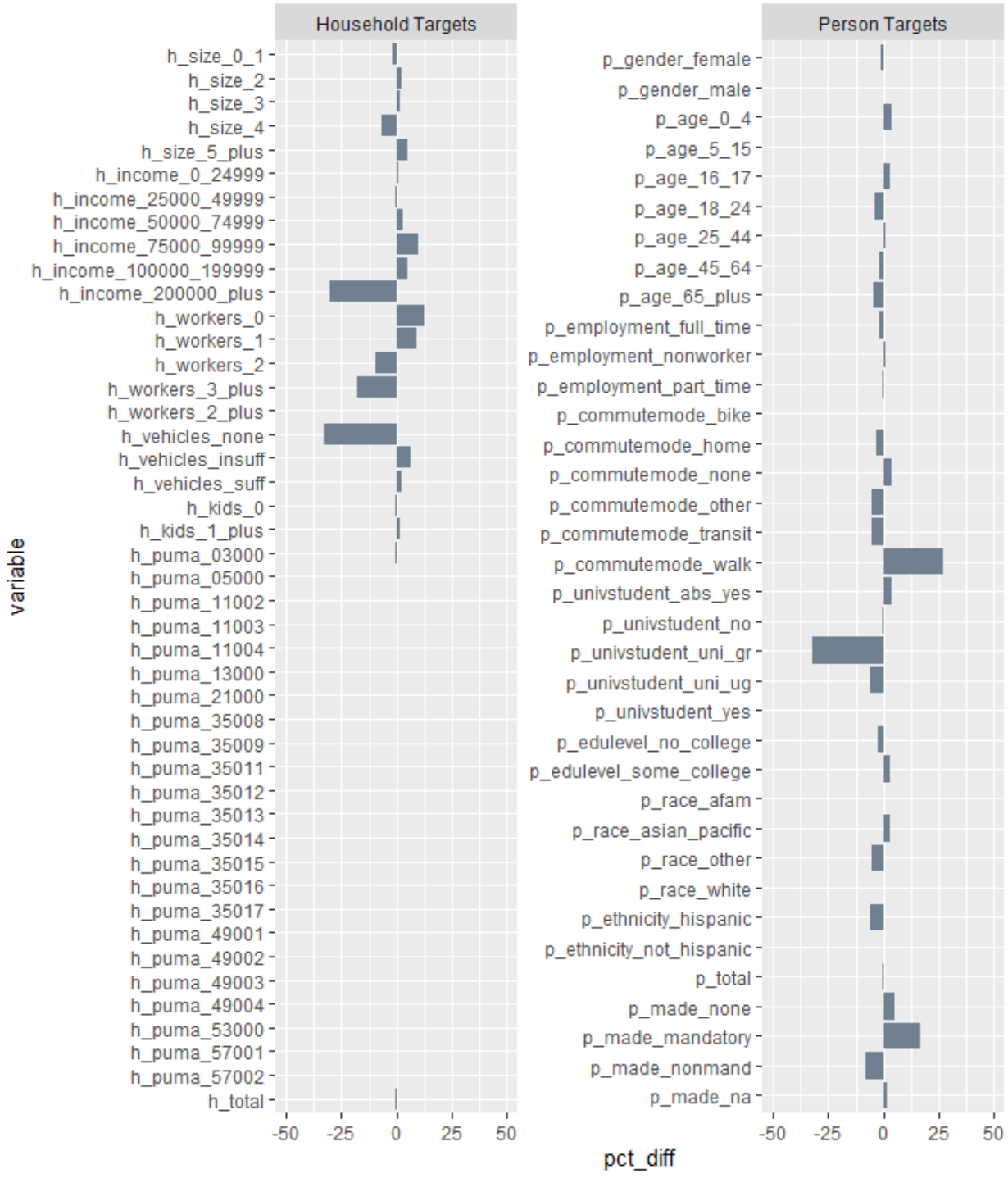

FIGURE 3: COMPARISON OF WEIGHTED COUNTS TO TARGETS (NORTHEAST)

FIGURE 4: COMPARISON OF WEIGHTED COUNTS TO TARGETS (WFRC)

FIGURE 5: COMPARISON OF WEIGHTED COUNTS TO TARGETS (EAST)

FIGURE 6: COMPARISON OF WEIGHTED COUNTS TO TARGETS (SOUTH)

FIGURE 7: COMPARISON OF WEIGHTED COUNTS TO TARGETS (MAG)

FIGURE 8: COMPARISON OF WEIGHTED COUNTS TO TARGETS (SOUTHWEST)

TABLE 15: DAY PATTERN MODEL SUMMARY

Alternative	Parameter	Description	Estimate	std error	t-stat	P-value
Makes mandatory trips	(Intercept)	N/A	-2.130	0.078	-27.47	<0.001
Makes mandatory trips	online_data	Online diary data	0.462	0.037	12.44	<0.001
Makes mandatory trips	call_center_data	Call center diary data	-0.653	0.188	-3.48	<0.001
Makes mandatory trips	zero_vehicle	Zero vehicle household	-0.828	0.093	-8.93	<0.001
Makes mandatory trips	income_1	Income $25,000–$50,000	0.285	0.070	4.08	<0.001
Makes mandatory trips	income_2	Income $50,000–$75,000	0.173	0.068	2.54	0.011
Makes mandatory trips	income_3	Income $75,000–$100,000	0.240	0.069	3.48	<0.001
Makes mandatory trips	income_4	Income $100,000–$200,000	0.232	0.064	3.62	<0.001
Makes mandatory trips	income_5	Income over $200,000	-0.097	0.072	-1.35	0.176
Makes mandatory trips	age_under_35	Age < 35 years	0.095	0.045	2.12	0.034
Makes mandatory trips	age_over_65	Age > 65 years	-0.240	0.054	-4.48	<0.001
Makes mandatory trips	Is_employed	Employed full/part/self	2.949	0.049	59.67	<0.001
Makes mandatory trips	is_student	Full or part-time student	1.151	0.062	18.69	<0.001
Makes mandatory trips	online_data:age_under_35	Online diary data x age	-0.156	0.063	-2.48	0.013
Makes mandatory trips	call_center_data:age_over_65	Call center diary data x age	0.590	0.271	2.18	0.029
Makes non-mandatory trips only	(Intercept)	N/A	1.130	0.058	19.51	<0.001
Makes non-mandatory trips only	online_data	Online diary data	-0.665	0.033	-20.11	<0.001
Makes non-mandatory trips only	call_center_data	Call center diary data	-1.324	0.169	-7.83	<0.001
Makes non-mandatory trips only	zero_vehicle	Zero vehicle household	-0.645	0.073	-8.86	<0.001

Alternative	Parameter	Description	Estimate	std error	t-stat	P-value
Makes non-mandatory trips only	income_1	Income $25,000–$50,000	0.087	0.061	1.44	0.15
Makes non-mandatory trips only	income_2	Income $50,000–$75,000	0.025	0.059	0.42	0.674
Makes non-mandatory trips only	income_3	Income $75,000–$100,000	0.271	0.060	4.49	<0.001
Makes non-mandatory trips only	income_4	Income $100,000–$200,000	0.369	0.056	6.65	<0.001
Makes non-mandatory trips only	income_5	Income over $200,000	0.305	0.063	4.85	<0.001
Makes non-mandatory trips only	age_under_35	Age < 35 years	0.036	0.040	0.91	0.36
Makes non-mandatory trips only	age_over_65	Age > 65 years	-0.104	0.039	-2.65	0.008
Makes non-mandatory trips only	Is_employed	Employed full/part/self	0.076	0.031	2.50	0.013
Makes non-mandatory trips only	is_student	Full or part-time student	0.057	0.061	0.93	0.352
Makes non-mandatory trips only	online_data:age_under_35	Online diary data x age	-0.321	0.060	-5.39	<0.001
Makes non-mandatory trips only	call_center_data:age_over_65	Call center diary data x age	0.941	0.205	4.58	<0.001

McFadden's rho-squared: 0.129
"No Travel" is the reference alternative and does not report coefficients.

TABLE 16: HOME-BASED WORK TRIP MODEL

Parameter	Description	Estimate	std error	t-stat	P-value
(Intercept)	N/A	-2.613	0.057	-45.69	<0.001
diary_online	Online diary data	-0.495	0.019	-26.16	<0.001
diary_call	Call center data	-0.721	0.121	-5.95	<0.001
income_under_50k	Income under $50,000	0.078	0.026	2.97	0.003
income_50k_to_100k	Income $50,000-$100,000	0.043	0.021	2.09	0.037
sf_home	Single-family home	0.034	0.024	1.46	0.145
age_under_25	Age < 25 years	0.255	0.027	9.59	<0.001
age_over_65	Age > 65 years	-0.132	0.037	-3.58	<0.001
bachelors	Has bachelor's degree	0.038	0.021	1.79	0.074
grad_degree	Has graduate degree or higher	0.013	0.026	0.49	0.624
is_student	Full or part-time student	0.399	0.031	13.07	<0.001
employed_ft	Employed full-time	1.810	0.051	35.61	<0.001
employed_pt	Employed part-time	1.585	0.053	29.99	<0.001
work_loc_varies	Work location regularly varies	-0.039	0.028	-1.39	0.165
two_plus_jobs	Has 2+ jobs	0.159	0.028	5.57	<0.001
telework_everyday	Teleworks 5+ days per week	0.055	0.062	0.88	0.378
telework_rarely	Teleworks once per month or less	0.850	0.022	38.81	<0.001

McFadden's rho-squared: 0.165

TABLE 17: HOME-BASED OTHER TRIP MODEL

Parameter	Description	Estimate	std error	t-stat	P-value
(Intercept)	N/A	0.814	0.025	32.54	<0.001
diary_online	Online diary data	-0.727	0.012	-62.59	<0.001
diary_call	Call center data	-0.868	0.052	-16.75	<0.001
income_under_50k	Income under $50,000	-0.066	0.015	-4.47	<0.001
income_50k_to_100k	Income $50,000-$100,000	0.028	0.011	2.49	0.013
sf_home	Single-family home	0.192	0.015	13.16	<0.001
age_under_25	Age < 25 years	-0.264	0.019	-13.59	<0.001
age_over_65	Age > 65 years	-0.288	0.014	-19.89	<0.001
bachelors	Has bachelor's degree	0.219	0.011	19.22	<0.001
grad_degree	Has graduate degree or higher	0.166	0.014	12.07	<0.001
is_student	Full or part-time student	-0.124	0.021	-5.79	<0.001
employed_ft	Employed full-time	-0.403	0.020	-20.55	<0.001
employed_pt	Employed part-time	0.005	0.021	0.25	0.804
work_loc_varies	Work location regularly varies	0.163	0.019	8.75	<0.001
two_plus_jobs	Has 2+ jobs	0.080	0.017	4.64	<0.001
telework_everyday	Teleworks 5+ days per week	0.086	0.030	2.84	0.004
telework_rarely	Teleworks once per month or less	-0.057	0.013	-4.46	<0.001

McFadden's rho-squared: 0.09

TABLE 18: NON-HOME-BASED WORK TRIP MODEL

Parameter	Description	Estimate	std error	t-stat	P-value
(Intercept)	N/A	-2.229	0.044	-50.19	<0.001
diary_online	Online diary data	-0.256	0.015	-17.34	<0.001
diary_call	Call center data	-0.772	0.099	-7.83	<0.001
income_under_50k	Income under $50,000	0.063	0.021	3.02	0.003
income_50k_to_100k	Income $50,000-$100,000	-0.014	0.017	-0.81	0.415
sf_home	Single-family home	-0.032	0.019	-1.73	0.084
age_under_25	Age < 25 years	0.100	0.022	4.58	<0.001
age_over_65	Age > 65 years	-0.010	0.029	-0.35	0.723
bachelors	Has bachelor's degree	-0.044	0.017	-2.59	0.01
grad_degree	Has graduate degree or higher	-0.212	0.021	-10.10	<0.001
is_student	Full or part-time student	0.535	0.024	22.15	<0.001
employed_ft	Employed full-time	2.171	0.039	55.95	<0.001
employed_pt	Employed part-time	1.681	0.041	41.00	<0.001
work_loc_varies	Work location regularly varies	0.406	0.020	20.68	<0.001
two_plus_jobs	Has 2+ jobs	0.332	0.021	15.74	<0.001
telework_everyday	Teleworks 5+ days per week	-0.268	0.049	-5.43	<0.001
telework_rarely	Teleworks once per month or less	0.471	0.016	28.84	<0.001

McFadden's rho-squared: 0.152

TABLE 19: NON-HOME-BASED OTHER TRIP MODEL

Parameter	Description	Estimate	std error	t-stat	P-value
(Intercept)	N/A	0.518	0.029	17.63	<0.001
diary_online	Online diary data	-0.272	0.013	-21.05	<0.001
diary_call	Call center data	-0.018	0.040	-0.45	0.654
income_under_50k	Income under $50,000	0.045	0.017	2.65	0.008
income_50k_to_100k	Income $50,000-$100,000	0.009	0.014	0.62	0.534
sf_home	Single-family home	-0.104	0.016	-6.44	<0.001
age_under_25	Age < 25 years	-0.244	0.022	-10.85	<0.001
age_over_65	Age > 65 years	0.026	0.016	1.60	0.109
bachelors	Has bachelor's degree	0.196	0.014	14.21	<0.001
grad_degree	Has graduate degree or higher	0.061	0.017	3.60	<0.001
is_student	Full or part-time student	0.022	0.024	0.93	0.352
employed_ft	Employed full-time	-0.443	0.024	-18.70	<0.001
employed_pt	Employed part-time	-0.021	0.026	-0.80	0.423
work_loc_varies	Work location regularly varies	0.167	0.023	7.28	<0.001
two_plus_jobs	Has 2+ jobs	0.108	0.021	5.20	<0.001
telework_everyday	Teleworks 5+ days per week	0.078	0.037	2.10	0.035
telework_rarely	Teleworks once per month or less	-0.159	0.016	-10.03	<0.001

McFadden's rho-squared: 0.04