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2017 NHTS Weighting Report

Task P

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Overview 1

The sample design for the 2017 National Household Travel Survey (NHTS) is described in the December 31, 2015 document 'Task C: Sample Design' (Task C Deliverable, Task_C_Sample_Design FINAL 20151231.docx). The weighting report for the 2017 NHTS decribes the construction of the weights and provides some results. The methodology used was based roughly on the weighting procedures that were executed for the 2009 NHTS. This approach is appropriate for the NHTS 2017 because weighting procedures such as the ones used for the 2009 NHTS retain their robustness regardless of survey mode. These are standard procedures that apply to data collected in household surveys, and include basic steps of calculating the inverse of the selection probability for each sampled address as a base weight, adjusting the base weights for eligibility and nonresponse, and poststratifying the adjusted weights to reliable external source data, such as Census data. Some of the specifics of the adjustments, such as the adjustment for unknown eligibility, depend on the mode, and in such situations, the adjustments have been modified as appropriate. Otherwise, the weighting methodology was kept as similar as possible to 2009 also to allow an easier examination of travel trends.A few of the changes between 2009 and 2017 and key aspects of 2017 procedures are noted below:

- The 2017 study required that every household member age 5 and older complete a retrieval interview in order for the household to be considered complete.
- One set of weights was produced that can be used with the combined national sample and Add-on study samples, or separately for each Add-on's geographic area. Both 7-day and 5-day weights were provided for the Add-on areas.
- In 2009, independent selections were used to select the Add-on and national samples. In 2017, there was no need for independent selections (since all sample design decisions for both the National portion and the Add-on samples were finalized prior to selection of the addresses), so it was not necessary (or appropriate) to use composite estimation, as was done in 2017.
- The nonresponse analysis work to conducted under Task P included a concurrent nonresponse bias analysis that was completed before weighting was finalized, to allow for results from that work to inform the weighting process.

The NHTS 2017 survey design is quite complex in that there are numerous pieces which make up the full NHTS 2017 sample, including a national portion, 13 Add-on area portions, and two time

periods when addresses were selected from the address-based sampling vendor (referred to as "Sample Groups 1 and 2"). With regard to the two time periods, Sample Groups 1 and 2 were structured such that the Sample Group 1 was selected before data collection commenced and Sample Group 2 was selected about halfway through data collection efforts, to account for response rates up to that point. The timing of Sample Groups 1 and 2 allowed for operational flexibility in trying to maximize response and achieve desired sample yield targets. The sampling documentation (Task C deliverable, see above) describes this process.

Similar to NHTS 2001 and NHTS 2009, we performed a household-level nonresponse adjustment, which consisted of adjusting the weights for characteristics that were determined to be related to response propensity. We also did household-level raking to independent household control totals, such that the final raked weights sum to known benchmark controls from the American Community Survey (ACS), both 2015 1-year and 2011-2015 5-year data. Using both approaches allowed us to use a different cell structure such as using Census tract-level characteristics (which are available for both respondents and nonrespondents) to adjust for recruitment nonresponse, and variables such as Hispanic origin and number of vehicles (which are available only for respondents) to adjust for population undercoverage.

Also as in NHTS 2001 and NHTS 2009, we estimated variances (as a way of giving data users and readers an indication of the precision of the survey estimates) using a jackknife replication methodology. Replication, specifically the jackknife method, is described in Section 2.2.

Household weights, person-level weights,travel-day trip-level weights and vehicle weights were produced. The household-level weights are designed to represent all households in the study area, and were produced for the National sample (7-day only) and for all Add-on areas (7-day and 5-day). The person-level weights are designed to represent all persons in the study area. These also were produced for the National sample (7-day only) and for all Add-on areas (7-day and 5-day). As was the case in the 2001 NHTS and the 2009 NHTS, all of the weights produced are "annual" weights.

The overall steps in the weighting process were as follows (see Exhibit 1 below):

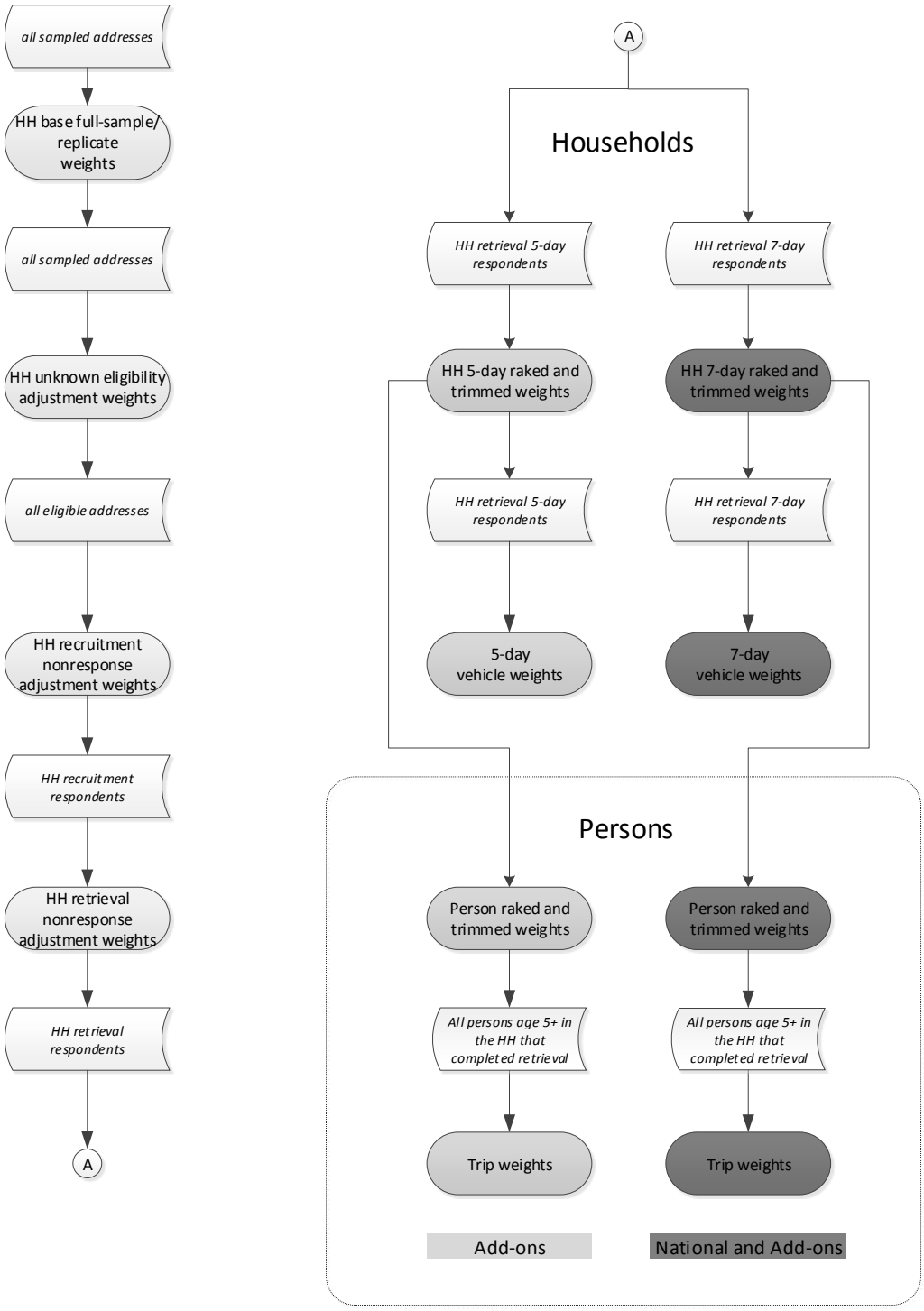
- Construction of base weights—the base weights are the reciprocals of the probabilities of selection within each sampling stratum (for the national sample) or substratum (for Add-ons) (see Task C: Sample design for stratum definitions);

- Construction of jackknife replicate weights—the replicate weights are designed to allow the user to easily produce valid jackknife variance estimates based on the sample design, using software designed for the analysis of complex sample survey data;[1]
- Household-level nonresponse adjustments (separate adjustments for unit nonresponse to the recruitment and retrieval efforts, done within each Add-on area and the rest of the Census division separately (see table 1 in section 3 for geographic definitions);
- Household-level raking and trimming (using the household-level nonresponse adjusted weights);
- Person-level raking and trimming;
- Computation of vehicle and trip weights; and
- Inclusion of the final weight variables in the preparation of data files for analysis--a set of files will be delivered to the specifications of FHWA, including all relevant final weights and identifiers.

The listing of chapters roughly follows the order that the weighting process was carried out. Chapter 2 describes the process for computing household-level base weights within each sampling stratum, which were defined during the sample design process and used for selection of addresses. Chapter 3 describes adjustments for nonresponse at the household level, done within the separate studies and sample groups. Chapter 4 describes the raking procedure at the household level. Chapter 5 describes the person-level raking adjustments. Finally, Chapter 6 describes special weights for vehicles and trips.

[1] Replicates simulate multiple samples from our single NHTS sample, allowing for estimation of variances. There are several methods, but the jackknife method works well for our data due to its sample design. Software such as WesVar, or the survey procedures in SAS, will easily compute appropriate standard errors using the replicate weights.

Exhibit 1 Flowchart of NHTS Weighting Procedures



Household Level Weights—Base Weights 2

The primary component of the base weight is the inverse of the probability of selection of the address in the given sampling stratum from the sampling frame.

The sample design for each stratum (or substratum) (see Task C: Sample Design for stratum and substratum definitions) is an equal probability sample of addresses, that is, all addresses had an equal chance of selection, from the Address-Based Sample (ABS) sampling frame for the stratum/substratum (the strata/substrata are defined in the December 31, 2015 sample design plan, see Task C: Sample Design). Although the sample was selected via two independent selections as described earlier (to ensure the sample yield, that is, the number of completed surveys, would be as close as possible to the target number of completed surveys, the differences between the two sampling frames were very minimal. Westat took into account the response rates (our experience from the first part of the sample) when deciding on sample sizes for the second part of the sample, to make sure we would hit our estimated targets. Additionally, different proportions of the sample were released from the two selections. All of the differences (between the two selections and their associated releases) are simply operational in nature, so in order to smooth the sampling rates, for weighting purposes, the sample was treated effectively as a single selection from a single frame[2]. The second sample selection was deduplicated against the first sample, so that no address could be sampled twice.

2.1 Full Sample Base Weights

The base weight is the inverse of the selection probability for the address. Note that the sum of the base weights for a given sampling stratum provides an estimate of the total number of addresses in the sampling stratum from which the addresses were drawn. The sum of the base weights across all sampling strata provides an estimate of the total number of addresses in the frame.

[2] The two parts of the sample were drawn from a single frame, the USPS file of addresses that is maintained by the sampling vendor Westat uses. This frame is updated on a monthly basis. In Westat's experience, the monthly updates are quite small. Accounting for the separate selections would have introduced considerable variation in the weights (due to variations in the separate probabilities of selection) that is not necessary considering that they yielded, effectively, a single sample (released on a weekly basis). Given that, we treated the two independent samples as if they had been selected in a single draw from a single frame.

2.2 Replicate Base Weights

Replicate base weights were also computed for each household in each sampling stratum separately. Replicate base weights are important because they simulate multiple samples from our single NHTS sample, allowing for estimation of variances of survey estimates.

Variance strata are geographic areas that were used in the weighting process to make sure the weights were created in a manner that is related to the sample design, and were formed using National sample only states and the thirteen Add-on areas separately.

Replicate base weights were computed using similar methodology to what was used for the 2009 and the 2001 NHTS weights. We used the stratified jackknife replication method (JKn; see WesVar® 4.2 User's Guide (2002)) to create G=98 replicates[3]. We numbered each sampled address from 1 to 7 within each of the fourteen sample areas, the thirteen areas determined by the Add-ons and the rest of the nation, in selection order within the sample areas (variance strata) to form variance units. We ensured that there was at least one completed interview within each variance stratum. Replicates were formed within each variance stratum by deleting one variance unit at a time and multiplying the weights for the other variance units in the same variance stratum as the deleted unit by $n_h/(n_h - 1)$, where n_h is the number of variance units in the variance stratum with the deleted unit (in this case, $n_h = 7$). In other words, within each of the 14 variance strata, all replicate weights are equal to the full-sample weight except for those in the variance stratum containing the deleted variance unit for the replicate, which are 'perturbed' by setting the deleted variance unit's weight to zero (for that replicate) and multiplying the weights of the other variance units in that variance stratum by $n_h/(n_h - 1)$. These procedures resulted in 7 replicates created in each of the 14 sample areas (variance strata), for a total of 98 replicates.

Full sample and replicate base weights were used as the starting weights for the household level nonresponse adjustments. The full-sample weights and each of the replicate weights received the same set of adjustment steps, as described in the remaining sections of this report.

[3] The goal of replication is to create a sufficient number of "simulated" samples such that precision can be gained in variances of the survey estimates. Within each of the fourteen sample areas, 7 variance units were assigned, which yielded a total of 14*7=98 replicates. For a survey of this size, 98 replicates is sufficient.

Household Level Nonresponse Adjustments 3

Nonresponse to surveys unfortunately is a major and continuously growing problem with virtually every survey. Our approach to controlling unit nonresponse has two parts: a nonresponse bias analysis where we analyzed survey nonresponse and the potential for bias, and the development of appropriate nonresponse adjustments to the weights based on the results of this analysis.

The nonresponse adjustments are based on a paradigm generally used in survey research (Oh and Scheuren 1983). Under this paradigm, nonresponse is treated as a subsampling process within carefully selected nonresponse-adjustment cells. The nonresponse-adjustment cells are selected to be heterogeneous in response propensity (the probability of responding) across cells, and homogeneous in response propensity within cells. The nonresponse bias analysis informed this cell selection process by finding characteristics which were related to response propensity (propensity to cooperate at the recruitment level, propensity to cooperate at the retrieval level). The final nonresponse adjustments are equal to the inverse of the base-weighted response rates within the selected nonresponse adjustment cells. These nonresponse adjustment cells are nested within the strata used in sample selection. The cells were not smaller than 29 sample units, as cells with limited numbers of sample units generate unreliable (highly variable) nonresponse adjustments. In addition, cells with very low weighted response rates or very small size were collapsed with other cells to avoid extreme weighting adjustments, which can introduce too much variability[4].

Nonresponse adjustment was done separately at the recruitment level (recruitment nonresponse) and the retrieval level (retrieval nonresponse within recruited households).[5] The cell structure differed between the stages since response patterns were quite different for the different stages of data collection. Additionally, the nonresponse adjustments for recruitment nonresponse included an

[4] There is not a pre-defined cut-off but we did not want to create weights that were too extreme. Cells with particularly low response rates would get higher adjustments factors which can result in large weights. We carefully reviewed the adjustment factors for all cells and determined where collapsing was needed.

[5]It is standard practice to adjust for nonresponse at each phase in a multi-phase study. For each phase of data collection, we weight up the respondents so that they represent the population, and this weighting up is done under the pseudo-randomization paradigm (which treats nonresponse as another phase of sampling, as described in the Oh & Scheuren reference). For NHTS it is particularly crucial to adjust for nonresponse at the recruitment level, because that is where the majority of our nonresponse (and potential bias) is occurring.

adjustment reflecting the proportion of cases with unknown eligibility that are estimated to be eligible.

The variables used for these unit nonresponse adjustment steps must be available for both respondents and nonrespondents. Thus, the data available to adjust for recruitment nonresponse were mainly aggregate variables appended to the address based on its geocoded location, e.g., Census tract-level variables (see Appendix B for a list of variables that were considered for this adjustment). A few items from the ABS frame were also included for consideration. While the ABS vendor can also append household- and person-level characteristics, research has shown that these appended variables are incomplete and often inaccurate (Roth, Han, and Montaquila 2013). Based on the nonresponse bias analysis, we determined characteristics to use to define adjustment cells[6] (those characteristics which are related to recruitment response propensity and are also related to key travel variables from the NHTS, such as household vehicle trips, person trips, average number of daily trips per household, average annual vehicle miles of travel per household, or average time spent driving on any trip).

For the retrieval nonresponse-adjustment cells, we also included information from the recruitment questionnaire, such as household size, race and ethnicity of reference person, home ownership, location, home type, and number of vehicles in household. The 2009 NHTS nonresponse bias report showed that many recruitment variables are associated with retrieval response; we re-examined this as part of the nonresponse bias analysis for the 2017 NHTS. We found that many of these variables were appropriate to be used in nonresponse cell generation.[7]

Geographic adjustment cells were defined geographically as state, for states where the Add-on area encompasses the entire state (specifically, AZ, CA, GA, MD, NC, NY, SC, and WI); Add-on area, for the sub-state-level Add-ons (Des Moines, Iowa Northland, Indian Nations (OK), and North Central (TX); Texas, which includes the TX DOT Add-on as well as the remainder of the state, or

[6] Tract-level variables and ABS frame variables were assessed during the nonresponse bias analysis to see if they were a good fit for our nonresponse adjustment process. Data that are available for all sampled addresses to adjust for recruitment nonresponse has to be used for this adjustment. The nonresponse bias analysis in conjunction with Westat's extensive experience in adjusting for nonresponse to surveys results in adjustments to the weights that will ultimately provide for better (less biased, more accurate) estimates and variances.

[7] The objective was to find variables that are associated with both key survey outcome variables and response propensity. To examine association with response propensities, we used a SAS procedure, HPSPLIT, which uses chi-square testing at each split to identify characteristics that are (conditional on previous splits) significantly associated with response propensity.

"balance of Census division" (for the remaining states and sub-state areas in each Census division)[8]. Table 1 shows these 22 geographic definitions. These geographic adjustment cells were used for both non-response adjustments and as 'Geographic adjustment cells' for raking.

Table 1 Geographic Adjustment Cell Definitions for Non-response Adjustment and Raking

Geographic adjustment cell	Name	Area
1	Arizona DOT	AZ
2	Caltrans	CA
3	Des Moines	Des Moines blocks in IA
4	Georgia DOT	GA
5	Indian Nations COG	Indian Nations blocks in OK
6	Iowa Northlands Regional COG	Iowa Northlands blocks in IA
7	Maryland State Highway Administration	MD
8	North Carolina DOT	NC
9	North Central Texas COG	NCTCOG counties in TX
10	New York State DOT	NY
11	South Carolina DOT	SC
12	Texas DOT	TX, excluding NCTCOG counties
13	Wisconsin DOT	WI
14	Census Division 1	CT, ME, MA, NH, RI, VT
15	Census Division 2, excluding NY	NJ, PA
16	Census Division 3, excluding WI	IN, IL, MI, OH
17	Census Division 4, excluding IA Add-on areas	KS, MN, MO, NE, ND, SD, rest of IA
18	Census Division 5, excluding GA, MD, NC, SC	DE, DC, FL, VA, WV
19	Census Division 6	AL, KY, MS, TN
20	Census Division 7, excluding TX and Indian Nations Add-on area	AR, LA, rest of OK
21	Census Division 8, excluding AZ	CO, ID, NM, MT, UT, NV, WY
22	Census Division 9, excluding CA	AK, HI, OR, WA

[8] NCTCOG was raked separately from the remainder of Texas, as shown in rows 9 and 12. Since each respondent within an NCTCOG county must only be counted once, these counties were excluded from the raking for TXDOT.

3.1 Recruitment Adjustment for Unknown Eligibility and Nonresponse Adjustments within Geographic Adjustment Cells[9]

Recruitment nonresponse occurs when an eligible[10] sampled address does not complete the recruitment instrument. A completed recruitment instrument is one for which the respondent has completed the household and vehicle enumeration parts of the instrument.

In general, nonresponse adjustments are equal to the summation of base weights[11] for all eligible addresses divided by the summation of base weights for all recruitment respondent households, within the cells we define as a result of nonresponse bias analysis. The numerator includes all sample units which are definitely identified as being eligible (respondent or not), and exclude all sample units which are definitely identified as being ineligible.

Because the survey weights should account for only the eligible population, it is important to identify ineligibles and exclude them from the weighting process. When mail is returned to us from an address, we are able to determine the eligibility of the address. If a household completes the recruitment instrument and returns it, or the household writes something on the instrument indicating they do not wish to participate and returns it, we know the mailing has reached an eligible address. If the recruitment mailing is returned by the USPS with a message indicating an undeliverable address, we know the mailing has reached an ineligible address.

Across all categories of addresses[12], there is one general category of addresses, unreturned mail, where eligibility is uncertain at the completion of the recruitment process. Since we do not know if unreturned mail addresses are eligible or not, the number of eligible addresses among them is estimated. This estimate is then used in the recruitment nonresponse adjustment process to adjust the weights accordingly. For the set of addresses for which eligibility is unknown, the estimated

[9] The study design resulted in a large amount of unreturned mail for which Westat is unable to determine that address's eligibility. Through the process described here, we estimate the proportion of those that are eligible, and also ineligible. This is important because the goal is for the weighted sample to represent eligible households (and persons within those households) but not represent ineligible addresses.

[10] Ineligibility in this study arises from vacant addresses, vacation homes, invalid addresses, or addresses that are not dwelling units.

[11] Sections 2.1 and 2.2 result in full sample and replicate base weights. Those are the weights we adjusted for unknown eligibility.

[12] Categories include Residential, Business, Vacant, Seasonal, Educational (e.g., college dorm), Throwback (city style address that does not accept mail delivery), Drop point (single delivery point servicing multiple residences), and unreturned mail.

portion of eligible addresses *e* described below was computed, and added to the numerator described in the previous paragraph. This is similar to the approach that was used to treat telephone numbers in the older RDD sampling approach where the phone number rang but was never answered.

The approach to estimating eligibility can be referred to as the "backing out" approach to estimating *e*. Here we use the estimate of the total number of households within each geographic adjustment cell (T_{ACS}), the total number of respondents in each geographic adjustment cell (T_R), the total number of nonrespondents in each geographic adjustment cell (T_{NR}), and the total number of unknown eligibility cases in each geographic adjustment cell (T_U) to estimate *e* as follows:

$$\hat{T}_{ACS} = \hat{T}_R + \hat{T}_{NR} + e\hat{T}_U \ ,$$

where $\hat{T}_{ACS}$ is estimated number of households from most recent (2015) ACS. So

$$e = \left(\frac{1}{\hat{T}_U}\right)\left(\hat{T}_{ACS} - \hat{T}_R - \hat{T}_{NR}\right).$$

The recruitment nonresponse adjustment cells are intended to be homogeneous in recruitment response and contact propensity within the cells and heterogeneous in recruitment response and contact propensity across cells. The cells were generated after a selection of cells using the SAS procedure HPSPLIT (a binary search algorithm software routine), as discussed in Section 3.3 below.

The recruitment nonresponse adjusted weight for each recruitment respondent is equal to the base weight multiplied by the recruitment nonresponse adjustment for the nonresponse cell containing the respondent.

3.2 Retrieval Nonresponse Adjustments within Geographic Adjustment Cells

A household is considered complete *if the retrieval survey has been completed for all household members ages 5 and older*. Otherwise, the household is viewed as a nonrespondent at this level. Therefore, in all following discussions, "retrieval response" refers to having completed retrieval surveys for all household members ages 5 and older.

To adjust for retrieval nonresponse, each completed household receives an adjustment for nonresponding households that completed the recruitment survey but not the retrieval survey; this adjustment is equal to the reciprocal of the weighted retrieval response rate in its adjustment cell. These adjustment cells were selected to be as heterogeneous in terms of retrieval response rates across cells as possible, and as homogeneous in terms of retrieval response rates within cells as possible. The cells were selected following an analysis of household characteristics found to be correlated with completion rates (see Section 3.3 below).

As compared to recruitment nonrespondents, there is more information available about retrieval nonrespondents (households that have not completed the retrieval survey). This extra information, such as home ownership, vehicle count, and age, gender, race/ethnicity, and educational attainment for the recruitment respondent, comes from the completed recruitment instrument.

The nonresponse adjustments for each cell is the weighted sum of recruitment responding households within the cell divided by the weighted sum of completed households within the cell. The weights used in computing these weighted sums were the recruitment nonresponse adjusted weights described in the previous section 3.1. The final household-level nonresponse adjusted weight for each completed household is the recruitment-nonresponse-adjusted weight multiplied by the retrieval nonresponse adjustment for the retrieval nonresponse cell containing the household.

3.3 Specification of Nonresponse Adjustment Cells

The SAS procedure HPSPLIT was used to define nonresponse cells within each sampling stratum for both recruitment nonresponse and retrieval nonresponse separately. HPSPLIT is a high performance SAS procedure that builds classification trees to model response. More details on the procedure can be found at
https://support.sas.com/documentation/onlinedoc/stat/141/hpsplit.pdf.

For recruitment nonresponse adjustment cells, the HPSPLIT procedure created a classification tree within each geographic adjustment cell separately. The algorithm avoided constructing cells with a sample size smaller than 30, and avoided adjustments significantly larger than five times the mean adjustment for the stratum. In cases of violation of these norms, the cells were collapsed such that the minimum cell size of 30 requirement was met, and such that the adjustment factors were not larger than five times the mean adjustment.

Potential cells were generated based on ABS frame information and variables that could be linked to the sample (e.g., Census tract-level variables). The nonresponse cells were dichotomous cells (above-median and below-median) using weighted medians of ABS frame characteristics within stratum. For example, one set of cells was households with an appended telephone number for a particular stratum. Not every set of cells was chosen: only those that registered as significantly correlated to response propensity within the stratum, and which satisfied the criteria defined in the previous paragraph. Also, not every frame characteristic was tested: only those that registered as important in the nonresponse bias analysis were included in the analysis. The listings of characteristics included in the recruitment nonresponse bias analysis (which was subsequently tested for cell formation by HPSPLIT) is given in Appendix B.[13]

For retrieval nonresponse adjustment cells, HPSPLIT searched using the characteristics given in the tables in Appendix B. Most of these are recruitment questionnaire variables, but some are ABS frame characteristics.

The final nonresponse adjusted household-level weights were used as the input weights for the household-level raking procedures outlined in section 4.

[13] The list is based on the Census tract-level characteristics used in the 2009 NHTS weighting process, updated for 2017 to add two variables from the ABS frame that were useful for nonresponse bias analysis, which arewhether a phone number could be matched to the address and type of dwelling unit: single- or multi-family.

Raking Procedures—Household Level 4

ABS frames provide excellent coverage of the population as a whole; for surveys like the NHTS that make contact with households via mail (so that households with nonlocatable addresses such as PO box addresses or rural route addresses are included), the coverage is estimated to be about 98 percent (see Link et. al., 2010). However, coverage varies among different types of areas (e.g., as described by the four primary sampling strata). It is possible to adjust for differential coverage through a calibration weighting process called "raking," where the weights are iteratively adjusted to independent controls totals for various demographic categories[14]. The process has the effect of differentially adjusting the weights of the sampled households within groups of demographically similar households, so that the total sum of weights for the sampled households equals the corresponding independent control totals for all households (including those not covered by the ABS sample).

Raking and trimming steps were performed iteratively at the household level[15]. The starting point was the household retrieval nonresponse adjusted weights described in Section 3. The trimming steps included a 'pre-trim' step preceding the first household raking step, and a 'post-trim' step following each household raking step. Each trimming step was applied within the geographic adjustment cells.

The pre-trim step for each geographic adjustment cell consisted of checking for weights that were more than 3.0 times the median weight.[16] If less than 1% of the weights fell into this category, then all such weights were trimmed back to equal the cutoff (3.0 times the median weight for the stratum). If more than 1% of the weights fell into this category[17], then the largest 1% set of the weights were trimmed back to equal the 99th percentile of the weights.

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[14] Control totals were comprised of 2015 ACS 1-year data where possible and 2011-2015 5-year data adjusted to 1-year totals where geographies were too small to use the 1-year data directly. In a few special cases we used the 2010 Census SF1, also adjusted to 1-year ACS totals. Please see section 4.1 for details on the control totals sources.

[15] The idea of trimming is to limit the size of the weight that can be associated with a single household so that it does not have too much influence on the estimates.

[16] This is the median value of all of the household level raked weights after the raking adjustment. If any household raked weight violated 3*median threshold prior to trimming, it was trimmed as described.

[17] The number of weights affected by this rule was 1% of the number of sample units, rounded up to the smallest larger integer. For example, if the sample size was 120, then the number of trimmed weights was 2 (1.2 rounded up). In

The post-trim steps follow the raking steps and were also done within each geographic adjustment cell, and targeted for trimming any weights that were 4.5 times smaller or 4.5 times larger than the median weight for the geographic adjustment cell. A maximum of 2.5% of the weights were trimmed on the high side and a maximum of 2.5% of the weights were trimmed on the low side for each post-trim step[18]. If more than 2.5% of the weights were greater than 4.5 times the median weight (less than 4.5 times the median weight), then the largest (smallest) 2.5% of the weights were trimmed back to the 97.5th percentile (the 2.5th percentile). This procedure with its associated limits was adopted for the 2009 NHTS after extensive expert review, and therefore was followed for the 2017 NHTS[19].For more information on trimming procedures, see Potter (1993).

The iteration of raking and trimming steps was complete when all of the trimming factors for that final putative trimming step were between 0.99 and 1.01. In other words, once raking converged and all trimming factors were between 0.99 and 1.01, the weights were considered final. A flag indicating that a weight was trimmed is provided on the delivery files.

This raking and trimming process has a number of "dimensions." The dimensions are discussed in detail in section 4.1 below. The weights were adjusted to equal the totals within the cells for each dimension in an iterative process, until the process converged, and every dimension's cell totals equal (to within the specified tolerance) the independent control totals. Each household raking step in the cycle was done to a tolerance of ±1, i.e., the weighted household totals were raked until they were within 1 of the household control totals. If convergence was not achieved initially, cells were collapsed (within dimensions) until convergence was reached.

particular, there was always be at least one weight trimmed if any weight exceeds 3.0 times the median weight. The actual percentage of trimmed weights then could be slightly larger than 1%.

[18] This count of trimmed weights was 2.5% of the number of sample units, rounded up to the smallest larger integer. For example, if the sample size was 100, then the maximum high side or low side number of trimmed weights was 3 (2.5 rounded up). The actual percentage of trimmed weights on the high and low side could be slightly larger than 2.5%.

[19] The procedures and thresholds are set with the goal of reducing the impact in terms of the effect on variances and influence of particular observations on estimates. Limiting the amount of trimming performed is also a goal since trimming introduces bias.

4.1 Raking Dimensions for Households

We used the 2015 American Community Survey (ACS) data to develop the control totals. First, overall totals were obtained at the Census division level[20]. Within Census division, counts were derived from one-year 2015 ACS estimates where possible, using 2011-2015 five year estimates where necessary to obtain distributions for areas for which 2015 one-year ACS estimates were not available, within geographic adjustment cell, or geographic adjustment cell, definitions as described in table 1 above (section 3). In a few instances, the 2010 Census SF1 data were necessary to obtain distributions for areas defined by Census blocks, such as the Iowa Northlands Add-on area.

For the larger counties, the ACS provides population estimates based on one year of data alone (the most recent year). For many other counties, the ACS only provides estimates as moving averages based on the five most recent years. The five-year estimates (or Census SF1 counts) were only used to 'fill in' whatever distributions were not available from the one-year data (only percentages were used). Then, for each raking dimension, percentages within geographic adjustment cell totals were applied to the Census division totals to obtain geographic adjustment cell-level totals that summed to the Census division total. Appendix C describes in further detail the process of computing control totals.

The raking dimensions were as follows[21].

(1) Geographic adjustment cell *MSA/heavy rail sampling stratum

(2) Geographic adjustment cell * race (Black; non-Black for recruitment respondent)

(3) Geographic adjustment cell * Hispanic origin (Hispanic; non-Hispanic for recruitment respondent)

(4) Geographic adjustment cell * Owner/Renter (Owner; Renters and others)

(5) Geographic adjustment cell * Number of Vehicles (0, 1, and 2 or more Vehicles)

(6) Geographic adjustment cell * Month

(7) Geographic adjustment cell * Day of Week

[20] Although Census Divsions are larger than the state level geography, this level of geography was selected to ensure that we were able to get convergence during raking.

[21] These dimensions were ordered by importance. A higher number in the ordering indicates the dimension was collapsed sooner if there were convergence problems.

(8) Geographic adjustment cell * Household size * Number of workers in the household (1-person household with 0 worker, 1-person household with 1 worker, 2-person household with 0 workers, 2-person household with >=1 workers, 3-preson household with 0 workers, 3-person household with >=1 workers, 4-person and more household with 0 workers, and 4-person and more household with >=1 workers)

When convergence failed, the design called for the collapsing of cells (e.g., day to weekday/weekend), then variables within dimensions, and finally the elimination of a dimension. The raking dimensions for households focused on geography and overall household characteristics. When person-level characteristics were used, such as race and ethnicity, recruitment respondent information was used. In general, levels were collapsed if there were fewer than 8 retrieval households for the level.

4.2 Construction of Control Totals for Time Dimensions

At this point in the processing, adjustments for month and day were applied to the raked household weights resulting from section 4.1[22]. Those household weights were adjusted to account for the 12 months of data collection. Then those weights were adjusted to create both 7-day and 5-day sets of final household raked weights, as outlined next.

The time dimension control totals sum to the geographic adjustment cell household total for each geographic adjustment cell[23]. Each month was allocated approximately 1/12 of the household total, so that each month has an equal weight in the final estimator (the sum of household weights with travel dates corresponding to one month will be made equal to about 1/12 of the household total for each geographic adjustment cell). For 7-day weights, each day of the week was allocated 1/7 of the household total. For 5-day weights, each weekday (Monday through Friday) was allocated 1/5 of the household total (and only responding households with weekday travel days were included in the raking adjustment). However, the 5-day weights were also adjusted to exclude the following holidays, as specified by the Federal Highway Administration:

[22] The NHTS is designed to collect data evenly over a 12-month period, but even with diligent management, this was not exact. This adjustment was done to ensure that each month of the year represented approximately 1/12 of the responding households. Similar adjustments were done to ensure that data were represented equally across all 7 days of the week for the 7-day weights, or all 5 days of the week for 5-day weights.

[23] The final weighted household total within each geography from table 1 were maintained even after adjustments for time dimensions.

- Monday May 30, 2016 – Memorial Day
- Monday July 4, 2016 – Independence Day
- Monday, Sept 5, 2016 – Labor Day
- Thursday, Nov 24, 2016 – Thanksgiving Day
- Monday, December 26, 2016 – Christmas Day
- Monday, January 2, 2017 – New Year's Day
- Monday, January 16, 2017 – Martin Luther King Birthday

All analyses using the 5-day weights will need to exclude data for travel days falling on these dates; that is, the 5-day (weekday) weights represent travel on all weekdays in the year *excluding these holidays*. Analysts (using either the 5-day or 7-day weights) may also choose to exclude other days from their analyses. However, they may not add the excluded holidays listed above back into analyses using the 5-day weights, as these dates do not have 5-day weights.

These adjustments result in 5-day and 7-day sets of final raked household-level weights. Both of these sets of weights were used as inputs to the person-level raking and were carried through the remaining procedures.

Person-Level Raking Adjustments 5

The aim of the survey was to complete retrieval interviews for each person age 5+ within each of the recruited households. In terms of sampling, this meant that every person age 5+ in the household had a probability of selection equal to that of the household. In principle, then, each person's base weight was equal to the household base weight. Since the people within a household were all selected along with the household, the starting weight for person adjustments was the final adjusted household weight from section 4. Both 5-day and 7-day household-level raked weights from section 4 were processed (separately) to create person-level raking adjustments, resulting in the final person-level weights (both 5-day and 7-day) that are included in the delivered datasets.

In addition to the household-level adjustments, the person weights included a person-level raking adjustment using the questionnaire items from completed retrieval surveys. In the person-level raking adjustments, as with households, we used the 2015 ACS data to develop the control totals. The control totals for all dimensions were derived from one-year 2015 ACS estimates where possible, using 2011-15 five year estimates or 2010 Census SF1 counts where necessary to obtain distributions for areas for which 2015 one-year ACS estimates are not available (in the same manner described above for the household-level control totals).

As described earlier, for the larger counties, the ACS provides population estimates based on one year of data alone (the most recent year). For many other counties, the ACS only provides estimates as moving averages based on the five most recent years and for some areas, counts were needed at the Census block level. The five-year estimates and Census SF1 block level counts were only used to 'fill in' whatever distributions were not available from the one-year data (only percentages were used).

Person level trimming and raking followed an iterative process. The starting point was the final raked household weight from section 4, applied to each person within the household. An initial trimming was done, followed by an initial raking, followed by cycles of trimming and raking and trimming to convergence.

The pre-trim step for each geographic adjustment cell consisted of checking for weights that were more than 3.0 times the median weight.[24] If less than 1% of the weights fell into this category, then all such weights were trimmed back to equal the cutoff (3.0 times the median weight for the stratum). If more than 1% of the weights fell into this category[25], then the largest 1% set of the weights were trimmed back to equal the 99th percentile of the weights.

During the raking process, trimming was done within each geographic adjustment cell and targeted for trimming any weights that were 4.5 times smaller or 4.5 times larger than the median weight for the geographic adjustment cell. A maximum of 2.5% of the weights were trimmed on the high side and a maximum of 2.5% of the weights were trimmed on the low side for each post-trim step[26]. If more than 2.5% of the weights was greater than 4.5 times the median weight (less than 4.5 times the median weight), then the largest (smallest) 2.5% of the weights were trimmed back to the 97.5th percentile (the 2.5th percentile).

The cycle of raking and trimming steps was complete when all of the trimming factors (the adjustments to the weight during the trimming step) for that potentially final trimming step were between 0.99 and 1.01. A flag indicating that a weight was trimmed is provided on the delivery files.

The person-level raking process was done to a tolerance of ±1, i.e., the weighted totals were raked until they were within 1 of the control totals. If convergence was not achieved with this restriction, it was relaxed until convergence was reached. The 'geographic adjustment cell' variable used in raking was defined in the same manner as for household raking; see Table 1 above which shows the 22 geographic definitions.

As noted earlier, the person-level weights had as their foundation their respective households weights. The person-level raking dimensions were as follows[27].

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[24] This is the median value of all of the person level raked weights after the raking adjustment. If any person raked weight violated 3*median threshold prior to trimming, it was trimmed as described.

[25] The number of weights affected by this rule was 1% of the number of sample units, rounded up to the smallest larger integer. For example, if the sample size was 120, then the number of trimmed weights was 2 (1.2 rounded up). In particular, there was always be at least one weight trimmed if any weight exceeds 3.0 times the median weight. The actual percentage of trimmed weights then could be slightly larger than 1%.

[26] This count of trimmed weights was 2.5% of the number of sample units, rounded up to the smallest larger integer. For example, if the sample size is 100, then the number of trimmed weights will be 3 (2.5 rounded up). The actual percentage of trimmed weights on the high and low side could be slightly larger than 2.5%.

[27] These dimensions were ordered by importance. A higher number in the ordering indicates the dimension was collapsed sooner if there were convergence problems.

(1) Geographic adjustment cell * MSA/heavy rail sampling stratum

(2) Geographic adjustment cell * Race (Black; non-Black)

(3) Geographic adjustment cell * Ethnicity (Hispanic; non-Hispanic)

(4) Geographic adjustment cell * Sex * Age group (Age 0-4 male, age 5-17 male, age 18-24 male, age 25-44 male, age 45-64 male, age 65 and older male, age 0-4 female, age 5-17 female, age 18-24 female, age 25-44 female, age 45-64 female, and age 65 and older female)

(5) Pairs of months (e.g., Jan-Feb, Mar-Apr, etc.)

(6) Day of week

Race and ethnicity were collected as household level variables for the recruitment respondent and then for all household members in the retrieval survey in the NHTS. Person-level characteristics for all dimensions apply to all persons in the households, not just the head-of-household.

After this step, the weighting process was complete for households and persons, for both 5-day and 7-day weights.

Other Weights and Quality Control of the Weights 6

6.1 Vehicle and Trip Weights

The final household weight can be used to analyze characteristics of vehicles reported by households. Travel-day trip weights are a function of the person weight multiplied by a constant to inflate the weight to represent an annualized weight. These are the appropriate weights for counting trips for the year (e.g., for annual travel estimates).

6.2 Quality Control of the Weighting Process

Quality control for each stage of weighting was implemented as follows:

- **Base weights**: checked that the sum of base weights was equal to address-based sampling frame counts for each sampling stratum;
- **Unknown eligibility weights**: checked that the sums of weights for respondents were the same as the sums of their base weights; checked that the sums of weights for cases with unknown eligibility were the same or adjusted slightly down to account for never-received mail from sampled addresses for which survey eligibility was not known;
- **Nonresponse adjustment weights (recruitment and retrieval)**: checked that the adjustment factors for all nonresponse adjustment cells were lower than the maximum factor allowed; checked that the adjustment cell size for each cell was larger than the minimum size that was allowed;
- **Imputation**: checked that the imputation was done correctly within the boundaries defined by the weighting plan for each item; checked that the imputation flags were created correctly for imputed cases; checked that the imputed values made sense logically by comparing distributions for each item that was imputed before and after imputation;
- **Pre-rake trimmed weights:** checked that the percentages of the cases that were trimmed by each sampling stratum were within the thresholds defined in the weighting plan; checked that sums of the trimmed weights were the same as the sums of pretrimmed weights or were adjusted slightly down;
- **Raked weights**: checked that the raking dimensions were defined correctly in the survey data, according to the weighting plan, for both household and person raking; checked that the sum of the control totals was equal to the 2015 ACS 1-year total sum of households (for household raking) or population (for person raking), both overall and by Census division;

checked that sums of final raked weights were equal to the control totals (2015 ACS 1-year, households and population);

- **Final comparison across all weighting stages**: After weighting was completed, a series of checks were done to examine the distribution of the weights across all the weighting stages and ensure that design effects due to weighting were within reasonable limits.

Final household-level raked full-sample and replicate weights and person-level raked full-sample and replicate weights for respondents reporting travel on travel days covering all 7 days of the week were provided as final products for the National sample. Final household-level raked full-sample and replicate weights and person-level full-sample and replicate raked weights for both respondents reporting travel on travel days covering all 7 days of the week (7-day weights) and those reporting travel only on non-Holiday weekdays (5-day weights) were provided as final products for each Add-on area separately. Vehicle weights are the household weights, and travel day trip weights were also provided for the National sample and each Add-on area. Weighting factors at each stage of weighting were also provided.

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Appendix A

Characteristics to be Used to Form Recruitment Nonresponse Adjustment Cells

Table A-1 below presents a table detailing the characteristics which were considered to define recruitment nonresponse adjustment cells. Most of these characteristics are ACS tract-level characteristics, which were dichotomized as above or below the median value. In addition, we considered using whether or not there is a telephone number associated with the address, and the dwelling type of the address (single family or multi family unit). These two characteristics were available from the sampling frame at the address level. Cells with Xs indicate which characteristics were used to adjust for recruitment nonresponse in each of the sample areas.

Table A-1 Dichotomous Cells for Nonresponse Adjustment Cells By Study (Part 1 of 2)

	01-AZ	02-CA	03-Des Moines	04-GA	05-Indian Nations	06-Iowa Nrthlnds	07-MD	08-NC	09-NCTCOG	10-NY	11-SC
Central City with Heavy Rail		X								X	
Central City without heavy rail	X	X								X	
nonMetro	X	X								X	
Median income				X						X	
Median rent											
Median home value	X			X	X		X	X	X		
Percent Homeowners							X			X	
Percent with children <18		X						X	X		
Percent 18 to 34		X							X		
Percent 45+	X	X	X	X	X			X	X	X	
Percent 55 to 64		X	X	X							
Percent 65+		X				X			X	X	X
Percent Asian		X							X		
Percent Black		X								X	
Percent Hispanic	X			X						X	
Percent White		X							X	X	X
Percent College Grads	X	X	X						X	X	X
Percent Income $0 to $25K		X		X		X					
Percent Income $0 to $35K											
Percent Income $0 to $50K						X					X
Percent Income $100K up		X							X	X	X
Address with phone number	X	X	X	X	X	X	X	X	X	X	X
Multi-family DU	X	X	X	X	X		X	X	X	X	X

Table A-1 Dichotomous Cells for Nonresponse Adjustment Cells By Study (Part 2 of 2)

	12 - TX	13 - WI	14-CenDIv1	15-CenDIv2	16-CenDIv3	17-CenDIv4	18-CenDIv5	19-CenDIv6	20-CenDIv7	21-CenDIv8	22-CenDIv9
Central City with Heavy Rail Central City without heavy rail nonMetro											
Median income Median rent Median home value Percent Homeowners	 X 	 	 	 X	X 	 	 	 	 	 	
Percent with children <18 Percent 18 to 34 Percent 45+ Percent 55 to 64 Percent 65+	X X X X	 X X X	 	X 	 X	 	 X 	 X	 	 	 X
Percent Asian Percent Black Percent Hispanic Percent White	 X X	 X X X	 X X 	 	 	 	 	 	 	 X X 	
Percent College Grads	X	X	X				X	X		X	X
Percent Income $0 to $25K Percent Income $0 to $35K Percent Income $0 to $50K Percent Income $100K up		X X									
Address with phone number	X	X	X	X	X	X	X	X	X	X	X
Multi-family DU	X	X	X		X	X	X	X	X	X	X

Appendix B

ABS Frame and Recruitment Questionnaire Characteristics to be Used to Form Household Retrieval Nonresponse Adjustment Cells

Table B-1 below presents for each geographic adjustment cell the ABS frame and recruitment questionnaire characteristics which were considered to define retrieval nonresponse adjustment cells, similar to those of Appendix A. Cells with Xs indicate which characteristics were used to adjust for retrieval nonresponse in each of the sample areas.

Table B-1 Dichotomous Cells for Potential Retrieval Nonresponse Adjustment Cells By Geographic Adjustment Cell (Part 1 of 2)

	01 - AZ	02 - CA	03- Des Moines	04 - GA	05- Indian Nations	06- Iowa Nrthlnds	07 - MD	08 - NC	09- NCTCOG	10 - NY	11 - SC
Recruitment respondent age 18 to 34											
Recruitment respondent age 35 to 54											
Recruitment respondent age 55 to 64											
Recruitment respondent age 65+											
Recruitment respondent age missing	X	X	X	X	X	X	X	X	X	X	X
Recr resp less than high schl diploma		X		X		X	X	X	X	X	X
Recr resp high school diploma or GED		X		X		X	X	X	X	X	X
Recr resp Bachelor's Degree		X		X		X	X	X	X	X	X
Recr resp graduate degree		X		X		X	X	X	X	X	X
Recr resp educ missing		X		X		X	X	X	X	X	X
Household has children		X		X				X	X	X	X
Recr respondent Hispanic											
Recr respondent nonHispanic White	X	X		X	X	X		X	X	X	X
Recr respondent nonHispanic Black		X									X
Household in single family house											
Household with one adult	X	X		X	X		X	X	X	X	X
Household with more than 2 adults	X	X	X	X	X	X	X	X	X	X	X
HH has fewer vehicles than drivers		X						X			
HH has more vehicles than drivers		X						X	X		
Homeowner vs renter				X							
Median home value (tract level)										X	
Census tract percent age 0 to 17										X	
Census tract percent age 18-34											
Census tract percent age 45+											
Census tract percent age 55-64											
Census tract percent age 65+											
Census tract percent homeowners											
Census tract percent Asian											
Census tract percent Black											
Census tract percent Hispanic										X	
Census tract percent White											
Cen trct pct annl inc less than $35K											
Cen trct pct annl inc less than $50K											

Table B-1 Dichotomous Cells for Potential Retrieval Nonresponse Adjustment Cells By Geographic Adjustment Cell (Part 2 of 2)

	12-TX	13-WI	14-CenDiv 1	15-CenDiv 2	16-CenDiv 3	17-CenDiv 4	18-CenDiv 5	19-CenDiv 6	20-CenDiv 7	21-CenDiv 8	22-CenDiv 9
Recruitment respondent age 18 to 34											
Recruitment respondent age 35 to 54											
Recruitment respondent age 55 to 64											
Recruitment respondent age 65+											
Recruitment respondent age missing	X	X	X	X	X	X	X	X		X	X
Recr resp less than high schl diploma	X	X	X		X	X				X	X
Recr resp high school diploma or GED	X	X	X		X	X				X	X
Recr resp Bachelor's Degree	X	X	X		X	X				X	X
Recr resp graduate degree	X	X	X		X	X				X	X
Recr resp educ missing	X	X	X		X	X				X	X
Household has children	X	X	X			X					
Recr respondent Hispanic											
Recr respondent nonHispanic White	X	X	X	X	X	X	X		X		
Recr respondent nonHispanic Black											
Household in single family house											
Household with one adult	X	X	X	X	X	X	X		X	X	
Household with more than 2 adults	X	X	X		X	X	X			X	X
HH has fewer vehicles than drivers		X					X				
HH has more vehicles than drivers	X	X									
Homeowner vs renter		X									
Median home value (tract level)											
Census tract percent age 0 to 17											
Census tract percent age 18-34											X
Census tract percent age 45+											
Census tract percent age 55-64											
Census tract percent age 65+											
Census tract percent homeowners											
Census tract percent Asian									X		
Census tract percent Black											
Census tract percent Hispanic											
Census tract percent White											
Cen trct pct annl inc less than $35K											
Cen trct pct annl inc less than $50K											

Appendix C

Construction of Control Totals from the American Community Survey

To compute control totals within geographic adjustment cells, the first step was to work with population estimates at the Census division level. Within the divisions, counts were obtained at the county level (either single counties or sets of counties) depending on the geographic adjustment cell definitions, and the proportions of households within those geographic adjustment cells were applied to the Census division totals. As mentioned in section 4.1, the ACS was used to obtain estimates of control totals using either one-year or five-year data, depending on the geographic adjustment cell components.

In the two examples below, we illustrate how control totals were developed for geographic adjustment cell 19 (Census division 6) and, separately, for geographic adjustment cells 5, 9, 12, and 20 (Census division 7). In both examples, for sake of illustration, we focus on the computation of control totals for just one dimension, home tenure. The first example illustrates control totals construction for geographic adjustment cell 19, which is the entire Census division 6, East South Central, consisting of Alabama, Kentucky, Mississippi, and Tennessee. There is no Add-on area within geographic adjustment cell 19, so this example illustrates the simplest case of control totals construction. The numbers in Table 1 are directly obtained from one-year 2015 ACS estimates. For this geographic adjustment cell, we used the overall estimates and estimates by tenure as shown in the table for the control totals. For geographic adjustment cells where the Add-on area encompasses the entire state, the same approach was used for control totals construction.

Table C-1 Table for Control Totals Derivation for Geographic Adjustment Cell 19 in Census division 6

	East South Central Division Estimate
Total:	7,197,189
Owner occupied	4,801,549
Renter occupied	2,395,640

In the second example, we explicate control totals for geographic adjustment cell 5 - Indian Nations COG (OK), geographic adjustment cell 9 - North Central Texas COG, geographic adjustment cell 12 - Balance of TX DOT, and geographic adjustment cell 20 - AR, LA, and rest of OK. Census division 7 – West South Central, is broken down into four geographic adjustment cells because Indian Nations blocks and North Central Texas COG reside in Oklahoma and Texas. The control totals for these four geographic adjustment cells were derived at the same time. Unlike in the first example, the total number of households come from both one-year and five-year ACS estimates.

Table C-2 shows the table shell that we used to derive the counts of households by home ownership tenure for the four geographic adjustment cells under Cenus division 7. The table is filled with artificial values to help illustrate the process.

It should be noted that the one-year and five-year ACS data do not agree with each other as to overall counts or tenure counts or percentages for geographic adjustment cells. Without appropriate adjustment, the total number of households for the geographic adjustment cells (the column E in the table 1) do not equal to the total number of household by tenure (the column G) which would result in failure of the raking procedure to converge given there are multiple dimensions in raking. We adjusted the total number of households and total number of households by tenure for each geographic adjustment cell so that they wereconsistent and both added up to the division total (column D). A similar procedure was applied to get control totals for all dimensions.

First we compiled total number of households in Census division 7 (column D), total number of households in the four geographic adjustment cells (column E), and total number of households by tenure in the four geographic adjustment cells (column G) using one-year 2015 ACS estimates where possible, and using 2011-2015 five year estimates where one-year ACS data are not available.

We utilize the one-year household total for Census division 7, and 'allocate' that total (column D) to the ten rows under the four geographic adjustment cells using the percentages from the total number of households in the geographic adjustment cell (column E). This step generates the total number of households in the geographic adjustment cells (column F) which sum up to the one-year household total for Census Division 7. The estimated total of number of household for each geographic adjustment cell was the overall control total for the geographic adjustment cell. For example, 319 (212.8 plus 106.4) is the overall control total for the geographic adjustment cell 5.

The next step was to estimate number of households by tenure. The estimated proportions by tenure (column H) were computed from the total number of households by tenure from either one-

year ACS or 5-year ACS (column G). Using the estimated proportions by tenure for the four geographic adjustment cells, the one-year household total for Census division 7 was again distributed to the four geographic adjustment cells. The final control totals by tenure for each geographic adjustment cell are given in the last column which is summed to the overall control total for the region. For example, the total number of owner and renter is 319 (234.0 plus 85.1) for region 5. Also, the total estimated number of households for the regions under Census division 7 and estimates by tenure for the regions add up to the one-year ACS total.

Table C-2 Table for Control Totals Derivation for Geographic Adjustment Cells in Census division 7

	A	B	C	D	E	F	G		H		I	
				Total # households in Census division 7	Total # HHs in geographic adjustment cell		Total # HHs by tenure from One-year ACS Totals or 5-year ACS Totals in geographic adjustment cell		Estimated proportions by tenure		Estimated # HHs by tenure	
	Geographic adjustment cell	Name	Area by ACS data availablity	One-year ACS	from One-year ACS or 5-year ACS	Estimated total # HHs for geographic adjustment cell	Own/other	Rent	Own/other	Rent	Own/other	Rent
1	5	OK Indian Nations COG	Indian Nations Census tracts with one-year totals available		200	212.8	150	50				
2			Indian Nations Census tracts without one-year totals available		100	106.4	70	30	0.0234	0.008511	234.0	85.1
3	9	North Central Texas COG	Texas NCTCOG counties with one-year totals available		2000	2,127.7	1,500	500				
4			Texas NCTCOG counties without one-year totals available		1000	1,063.8	700	300	0.23404	0.085106	2,340.4	851.1
5	12	Balance of TX DOT	TX counties with one-year totals available		3000	3,191.5	2,000	1,000				
6			TX counties without one-year totals available		1000	1,063.8	700	300	0.28723	0.138298	2,872.3	1,383.0
7	20	AR, LA, and rest of OK	AR, LA counties with one-year totals available		1000	1,063.8	700	300				
8			AR, LA counties without one-year totals available		300	319.1	200	100				
9			Rest of OK counties with one-year totals available		500	531.9	300	200				
10			Rest of OK counties without one-year totals available	10,000	300	319.1	200	100	0.14894	0.074468	1,489.4	744.7

Appendix D

Imputation Plan

There are missing values for almost all of the recruitment and retrieval variables used in the raking process. The rate of item missingness is very low, but even a small number of missing values need to be filled in (via imputation) for poststratification, as the weighted totals have to represent the full population to match the ACS control totals. Only variables which were used in raking were imputed.

The imputation methodology was hot deck imputation. Under this approach, each record which required an imputation for a particular item is called a 'beggar'. Each beggar was randomly assigned a 'donor': a record which had that particular item nonmissing. The donors were randomly selected within an imputation cell. This random selection guaranteed that the imputed records would have roughly the same conditional distribution (within cells) as the donor records, preventing for example a set of imputed values which had less variability because they were generated from the mean value for that varaible. The imputation cells were defined by levels of characteristics which are correlated to the item being imputed. This helped reduce the variability of the imputation, and guaranteed that the imputations would successfully pass edit checks (e.g., no seven-year old drivers). For example, if we were missing home ownership status for a particular household, we looked at households in the same geographic area, the ACS tract-level percentages associated with home ownership, household income, number of adults in the household, and other relevant characteristics to impute a value of home ownership status for the missing household.

Some characteristics had no missing values. These included geographic variables, ABS frame characteristics, and a few variables which are collected for all recruitment respondents.

The following variables were imputed in the following order (order is important in that later steps can use the imputations from the earlier steps):

- Age of person;
- Homeowner vs. renter or other at the household level;

- Worker status for all adults (full-time worker, part-time worker, self-employed, not working);
- Sex of person;
- Race/ethnicity of person.

The following characteristics were used for formation of imputation cells. Missingness was one category. For the imputation of age of person the following cell generators were:

- Age range
- Driver status;
- Worker status;
- Recoded primary activity last week (working age, going to school, retired, and other);
- Educational status of person;
- Respondent relationship to household respondent;
- Recoded race/ethnicity of person (Hispanic, nonhispanic White, nonhispanic Black, nonhispanic others).

For the imputation of homeowner vs. renter or other the following cell generators were used:

- Raking geographic adjustment cell;
- ACS tract level percentage of home owners (categorized into five categories by quintiles within geographic adjustment cell and domain quarter);
- Household income, categorized into less than $10,000 annual income, $10K-<$15K annual income, $15K-<$25K annual income, $25K-<$35K annual income, $35K-<$50K annual income, $50K-<$75 annual income, $75K-<$100K annual income, $100K-<$125K annual income, $125K-<$150K annual income, , $150K-<$200K annual income, $200K or more annual income, and missing household income.
- Number of adults in household;
- Presence of children in household;
- Age of reference person;
- Home type (single family home, etc.).

For imputation of working status of adults[28], the following cell generators were used:

- Raking geographic adjustment cell;
- Age of person, categorized into 0-15, 16-64, 65+;
- Educational status of adult;
- Race/ethnicity of adult;
- Family income (same categories as in the previous list);
- Home-owner vs. renter status;
- Presence of children in household;
- Number of adults in household, and working status of other adults (no other adults, one other adult who is working, one other adult who is not working, one other adult with unknown working status, more than one other adult).

For imputation of sex, the following list was used:

- Raking geographic adjustment cell;
- Number of adults in household, presence of children, and sex of other adults;
- Age of person, categorized into 0-17, 18-64, 65+.

For imputation of race/ethnicity, we imputed each person as Black nonHispanic, Hispanic, Black Hispanic, or nonHispanic other race (Whites, Asians, American Indians, Pacific Islanders). All persons in the household with missing race/ethnicity 'inherited' the race/ethnicity of the recruitment questionnaire respondent. Hotdeck imputation was only needed then to fill in race/ethnicity for the recruitment questionnaire respondent where it was missing. Multirace persons were viewed as nonBlack. The following characteristics were used (at the household level) to set up boundaries for imputation of race/ethnicity:

- Raking geographic adjustment cell;

[28] When missing, we impute working status for children as not working.

- ACS tract level percentage of Whites (categorized into six categories by percentiles[29] within geographic adjustment cell);
- ACS tract level percentage of Blacks (categorized into six categories by percentiles[30] within geographic adjustment cell);
- ACS tract level percentage of Hispanics (categorized into six categories by percentiles[31] within geographic adjustment cell);
- Education status of recruitment reference person;
- Presence of children in household;
- Household income, categorized into less than $10,000 annual income, $10K-<$15K annual income, $15K-<$25K annual income, $25K-<$35K annual income, $35K-<$50K annual income, $50K-<$75 annual income, $75K-<$100K annual income, $100K-<$125K annual income, $125K-<$150K annual income, , $150K-<$200K annual income, $200K or more annual income, and missing household income.

[29] 10th percentile, 25th percentile, median, 75th percentile, 90th percentile.

[30] 10th percentile, 25th percentile, median, 75th percentile, 90th percentile.

[31] 10th percentile, 25th percentile, median, 75th percentile, 90th percentile.

Appendix E

Summarization of Household Raking Steps (7-Day Weights)

Arizona

- Obtained full convergence to the control totals (with 0.88 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 15 rake-trim cycles
- A total of 6.9% of the records were trimmed

Caltrans

- Obtained full convergence to the control totals (with 0.75 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 15 rake-trim cycles
- A total of 5.9% of the records were trimmed

Des Moines

- Obtained full convergence to the control totals (with 0.76 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells required

  Collapse the records where household size 3 with no workders with household size 4+ with no workders

- Process required 16 rake-trim cycles
- A total of 1.6% of the records were trimmed

Georgia DOT

- Obtained full convergence to the control totals (with 0.50 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 13 rake-trim cycles
- A total of 5.7% of the records were trimmed

Indian Nations COG

- Obtained full convergence to the control totals (with 0.71 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 16 rake-trim cycles
- A total of 6.5% of the records were trimmed

Iowa Northlands Regional COG

- Obtained full convergence to the control totals (with 0.92 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was required.

  Collapse the records where household size 3 with no workders with household size 4+ with no workders
- Process required 12 rake-trim cycles
- A total of 2.1% of the records were trimmed

Maryland State Highway Administration

- Obtained full convergence to the control totals (with 0.92 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was required.

  Collapse the records where household size 3 with no workders with household size 4+ with no workders
- Process required 14 rake-trim cycles
- A total of 6.5% of the records were trimmed

North Carolina DOT

- Obtained full convergence to the control totals (with 0.82 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 15 rake-trim cycles
- A total of 5.6% of the records were trimmed

North Central Texas COG

- Obtained full convergence to the control totals (with 0.55 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 15 rake-trim cycles
- A total of 3.3% of the records were trimmed

New York State DOT

- Obtained full convergence to the control totals (with 0.42 being the largest observed difference between weight sum and control total)

- All dimensions retained
- Collapsing of cells was not required.
- Process required 15 rake-trim cycles
- A total of 6.4% of the records were trimmed

South Carolina DOT

- Obtained full convergence to the control totals (with 0.49 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 14 rake-trim cycles
- A total of 6.0% of the records were trimmed

Texas DOT

- Obtained full convergence to the control totals (with 0.56 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 14 rake-trim cycles
- A total of 4.5% of the records were trimmed

Wisconsin DOT

- Obtained full convergence to the control totals (with 0.46 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 16 rake-trim cycles
- A total of 3.6% of the records were trimmed

Census Division 1

- Obtained full convergence to the control totals (with 0.83 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 17 rake-trim cycles
- A total of 7.4% of the records were trimmed

Census Division 2, excluding NY

- Obtained full convergence to the control totals (with 0.44 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was required.

  Collapse the records where household size 3 with no workders with household size 4+ with no workders
- Process required 17 rake-trim cycles
- A total of 2.6% of the records were trimmed

Census Division 3, excluding WI

- Obtained full convergence to the control totals (with 0.51 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 17 rake-trim cycles
- A total of 1.5% of the records were trimmed

Census Division 4, excluding IA Add-on areas

- Obtained full convergence to the control totals (with 0.95 being the largest observed difference between weight sum and control total)

- All dimensions retained
- Collapsing of cells was required.

  Collapse the records where household size 3 with no workders with household size 4+ with no workders
- Process required 16 rake-trim cycles
- A total of 6.2% of the records were trimmed

Census Division 5, excluding GA, MD, NC, SC

- Obtained full convergence to the control totals (with 0.53 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 16 rake-trim cycles
- A total of 5.7% of the records were trimmed

Census Division 6

- Obtained full convergence to the control totals (with 0.59 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 16 rake-trim cycles
- A total of 0.8% of the records were trimmed

Census Division 7, excluding TX and Indian Nations Add-on area

- Obtained full convergence to the control totals (with 0.51 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was required.

  Collapse the records where household size 3 with no workders with household size 4+ with no workders

- Process required 16 rake-trim cycles
- A total of 3.4% of the records were trimmed

Census Division 8, excluding AZ

- Obtained full convergence to the control totals (with 0.95 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 15 rake-trim cycles
- A total of 6.5% of the records were trimmed

Census Division 9, excluding CA

- Obtained full convergence to the control totals (with 0.82 being the largest observed difference between weight sum and control total)
- All dimensions retained
- Collapsing of cells was not required.
- Process required 16 rake-trim cycles
- A total of 5.8% of the records were trimmed

Appendix F

Summarization of Person-Level Raking Steps

Arizona

- Obtained full convergence to the control totals (with 0.94 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 8 rake-trim cycles
- A total of 5.7% of the records were trimmed

California

- Obtained full convergence to the control totals (with 0.24 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.3% of the records were trimmed

Des Moines

- Obtained full convergence to the control totals (with 0.32 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 4 rake-trim cycles
- A total of 4.4% of the records were trimmed

Georgia DOT

- Obtained full convergence to the control totals (with 0.44 being the largest observed difference between weight sum and control total)

- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.4% of the records were trimmed

Indian Nations COG

- Obtained full convergence to the control totals (with 0.73 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 5 rake-trim cycles
- A total of 5.6% of the records were trimmed

Iowa Northlands Regional COG

- Obtained full convergence to the control totals (with 0.47 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 5 rake-trim cycles
- A total of 5.6% of the records were trimmed

Maryland State Highway Administration

- Obtained full convergence to the control totals (with 0.38 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.9% of the records were trimmed

North Carolina DOT

- Obtained full convergence to the control totals (with 0.07 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles

- A total of 5.6% of the records were trimmed

North Central Texas COG

- Obtained full convergence to the control totals (with 0.03 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.1% of the records were trimmed

New York State DOT

- Obtained full convergence to the control totals (with 0.10 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.6% of the records were trimmed

South Carolina DOT

- Obtained full convergence to the control totals (with 0.59 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.6% of the records were trimmed

Texas DOT

- Obtained full convergence to the control totals (with 0.56 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 7 rake-trim cycles
- A total of 5.5% of the records were trimmed

Wisconsin DOT

- Obtained full convergence to the control totals (with 0.60 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.0% of the records were trimmed

Census Division 1

- Obtained full convergence to the control totals (with 0.09 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.6% of the records were trimmed

Census Division 2, excluding NY

- Obtained full convergence to the control totals (with 0.62 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 5 rake-trim cycles
- A total of 2.2% of the records were trimmed

Census Division 3, excluding WI

- Obtained full convergence to the control totals (with 0.76 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 7 rake-trim cycles
- A total of 2.8% of the records were trimmed

Census Division 4, excluding IA Add-on areas

- Obtained full convergence to the control totals (with 0.68 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.9% of the records were trimmed

Census Division 5, excluding GA, MD, NC, SC

- Obtained full convergence to the control totals (with 0.20 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.6% of the records were trimmed

Census Division 6

- Obtained full convergence to the control totals (with 0.06 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 7 rake-trim cycles
- A total of 2.0% of the records were trimmed

Census Division 7, excluding TX and Indian Nations Add-on area

- Obtained full convergence to the control totals (with 0.30 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 8 rake-trim cycles
- A total of 5.6% of the records were trimmed

Census Division 8, excluding AZ

- Obtained full convergence to the control totals (with 0.33 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.7% of the records were trimmed

Census Division 9, excluding CA

- Obtained full convergence to the control totals (with 0.28 being the largest observed difference between weight sum and control total)
- All dimensions retained
- The process required 6 rake-trim cycles
- A total of 5.6% of the records were trimmed