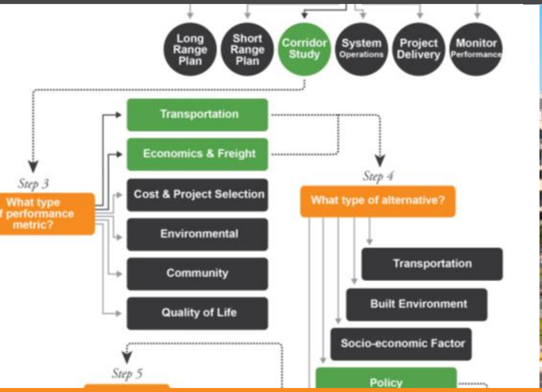
ACTIVITY-BASED MODEL 2: MODEL UPDATE

Project Report | August 21, 2018



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1.0 INTRODUCTION

This document describes work performed to update the San Diego Association of Governments travel demand model in preparation for use in the 20 Federal Regional Transportation Plan. The travel model was updated based upon 2016/2017 household travel survey data and 2015 transit on-board survey data, and the base-year of the model was updated to 2016. Several changes and enhancements were also made to the travel model system, including:

- Conversion of the commercial transportation modeling package from TransCAD to EMME[1]
- Implementation of a new model that explicitly models ‘partially joint’ travel episodes; specifically, the drop-off and pickup of children at school by parents
- Incorporation of recently-completed work to implement Strategic Highway Research Program recommendations regarding improving the sensitivity of travel models to pricing and reliability[2]
- Update of the algorithm used to find transit paths
- Update of volume-delay function parameters based upon an analysis of INRIX travel time data
- Replacement of an asserted, aggregate commercial vehicle model with a disaggregate commercial vehicle model developed several years ago but not previously integrated with the San Diego travel model system[3]
- Update of the heavy truck model, which models internal-external truck flows, to incorporate the latest Freight Analysis Framework (FAF4) data and projections
- Implementation of an airport ground access model for the Cross-Border Express (CBX) facility, serving Tijuana International Airport
- Update of models to better match ‘big data’ for special travel destinations including beaches, parks, hospitals, and shopping malls
- Incorporation of a new population synthesizer developed by SANDAG
- Update of the SQL model reporting database to incorporate the revisions noted above and streamline the database reporting process

[1] For documentation regarding the model conversion project, see SANDAG Travel Model in Emme User Guide, INRO consultants, 2017.
[2] For documentation regarding the SHRP2 C04 model enhancements, see Pricing and Travel Time Reliability Enhancements in the SANDAG Activity-Based Travel Model: Final Report, Prepared for San Diego Association of Governments by RSG, June 30, 2016.
[3] For documentation regarding the disaggregate commercial vehicle model, see Final CVM Model Development and Calibration Project Deliverable: M.9B by HBA Specto Incorporated, July 2014

The new model system is referred to as “ABM2”. This document describes model changes and enhancements completed as part of this project, the data used to recalibrate and validate the revised model, and the process and results of model calibration and validation.

2.0 MODEL ENHANCEMENTS

Below find a description of model enhancements and changes implemented into the new SANDAG travel model.

2.1 EMME CONVERSION

The SANDAG travel demand model system was converted from the TransCAD commercial modeling software (by Caliper) to EMME software (by INRO) under a separate project. The following description is from the final report of that project (see previous page for reference) and repeated here for informational purposes.

The main goal of the conversion project was to replace the previous traffic and transit assignments, aggregate demand model components, and other ancillary tools with equivalent Emme procedures. Most components were mapped to direct "drop-in" replacements with few model procedure changes. Previous GISDK scripts files were replaced by Emme Modeller tools implemented as Python scripts.

The other significant change is the use of open matrix format (OMX) files for data exchange of skims and demand between the Emme network model, environment CT-RAMP and other Java-based procedures. Corresponding import from / export to OMX tools are included in the SANDAG toolbox. The Java procedures and UEC definitions have been updated to read / write matrices from / to the new OMX files.

The transit network assignment model (transit path builder) is a more sophisticated algorithm than used previously in that it produces richer transit passenger routings through more paths. The transit impedances (generalized cost) are generally the same or shorter than those from previous versions. Note that the relative breakdown between different sub-components of travel impedance can be different (the amount of waiting time vs. walking time vs. time in-vehicle) even when the total generalized cost is quite similar.

The model is implemented using two frameworks: i) Assignments and aggregate demand model components implemented using Python and Emme, and ii) the CT-RAMP family of activity-based models in Java. The main interchange between these two frameworks are skim and demand matrices stored in OMX files. The model is operated and controlled from Emme using the Master run tool.

There are two different zone systems used in the Emme models: one for traffic and one for transit. The traffic assignment demand and skims are based on 4,996 Traffic Analysis Zones (TAZ) and the transit assignment demand and skims are based on 1,738 (for the base 2016 year) Transit Access Points (TAP). (The number and location of TAPs can change in different networks.) The zone systems and corresponding databases are maintained in two distinct Emme databases.

For more information, please see the project report.

2.2 TRANSIT BEST-PATH FINDING ALGORITHM

The CT-RAMP activity-based model and associated special market models (Mexican resident travel, overnight visitor travel, airport ground access models, and special event models) utilize transit network level-of-service matrices (skims) that are based on Transit Access Points (TAPs) instead of zones. Each TAP represents a transit stop or group of transit stops that are geographically proximate to each other. The skims therefore represent the time and cost from the first transit boarding stop to the last transit alighting stop rather than from the origin zone to the destination zone. The CT-RAMP software evaluates the transit stop-to-stop skims for each tour and trip, and determines the utility of each stop pair for each mode of access and egress (walk-transit-walk, drive-transit-walk, and/or walk-transit-drive) based on the stop-to-stop time and cost as well as the access and egress times and costs.

The previous structure of the CT-RAMP software was to perform this evaluation for each 'line-haul' mode, or transit technology available between the origin and destination; local bus, express bus, bus rapid transit (BRT), light-rail transit (LRT), and/or commuter rail. Previously, only the 'best' TAP pair (the one with the highest utility) within each combination of line-haul mode and access/egress mode was retained for consideration in mode choice. There were only two types of stop-to-stop transit skims built for each time period; a local-bus only skim, and a premium skim. The local-bus only skim contained only times and costs for local bus, whereas the premium skim included all transit technologies; only the best transit path was selected for each TAP-to-TAP pair. The model would then use the local-only skim for the local mode. For the four 'premium' modes, the model would assign a mode label to each TAP pair according to a modal hierarchy (commuter rail>LRT>BRT>express bus). Then that mode label would be used to identify which mode choice mode the TAP pair represents or belongs to.

This approach is problematic for a few reasons. First, it was very complicated. A significant amount of software code was dedicated to the process of identifying 'best' transit mode for each TAP pair, calculating and setting level-of-service matrices for each TAP pair for mode choice, and calculating mode choice utilities. The mode choice model had 15 transit modes (five line-haul modes for each of walk, park-and-ride, and kiss-and-ride access modes) and a separate utility was calculated for each mode.

Second, the structure of the model did not properly represent the competition for different boarding and alighting TAPs within each line-haul mode. Many origin-destination pairs in San Diego have a choice of bus routes; particularly for trips starting or ending in downtown San Diego. Trips may have a choice of a short walk to a bus with a transfer to LRT versus walking further to avoid the transfer. Drive-access transit trips typically have a choice of stops for the same route or different routes within the same mode.

The new transit path-builder component in CT-RAMP eliminates these problems. Instead of labelling each TAP pair as one of the five line-haul modes and retaining only the 'best' TAP pair, the new approach ranks and retains the best *four* (a user-defined variable) TAP pairs regardless of mode. This approach is more similar to what one might expect from Google Transit directions, where each of the best three or four transit paths is enumerated for the user regardless of mode.

The transit skim process was modified to support this new procedure. There are now three transit skims built for each TAP pair, to ensure that a maximum variety of transit choices are represented for each trip. They include a local-only skim, a premium-only skim, and a local plus premium skim (with a required transfer). A post-processing script ensures that the path between each TAP-pair is unique across all three skims. For example, if the local plus premium skim does not include a transfer between local bus and one of the premium modes, the skim values are set to zero, since the path would already be represented in either the local skim or the premium skim.

CT-RAMP code was significantly overhauled to support the new transit path-finding algorithm. The best transit path calculator class is responsible for all transit-related utility calculations. The software calculates a logsum across the best TAP-pairs for each access mode, and passes those on to the mode choice models. The logsum is restricted to only the best TAP pair within each of the skim sets (local only, premium only, and local+premium transfer) so that overlapping transit paths don't unduly influence the logsum[4]. The mode choice model is simplified such that the number of transit modes is reduced from 15 (by line-haul mode and access mode) to 3 (by access mode). The results demonstrate that the revised model is superior to the previous model in terms of goodness of fit at a route level. The software is also much more stable and easier to maintain.

2.3 SCHOOL ESCORT MODEL

Multi-occupant vehicles accounts for a significant portion of overall transportation demand. A significant proportion of multi-occupant vehicles are made up of members of the same household. Of these, approximately half are made by members who participate in all activities on the tour. These are explicitly modeled as 'fully joint' tours in CT-RAMP. The rest of shared-ride travel within households occurs by household members picking and dropping off (e.g. 'escorting') other household members. This was not previously modeled explicitly in the SANDAG model system. A new model was implemented to explicitly address picking up and dropping off of children at school. The model was adopted from the CT-RAMP model developed for Maricopa Association of Governments.[5]

The model is run after work and school locations have been chosen for all household members, and after work and school tours have been generated and scheduled. The model labels household members of driving age as potential 'chauffeurs' and children with school tours as potential 'escortees'. The model then attempts to match potential chauffeurs with potential

[4] This occurs when two boarding or alighting stops on the same route are available. Since these are essentially the same transit choice, the utility of transit should reflect this.
[5] Gupta, Surabhi, P. Vovsha, V. Livshits, P. Maneva, and K. Jeon (2014) Incorporation of Escorting Children to School in Modeling Individual Daily Patterns of the Household Members, Transportation Research Record 2429, page(s): 20-29.

escortees in a choice model whose alternatives consist of ‘bundles’ of escortees with a chauffeurs for each half tour.[6]

The model classifies each child’s school tour into three types:

1) No escorting: the child walks, bikes, takes transit, drives, or takes a school bus to/from school.
2) Pure escort: the child gets a ride to/from school, where the purpose of the chauffeur’s tour is solely for the purposes of picking up or dropping off the child.
3) Rideshare: the child gets a ride to/from school, where the child is dropped-off or picked-up on the way to or from the driver’s work or school primary destination.

The model considers up to three children with school tours and up to two potential chauffeurs in each household. If there are more children in the household with school tours, the model selects the youngest three who are most likely to require escorting. A rule-based algorithm is used to select the most likely chauffeurs in households with more than two potential drivers. The potential choice set is also truncated based on scheduled work and school times for Rideshare tours, where only drivers whose departure time from home (or arrival time back at home) is within 30 minutes of the child requiring escorting are considered as potential combinations of chauffeurs\escortees. Only drivers with open time windows are allowed as potential chauffeurs for Pure Escort.

In summary, the model bundles which children are escorted by which drivers and by what type of school escort type. Figure 1 shows an example of bundling children by chauffeur for a household with three children attending school and two eligible drivers. The first row of the alternatives shows different combinations of children being escorted. For example, in the left-most alternative, all three children are escorted, whereas in the right-most alternative, no children are escorted. The dark blue boxes under each of the first row alternatives show different combinations of bundling children by tour; in the first box underneath the left-most alternative, both children are escorted on one half-tour (one task). In the next alternative, child 1 and 2 are escorted on one tour whereas child 3 is escorted on another tour (two tasks). Each task is matched with a chauffeur by tour type (Pure Escort vs Rideshare). So in this example, there are 15 alternatives, 22 potential tasks, and each task has a potential of four different options for chauffeur type and tour, yielding 189 alternatives.

The explanatory variables in the model include the following:

- Chauffeur disutility for ridesharing – out-of-direction distance and time
- Escortee utility for ridesharing, which considers age
- Escortee utility for non-rideshare (non-motorized time to school)

[6] A half tour is a sequence of trips between the tour origin (home) and the tour primary destination. For the chauffeur, the primary destination is the furthest drop-off or pickup activity from home. For the child being escorted, the primary destination is school.

- Bundling utilities (the utility of driving each child separately versus taking children together)

The model is run for each direction separately. Since a strong symmetry effect is observed in the data, the model is run iteratively; first for the outbound direction, then for the inbound direction, and again for the outbound direction, considering the outcomes of the inbound direction. Tours are formed directly from the model results. In the case of multiple pickups or drop-offs on a half tour, the children are arranged by proximity to home; the nearest child is dropped off first or picked up last. The occupancy is calculated based on the number of children in the car for each trip. The software explicitly links the drivers to the children and writes all relevant information to the tour and trip file.

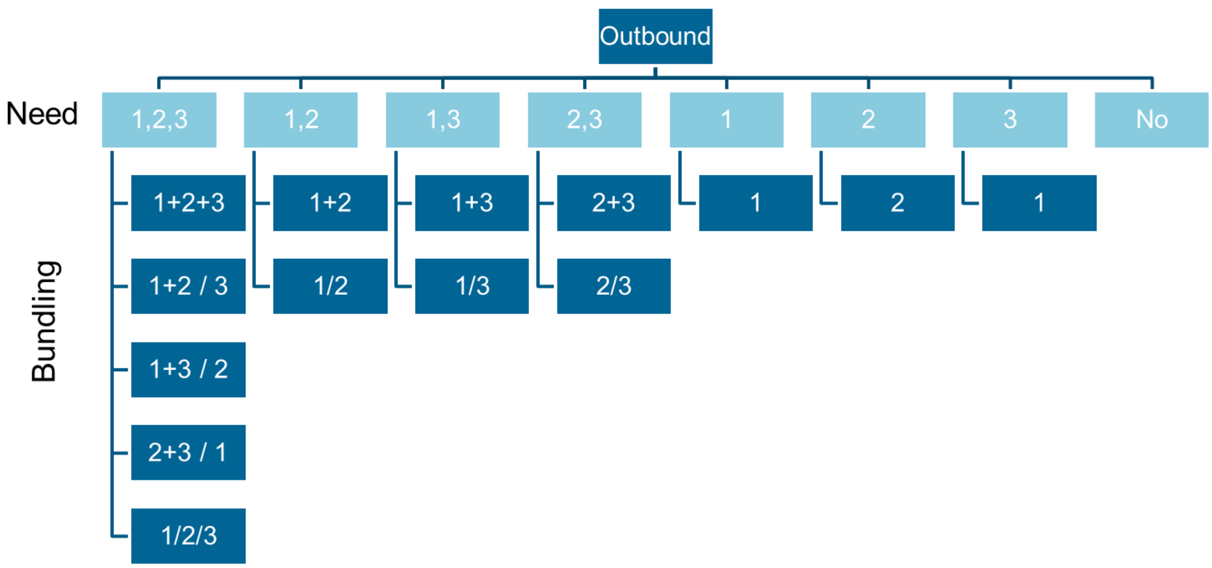


FIGURE 1: SCHOOL ESCORT MODEL EXAMPLE OF BUNDLING CHILDREN BY HALF-TOUR

2.4 TRAVEL TIME RELIABILITY AND PRICING ENHANCEMENTS

Travel time and reliability enhancements are based upon recent federal research conducted under the Strategic Highway Research Program (SHRP) 2 C04 track to improve our understanding of how highway congestion and pricing affect travel demand. The enhancements are described in the previously-cited report. They include:

- Implementation of travel time heterogeneity in CT-RAMP in which traveler's sensitivity to time is drawn from a log-normal distribution with a mean equal to the previously-estimated travel time coefficient and a standard deviation that generally matches stated preference estimates of travel time distributions in a number of studies across the United States
- Continuous cost coefficients that are based on household income, auto occupancy, and tour\trip purpose. They replace the previous version cost coefficients that were based on household income group (not continuous).

- Value-of-time bins used in assignment in which trips written by CT-RAMP are grouped into three value-of-time bins and assigned using a relevant cost coefficient for each bin, to reflect different cost sensitivities in skimming and assignment.
- Implementation of a link-level measure of travel time reliability based on an analysis of INRIX data. The reliability measure is based on link characteristics including volume/capacity ratio, link speed, and proximity of the link to major interchanges (to account for unreliability due to weaving conflicts), among other variables. The reliability measure is incorporated into the CT-RAMP mode choice model utilities and therefore also affects upstream model components such as time-of-day choice and destination choice.
- Implementation of a previously-estimated toll transponder ownership model. The model was not implemented in the previous version of the model, but it was found to significantly improve model goodness-of-fit for forecasting demand on I-15 managed lanes.

The enhanced models have been shown to match observed demand on existing toll roads in San Diego better than the previous model, and demonstrate reasonable elasticities to changes in toll cost. We find that accurate representation of toll entry\exit points and costs, and inclusion of a toll transponder ownership model to constrain demand, are important features of the revised model system.

More details can be found in the project report.

2.5 VDF ESTIMATION

As part of the SANDAG AB2 Calibration Project, RSG estimated new volume-delay function coefficients based on INRIX travel time and SANDAG transport network data. Data was based on INRIX travel time data for 2015 and SANDAG auto networks and estimated volumes. The data, estimation approach, and results are described below.

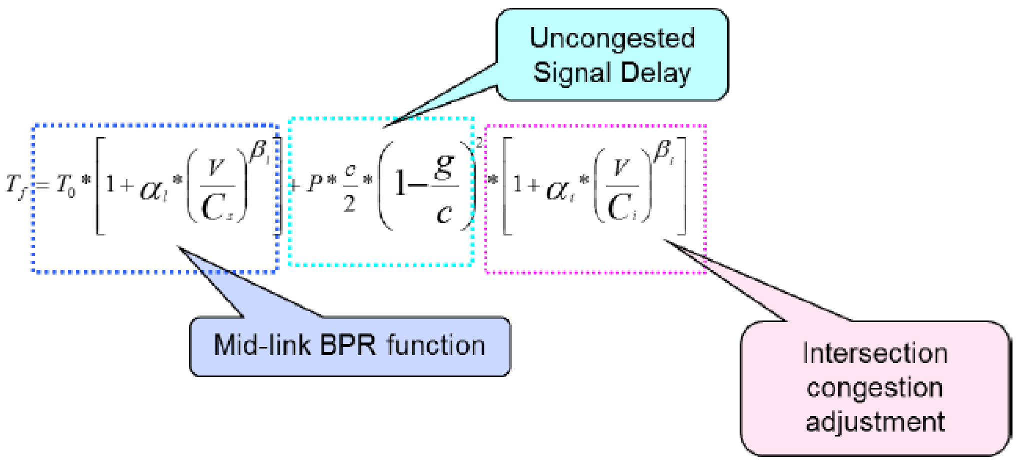
Volume-Delay Function Estimation Data

SANDAG staff used GIS procedures to attach INRIX average travel speeds for October, 2015 to the SANDAG calibrated 2015 model loaded auto networks. SANDAG staff created a dataset of INRIX speeds, estimated speeds, and estimated volumes (in passenger car equivalents) that RSG used for the estimation process. SANDAG staff removed links with flow less than 100 PCEs due to suspected unreliability, and very short, congested links since the INRIX TMC code link lengths are much greater than these short links. Each link was replicated five times, once for each time period, and the observed speed was set to the average INRIX speed for the time period for each link.

The SANDAG volume-delay function (VDF) is a link-based function that consists of both a mid-block and an intersection component, and is used to calculate travel time within a static equilibrium traffic assignment model. It was originally developed for use in the Pima Association of Governments travel model, and subsequently adopted by SANDAG. The functional form of the equation is shown in

Figure 2 below. The intersection component is only active when the B-node of the link is controlled by a traffic signal, stop sign, roundabout, or ramp meter. Otherwise the intersection component adds no delay. The VDF results in travel times that increase monotonically with respect to volume. Capacities are based on link and intersection characteristics but do not consider volumes on upstream links or opposing volumes.

FIGURE 2: VOLUME-DELAY FUNCTION



$$T_f = T_0 * \left[1 + \alpha_l * \left(\frac{V}{C_l}\right)^{\beta_l}\right] + P * \frac{c}{2} * \left(1 - \frac{g}{c}\right)^2 * \left[1 + \alpha_i * \left(\frac{V}{C_i}\right)^{\beta_i}\right]$$

Where:

T_f is link congested travel time (minutes)

T_0 is link free-flow travel time (minutes)

V is link volume

C_l is mid-link capacity

C_i is intersection capacity, which is a function of intersection geometry and g\c ratio for the approach

g/c is green time ratio for the approach for signalized intersections, or some factor representing the g/c ratio for stop-controlled, metered, or roundabout controlled intersections

c is the cycle length in minutes

P is a factor representing progression for coordinated signals, or lack of progression for uncoordinated signals; typically ranging from 0.6 to 1.2, where the default value is 1.0

α_l, β_l, α_i, β_i, are parameters calibrated to result in monotonically increasing congestion with respect to increases in volume for link (l) and intersection (i) components

Volume-Delay Function Estimation

RSG specified a generalized linear model in Stata of the form used in the SANDAG volume-delay function to estimate model parameters. RSG used the following assumptions for the estimation process:

1. The link and intersection capacity, intersection signal green time ratio and cycle length are accurately coded on each link in the SANDAG auto network.
2. The assigned, validated volume on each link was accurate enough to use as observed demand. Otherwise, the estimation process would have been restricted to just those links with observed volumes by time of day. This would have resulted in a much smaller estimation dataset.

We quickly found that while we were able to obtain reasonable estimation results for freeway links, the estimation results were not reasonable for any functions that included an intersection component. We suspect this is because the INRIX data is based on TMC segments that often span one or several intersections on arterials. Thus, both signal-controlled link segments and signal-controlled segments were allocated the same average INRIX speed, which in turn prevents the model from understanding the effect of intersection volume-to-capacity ratio, green time percent, or cycle length on delay. It is also possible that relatively greater error in the estimated volumes on arterials and smaller functional classification facilities compared to freeways confounded the estimation process. Therefore we present only the estimation results for freeway segments below.

The first line is the estimation function in Stata; nl stands for nonlinear least-squares estimation. The estimation was limited to freeways (ifc=1) and links with a volume-to-capacity ratio of 0.6 (LOS B) or greater, and the average confidence score for the INRIX travel time for the period is greater than 20. We also show all program output including number of iterations and residual sum of squares for each iteration and the final iteration, the number of observations (953 links), and the adjusted model R^2 (0.9578). The estimated alpha parameter (αl) is 0.24 and the estimated beta parameter (βl,) is 5.5. These parameters are not very different from the widely-used Bureau of Public Roads formula parameters of 0.15 and 4, respectively. Therefore the parameters seem reasonable and were adopted for use in the ABM2 EMME assignment process. For non-freeway links, BPR factors of 4.5 and 2.0 were used, as previously-calibrated by SANDAG staff.

```
nl ( congTimeINRIX = ffTimeINRIX * (1+{a1}* linkVC^{b1}))  if ifc==1 & linkVC>0.6 &
avg_conf_s>20
(obs = 953)

Iteration 0:  residual SS =  20.74058
Iteration 1:  residual SS =  17.81281
Iteration 2:  residual SS =  16.53006
Iteration 3:  residual SS =  15.87733
Iteration 4:  residual SS =  15.83064
Iteration 5:  residual SS =  15.82814
Iteration 6:  residual SS =   15.8101
Iteration 7:  residual SS =  15.81006
Iteration 8:  residual SS =  15.80997
```

```
Iteration 9:  residual SS =  15.80997
Iteration 10:  residual SS =  15.80997
Iteration 11:  residual SS =  15.80997

      Source |       SS       df       MS
-------------+------------------------------         Number of obs =        953
       Model |  359.51152      2  179.75576          R-squared     =     0.9579
    Residual |  15.809972    951  .016624576         Adj R-squared =     0.9578
-------------+------------------------------         Root MSE      =   .1289363
       Total |  375.321492   953  .393831576         Res. dev.     = -1201.825

------------------------------------------------------------------------------
congTimeIN~X |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         /a1 |   .2428438   .0159349    15.24   0.000     .2115723    .2741154
         /b1 |   5.549711   .4157519    13.35   0.000     4.733814    6.365608
------------------------------------------------------------------------------
```

2.6 HEAVY TRUCK MODEL UPDATE

The heavy truck model predicts truck flows into, out of, and through San Diego County. The model is based upon a dataset created by Bureau of Transportation Statistics and the Federal Highway Administration known as the Freight Analysis Framework (FAF). The FAF integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. The previous version of the Heavy Truck Model was based on FAF2 data, which is primarily informed by the 2002 Commodity Flow Survey. As part of this project, the model was updated to utilize FAF4 data, which is based on the 2012 Commodify Flow Survey, and provides forecasts through 2045.

There are several steps to the heavy truck model. In the first step, FAF commodity flows are used to generate a truck trip table, which is assigned to a national network. A subarea matrix is generated from this assignment using select link analysis, with nodes at the external stations to capture movements into, out of, and through San Diego County. The output of this step are External-External (EE) trip tables and estimates of Internal-External (IE) and External-Internal volume totals at each external station. This step is performed in TransCAD software; this portion of the model was not converted to EMME at this time, but the data was updated to FAF4. In the next step, the MGRA land-use data is used to calculated heavy truck attractions for IE and EI heavy truck trips by MGRA, which are then aggregated to a TAZ level. The revised 2015 MGRA data file was used to generate these attractions. Then trip ends from the external stations and internal TAZs are fed into a gravity model to create IE and EI trip tables. Finally, these trip tables are added to all other trips prior to highway assignment.

2.7 SQL DATABASE

SANDAG reporting of ABM results is primarily based on an ABM database. The database is built in Microsoft SQL server 2016 and stores relevant outputs from a successful model run. The process of extraction, transformation, and loading of outputs to the database is implemented using a combination of Python 2.7, Microsoft SQL Server Integration Services using SQL Server Data Tools for Visual Studio 17, and T-SQL. Appendix H provides details about the process.

This project updated the process (Extract-Transform-Loading pipeline) to coincide with the latest version of the SANDAG ABM. Further, some structural changes to the process resulted in significant improvements in the run time and storage in the database.

As the new model version differed significantly from previous versions, changes and improvements to the database process necessitated an entirely new database structure to go along with the latest SANDAG ABM. The new ABM database relies on a star-schema model for the ABM trip list to enable and encourage in-depth reporting across hundreds of model runs in contrast to the previous relational model database trip lists. The run-time for the Extract-Transform-Load data pipeline is reduced from one hour to twenty minutes and database storage cost per scenario is reduced from 45 GB to 6 GB. Moreover, reporting query speed and complexity are reduced significantly across the board.

2.8 OTHER MODEL UPDATES

In addition to the model enhancements described in the previous section, the project incorporated several model improvements made by separate efforts. Those improvements are:

1. New Cross-Border Express (CBX) terminal model
2. Disaggregate commercial vehicle Model
3. Special Generators Calibration
4. New population synthesizer

Note that this work directly borrowed these improvements from other works and incorporated them into the model. This work did not carry out any new improvements.

The following sections provides a brief description of the above improvements.

CBX Airport Model

A separate project effort developed and calibrated a new air passenger ground access model for the Cross-Border Express (CBX) terminal. The current project added the new CBX terminal in the model flow.

The CBX terminal is a unique facility that provides access to Tijuana International Airport from the United States via a pedestrian bridge. The terminal provides a much faster border crossing than is available at either San Ysidro or Otay Mesa, especially for returning passengers. In order to use the facility, each traveler must have a Tijuana Airport boarding pass. The terminal offers parking, rental car services, airline check-in services, duty-free shopping, and dining. It opened in December 2015.

The model structure is borrowed from the San Diego Airport Ground Access Model. The model is calibrated based on a passenger survey conducted beginning of April 2016 at Tijuana Airport. The survey collected information from departing passengers who either used the CBX facility or could have used the facility but chose to cross at one of the other border crossings instead. Out of the 837 completed survey, 239 respondents reported using CBX to access Tijuana Airport on their travel day. The 239 respondents were expanded to 4,912 total average weekday arriving and departing passengers.

For a complete description of model design, survey data, and model parameters, see *CBX Model Development Report*, dated February 05, 2018.

Commercial Vehicle Model

SANDAG completed development of a new, disaggregate commercial vehicle model (CVM) in 2014 (HBA Specto Incorporated 2014). This model was based upon a local commercial vehicle survey and replaces the aggregate intraregional HDTM and nonfreight commercial vehicle components of the original aggregate commercial vehicle model. The internal/external component of the HDTM was retained in the new model system but was updated to FAF 3 data. In 2016, RSG completed a full model validation, CVM with the ABM model person travel results. This project incorporated the new CVM into the family of SANDAG activity-based models. As part of this work, the CVM model was modified to work with Open-Matrix Format (OMX) skim files and automated to work within the new EMME model and all source code was checked into GitHub for version control. The new AB model system runs the CVM with a scale factor of 1 and the generated demand for light trucks in the mid-day period is scaled to 2 times to compensate for the lack of commercial vehicle travel in the disaggregate CV model.

For a complete description of the CVM validation, see *Activity-Based Model and Commercial Vehicle Model Validation Report*, dated October 31, 2016. Further information on adjustments to the commercial vehicle model during this work are provided in Appendix G.

Special Generator Analysis

The RSG team carefully analyzed model performance at special travel destination sites across San Diego county. This analysis included beaches, hospitals, major shopping centers, casinos, parks, and other amusement sites. The analysis was based on passively-collected Location-Based Services data from Smartphone applications (purchased from Streetlight) as well as traffic counts at key locations. An origin-destination intercept survey was also performed at a number of beach locations in Spring 2017. The data collection and analysis effort is documented separately[7].

A summary of the findings of this effort include the following:

- The travel model matches total magnitude of travel at major retail locations and hospitals accurately when compared to traffic counts
- Adjustments to beach trip attraction rates were necessary to better match total magnitude of travel to beaches
- In some cases, there appear to be inconsistencies in estimated versus observed trip lengths. For example, data suggests that outlet malls should attract longer distance trips

[7] See Special Destination Data Collection And Analysis, Prepared for San Diego Association of Governments By RSG, March 2018.

than the model predicts. However, the team has concerns about the accuracy of observed data and the consistency of model summaries to observed data.

- In some cases, the MGRA input data should be revised to re-classify employment according to its functional equivalent. For example, in some cases hospital employment at teaching hospitals is coded as education employment, and casino employment at casinos operated by Native American tribes is coded as government employment. Though these designations may be technically correct, they result in mismatch in terms of total trip making because the designations are inconsistent with the type of activity performed at the land-use. More functional designations for these employment categories (e.g. medical and amusement employment respectively) would result in a better match to actual trip rates.

3.0 DATA

This chapter describes observed datasets used in calibration and validation of the SANDAG Activity-based Model. Table 1 presents a list of those datasets.

TABLE 1 CALIBRATION AND VALIDATION DATA

DATASET	YEAR	SOURCE	PURPOSE
Household Travel Survey	2016-17	San Diego Regional Transportation Study	CT-RAMP Calibration
Transit On-Board Survey	2015	Transit On-Board Survey Program	CT-RAMP Calibration and Highway Validation
Traffic Counts	2016	PeMS, CalTrans Census, SANDAG Toll Counts, and local jurisdictions	Highway Validation
Vehicle Miles Travelled (VMT)	2016	HPMS (Caltrans Public Road Data)	Highway Validation
Transit Ridership	2016	Passenger Count Program	Transit Validation
Travel Speeds	2016	INRIX	VDF Estimation

2016 household travel survey (HTS) is the primary dataset utilized to calibrate the resident model (CT-RAMP). The 2016 HTS data provide up to one week's travel details of approximately 6,200 households in San Diego County. Approximately 70% of the data was collected by rMove, a GPS-enabled Smartphone survey application developed by RSG, whereas the remainder of the travel data was submitted by filling out an online survey (rSurvey). The data was weighted based on household and person demographic data and combined across household days to calculate representative travel patterns for an average weekday. The final weighted HTS data are processed to generate various calibration summaries (targets) that helped inform adjustments to different components of the model. Documentation describing the collection and expansion of the household survey data is available separately[8].

During the creation of calibration targets, the HTS's estimate of transit travel are replaced with more reliable transit trip data from the 2015 Transit On-board Survey. The transit on-board data provides transit trips and transit tours (inferred from transit trips) that are expanded to boardings and are therefore a more accurate description of transit ridership than randomly-collected household travel survey data. Initially, the transit on-board survey data was expanded to match

[8] See San Diego Regional Transportation Study Volume I Technical Report, Prepared for San Diego Association of Governments by RSG, and San Diego Regional Transportation Study Volume II: Final Technical Appendix, Prepared for San Diego Association of Governments by RSG.

FY15 (Fall 2014-Spring 2015) boardings. Since the model was calibrated for 2016, the data was adjusted to match FY17 (Fall 2016-Spring 2017) boardings. These transit mode targets are replaced in mode choice targets from the HTS data, and the targets for other modes are proportionately scaled to match total trips by trip purpose and market segment. Documentation describing the collection and expansion of the transit on-board survey data is available separately.[9]

SANDAG accumulate observed traffic counts from various sources such as PeMS, Caltrans, and local jurisdiction counts. The combined database with counts from 2016 are used to validate estimated daily traffic flow generated by the model. The observed Vehicle Miles of Travel (VMT) from the Highway Performance Monitoring System (HPMS, Caltrans Public Road Data) is used to examine regionwide VMT generated by the ABM.

A number of summaries of on-board survey data were used to calibrate and adjust the transit pathfinding algorithm in CT-RAMP and EMME. Estimated transit ridership is compared with the 2016 observed ridership data from the Transit Passenger Count Program and the estimated transit boarding rate (boardings/trips) is compared with the observed data using transit ridership from the Passenger Count Program and expanded transit trips from the Transit On-Board Survey.

3.1 MODEL CALIBRATION

Model calibration refers to the process of adjusting model parameters until the model replicates the travel patterns revealed by observed data (targets). The SANDAG ABM calibration is primarily based on targets derived from the 2016 Household Travel Survey and the 2015 Transit On-board Survey. Details about survey data processing are provided in Appendix A SANDAG HTS And Transit On-Board Survey Data Cleaning and Processing.

Preparing Calibration Targets

Once the data are transformed into a format similar to the CT-RAMP outputs, an R script[10] generates various summaries (targets) to compare the model outputs. To assist in this process, RSG created a web-based calibration tool, a HTML visualizer, customized specific to the SANDAG ABM. The HTML visualizer is an interactive dashboard[11] designed to compare outputs from a model run with the observed targets prepared from the HTS data.

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[9] See 2015 On-Board Transit Passenger Survey Final Report, Prepared for San Diego Association of Governments by ETC Institute.

[10] The R script is included in the final deliverables: summarizeHTS.R

[11] The dashboard is a validation and diagnostics tool for CT-RAMP based Activity Based Models. Users can compare model performance against a household survey as part of a validation exercise or compare two model runs for sensitivity testing.

The visualizer presents estimated versus observed summaries across five major categories (available in the navigation bar at the top of the visualizer document):

- Overview
- Long Term Models
- Tour Level Models
- Trip Level Models
- Assignment Results

The subsequent sections discuss these summaries in more detail. Note that the discussion in these sections is limited to form of summaries, their definition/purpose, and if any special processing is performed. The sections do not present any numerical targets. The numerical targets are included in the next Chapter (see 4.2 Resident Model (CT-RAMP)) which discusses the performance of the model outputs compared to observed travel data.

Overview

This category summarizes some general statistics for the model region. Table 2 presents a list of the summaries available in this category.

TABLE 2: OVERVIEW SUMMARIES

SUMMARY	DEFINITION	PROCESSING
Population	Total number of persons in the San Diego County	
Households	Total number of households	
Total Tours	Total number of tours	
Total Trips	Total number of trips	
Total Stops	Total number of stops made on tours	
Total VMT	Total vehicle miles travelled (in miles)	Converted person trips into vehicle trips and multiplied by trip distance
Tours Per Person	Total tours divided by total persons	Total persons are calculated using trip/tour weights
Trips Per Person	Total trips divided by total persons	Total persons are calculated using trip/tour weights

SUMMARY	DEFINITION	PROCESSING
Stops Per Person	Total stops divided by total persons	Total persons are calculated using trip/tour weights
Trips Per Households	Total trips divided by total households	
Person Type Distribution	Number of persons by person type	
Household Size Distribution	Number of households by household size	

All of the summaries rely on the expansion factors described above. In determining travel rates (tours per person, trips per person, and stops per person), total persons are calculated using tour/trip weights (trip adjustment factors - result of the last step in weighting analysis). The trip adjustment factors correct for bias due to trip under-reporting, as described in the survey data expansion documentation.

To calculate regionwide vehicle-miles travel (VMT), person trips were converted into vehicle trips using occupancy factors of 1, 2, and 3.5 for drive-alone, shared-ride 2, and shared-ride 3 respectively, and then multiplied by the distance between trip origin and destination TAZ using network skim matrices.

Long Term

The set of summaries in Table 3 are prepared to examine long term choices in CT-RAMP. The long-term choices include household auto ownership and mandatory (work, university, and school) tour location choice.

TABLE 3: LONG TERM SUMMARIES

SUMMARY	DEFINITION	PROCESSING
Long Term Models		
Auto Ownership	Number of vehicles per household.	
Working from Home	Share of workers with usual workplace at home	Provided by SANDAG
Percentage Working from Home	Percentage of workers working from home by district	Created from the HTS data
Mandatory TLFD		

SUMMARY	DEFINITION	PROCESSING
Work	Distribution of workers by distance between home and usual workplace	
University	Distribution of university going students by distance between home and university	
School	Distribution of school going students by distance between home and school	
Flows & Tour Lengths		
District-District Flows of Workers	Number of workers by home district and usual workplace district	
Average Mandatory Tour Lengths	Average distance between home and mandatory (work, university, and school) location by home district	

The long-term model summaries evaluate household auto ownership, work from home choice, and mandatory (work/university/school) location choice. The auto ownership model was calibrated to match the distribution of households by number of autos owned in the HTS data. The share of workers who work from home was compared to a target provided by SANDAG as a better indicator of workers working from home than the household travel survey, though the HTS data informs the share by residence district. Tour length frequency distributions help understand individual's choice of work/university/school location. For this purpose, a tour length is calculated as the distance between home and the mandatory location. The tour length frequency distributions are also prepared by 8 SANDAG pseudo MSAs or districts (see Appendix C for a map).

The flows and tour lengths summaries examine movement (flow) of workers from residence district to work district. The flow of workers is a useful summary in understanding distribution of mandatory travel in the region. The summaries also include average tour lengths for the three mandatory choices by home district.

Tour Level

These set of summaries, Table 4, are created to examine tour generation in CT-RAMP. The HTS data is transformed into various summaries including, tour frequency summaries, school escorting distributions, joint tour frequency, tour primary destination choice, tour departure and arrival period choice, and tour mode. The first three sets of summaries examine magnitude of travel in the region, whereas the next two explore spatial and temporal behavior of the travel. Tour mode choice identifies the preferred mode for the tour.

TABLE 4: TOUR LEVEL SUMMARIES

SUMMARY	DEFINITION	PROCESSING
Tour Summaries		
Coordinated Daily Activity Pattern (CDAP)	Percentage of persons by their daily activity pattern (M: mandatory, N: non-mandatory, and H:at-home). Available by person type.	Persons are calculated using trip/tour weights. Boosted mandatory targets for full time workers and non-mandatory targets for non-workers.
Percentage of Households with a Joint Tour	Percentage of households with at least one joint tour by household size	Coordinated Daily Activity Pattern model
Mandatory Tour Frequency	Percentage of persons by mandatory activity type (1 work, 2 work, 1 school, 2 school, and >1 work & >1 school). Only persons with a Mandatory activity pattern are included. Available by person type.	Mandatory tour frequency model
Total Tour Rate (only active Persons)	Tours per person by person type. Includes joint tours as well.	Only active persons. Number of persons are calculated using trip/tour weights
Persons by Individual Non-Mandatory Tours (by person type)	Percentage of persons with number of non-mandatory tours (0, 1, 2, 3+). Available by person type.	Individual non-mandatory tour model
School Escorting		
Student School Half-Tours by Escort Type - Outbound	Distribution of outbound leg of school tours by escort type (pure escort, ride share, and no escort) and by child type (non-	Half tour leg of a school tour

SUMMARY	DEFINITION	PROCESSING
	driving student, and preschooler)	
Student School Half-Tours by Escort Type - Inbound	Distribution of inbound leg of school tours by escort type (pure escort, ride share, and no escort) and by child type (non-driving student, and preschooler)	Half tour leg of a school tour
Chauffeured School Half-Tours by Escort Type - Outbound	Distribution of outbound leg of school tours by escort type (pure escort and ride share) and chauffeur type.	Half tour leg of a school tour
Chauffeured School Half-Tours by Escort Type - Inbound	Distribution of inbound leg of school tours by escort type (pure escort and ride share) and chauffeur type.	
Workers with School Drops Offs and Pickups	Counts of workers who performed at least one rideshare or pure escort drop-off or pickup	Only workers who go to work with children who go to school are counted in the no escort category
Joint Tours		
Joint Tour Frequency	Frequency (percentage) of households by number of joint tours	
Joint Tour Composition	Frequency (percentage) of tours by composition (adults only, children only, and mixed)	
Joint Tours by Number of Household Members	Frequency (percentage) of joint tours by the number of household member participating	
Joint Tours by Household Size	Frequency (percentage) of households by household size	

SUMMARY	DEFINITION	PROCESSING
	and the number of joint tours per household	
Party Size Distribution by Joint Tour Composition	Frequency (percentage) of joint tours by party size and tour composition.	
Destination		
Non-Mandatory Tour Length Distribution	Distribution of tours by distance between tour origin and destination for each non-mandatory purpose	Half-tours
Average Non-Mandatory Tour Lengths (Miles)	Average tour lengths between origin and destination by non-mandatory tour purpose	Half-tours
Time-Of-Day		
Tour Departure-Arrival Profile	Distribution of tours by departure time (time leaving home or work) and arrival time (time arriving back at home or work) in 30-min time bins. Available by tour purpose. Distribution of tour duration is also available.	Tour duration includes travel time and time spent at the primary destination and all intermediate stops
Tour Aggregate Departure-Arrival Profile	Distribution of tours by departure time and arrival time in five broad time periods consistent with assignment models	
Tour Mode		
Tour Mode Choice	Distribution of tours by tour mode and HH auto sufficiency (0-autos, autos>=adults, and autos <adults). Available by tour purpose.	HTS transit tour mode (walk to transit, PNR to transit, and KNR to transit) targets are replaced with the transit targets from the transit on-board survey

A distribution of individuals daily activity pattern in three aggregated categories – Mandatory (M), Non-Mandatory (N), and Home (H) describes the primary type of daily travel made by the individuals. Mandatory travel patterns are only available to workers and students, and describe a travel pattern in which there is at least one work or school tour on the travel day (and zero or more non-mandatory tours). A Non-mandatory pattern is one in which there are no mandatory tours but at least one non-mandatory tour. A Home travel pattern describes a case where the person either stays home on the travel day or is out of town.

The tour frequency comparisons (mandatory, joint non-mandatory, and individual non-mandatory) quantifies the magnitude of tours. Lastly, the average number of tours by active persons measures total tour making of persons who engage in travel.

The school escorting summaries compare households' school escorting behavior. The drop-off and pick-up of children at school is summarized along a number of dimensions including type of student escorted (driving-age or preschooler), the person type of the driver and the type of escort tour (pure escort, rideshare, or no escort).

The joint tour summaries examine joint travel by household members – where all household members participating in the tour travel to all tour activities together. The tour summaries provide a higher-level idea of households' participation in joint tours, whereas the joint tour summaries explore joint tour participation in more detail by looking at joint tour frequency, party size, party composition (adults only, children only, or mixed), and household size.

The destination summaries look into the spatial aspect of non-mandatory travel in the region. Note that mandatory travel is already examined in the long-term summaries. The spatial distribution of non-mandatory travel destinations is examined by summarizing tour lengths for each non-mandatory tour purpose. A tour length is calculated as distance between origin and primary destination of a tour. The tour lengths are summarized in two ways: tour length frequency distribution and average tour length. Tour length frequency distribution informs of magnitude of people travelling within distance bins of 1 mile. Average tour length represents a typical distance travelled from home to the primary non-mandatory activity location. The two summaries together provide a general understanding of individuals' behavior of choosing locations for non-mandatory activity participation.

The temporal behavior of tours is inspected in the tour time-of-day (TOD) summaries. The summaries include frequency of tours by departure time from home (or work for work-based tours) and arrival time back at home (or work). Tours are summarized two ways: by 30-min time-of-day bins and by five broad skim\assignment time periods (EA, AM, MD, PM, and EV). There are 40 half-hour bins, where the first bin includes 3:00 AM to 5:00 AM and the last bin includes 12:00 PM to 3:00 AM.

The tour mode summaries are indicators of individual's preference of mode to travel from origin to primary destination and back. The tour mode summaries examine the mode preference by tour purpose and auto sufficiency. Three auto sufficiency classes describe the relationship of number of cars to number of adults in the household: 0-autos, autos<adults, and autos>=adults.

As mentioned before, the tour mode targets are initially created from the HTS data. The targets include number of tours within each mode by auto sufficiency and by tour purpose. A better source of observed travel by transit, the transit on-board survey, is processed to provide transit tour mode targets (walk to transit, PNR to transit, and KNR to transit) within the same market segmentation. These transit targets are replaced in the initial tour mode targets created from the HTS. Then targets of the other tour modes are scaled up or down to match the total tours within the aforementioned tour mode market segmentation.

Note that the transit on-board survey are records of transit trips made within the San Diego region. The transit trips are first processed to create transit trip mode targets. Then a trip rate factor (trips per tour) from the model is used to convert transit trip mode targets into transit tour mode targets. Approximately 4.5k linked transit trips in the on-board survey reported using bicycle as either an access or egress mode. These trips were re-coded as Kiss-and-ride to transit since the model does not have an explicit transit bicycle access/egress mode.

The HTS data includes approximately 31,559 (0.3%) expanded trips who report using TNCs[12] (uber, lyft etc.) as well. Since the current ABM does not have a separate mode for taxi or TNC, these trips were combined the shared-ride (SR2) mode. Due to lack of proxy reporting for school children, the school bus mode targets from the previous 2006 household travel survey were adopted for use as school tour school bus targets.

Trip Level

These set of summaries, Table 5, are created to examine trip generation in CT-RAMP. Number of trips are function of tours and the stops made on tours. An additional stop on a tour results in a new trip. For example, a tour with no stops consists of two trips: one, going from origin to primary destination and second, returning from primary destination to the origin. If the person makes a stop during the first leg of the tour (going from origin to primary destination) then this splits the first trip into in two trips: first, from origin to the stop, and second, from the stop to primary destination. With this, number of trips can be calculated as double of number of tours plus the number of stops on the tours.

The four sets of HTS summaries including, stop frequency, location, TOD, and trip mode examine magnitude, spatial distribution, temporal distribution, and mode preference of travel at an activity level respectively.

[12] A Transportation Network Company (TNC) provides pre-arranged rides for compensation using a digital platform that connects passengers with drivers using a person vehicle.

TABLE 5: TRIP LEVEL SUMMARIES

SUMMARY	DEFINITION	PROCESSING
Stop Frequency		
Stop Frequency - Directional	Percent of tours by number of stops on the tour and tour direction (inbound/outbound). Available by tour purpose and total.	
Stop Frequency - Total	Percent of tours by number of total stops (inbound + outbound) on the tour	
Stop Purpose by Tour Purpose	Percent of intermediate stops by stop purpose and tour purpose	
Location		
Stop Location - Out of Direction Distance	Distribution of intermediate stops by out of direction distance and tour purpose	Out of direction distance is the extra distance to the destination as a result of traveling through the stop location
Average Out of Direction Distance (Miles)	Average out of direction distance by tour purpose	
TOD		
Stop & Trip Departure	Stop - Distribution of stops in 30-mins departure time bins. Trip - Distribution of all trips in 30-mins departure time bins. Trips include trips to/from intermediate stops and the tour primary destination. The summaries are also available by tour purpose.	
Aggregate Stop & Trip Departure	Frequency of stops and trips in five model time periods. The	

SUMMARY	DEFINITION	PROCESSING
	summaries are also available by tour purpose.	
Trip Mode		
Trip Mode Choice	Distribution of trips by trip mode and tour mode. Tour mode constraints the availability of each trip mode and influences the utility of each available trip mode). The summaries are also available by tour purpose.	

The stop frequency summaries present number of tours by frequency of intermediate stops in outbound (going to tour destination), inbound direction (returning to tour origin), and total. The stop frequencies are also summarized by tour purpose. As the model in its present form allow a maximum 3 intermediate stops in each direction (outbound or inbound) of a tour, initial targets were also summarized in the same manner by combining tours with more than 3 intermediate stops with the tours with exactly 3 stops. However, calibration with the initial targets resulted in underestimation of stops (trips) on tours in the model as stops higher than 3 in each direction are not accounted for in the model. To account for these missing stops (trips), the initial targets of number of tours within number of stops by direction are adjusted in such a way that equivalent number of stops from the tour frequencies sum up to the total number of stops regionwide. For each purpose, number of tours with higher stops (3+ in each direction) were put in the highest category for that direction. For example, 4+ outbound and 0 inbound were put in 3 outbound and 0 inbound category; 4+ outbound and 1 inbound were put in 3 outbound and 1 inbound bin and so on. The tours in other (lower) categories were then scaled down to match total tours and total stops. The HTML visualizer includes the scaled frequency distributions.

An alternative to this scaling is allowing more stops in the model. This was not possible to do in this effort as it would require new model estimation and some structural changes to the model. The previous model estimation did not see enough stops beyond 3, therefore to minimize complexity the model was limited to generate maximum of 3 stops in each direction.

The destination summaries include analysis of out of direction distance on a tour. The out of direction distance is defined as the extra distance to the destination as a result of travelling through the stop location. For stops in the outbound direction, it is based on the distance between the last known location (the tour origin or previous outbound stop) and the tour primary destination. For stops in the inbound direction, it is based on the distance between the last known location (the tour primary destination or previous inbound stop) and the tour origin. The analysis of the out of direction distance is by tour purpose and in two forms: frequency distribution of the distance and average of the distance.

The TOD summaries include frequency of stops and trips by their respective departure times. Like the TOD summaries at tour level, the stop and trip frequencies are summarized in both 30-min time-of-day bins and in five skim/assignment model time periods (EA, AM, MD, PM, and EV).

Lastly, the trip mode summaries describe the mode used for each trip on the tour. The trip mode is summarized as the frequency of trips by trip mode and tour mode, which constraints the availability of each trip mode. The frequencies are also examined by tour purpose. Like tour mode choice targets, the trip mode targets are initially created from the HTS data, and transit on-board survey trips are used to describe transit trip targets.

3.2 MODEL VALIDATION

Model validation describes the process used to compare model outputs to independent data, not used to estimate or calibrate model parameters, to ensure that it is ready to be used for forecasting. Estimated traffic volumes from the model are compared with traffic counts and estimated transit ridership is compared with observed transit boardings.

The next sections describe the observed data used in the model validation effort.

Traffic Counts

SANDAG maintain a traffic count database that is assembled from various sources: PeMS (Performance Measurement System) counts, Caltrans District 11 State Highway Traffic Census Counts, arterial counts from local jurisdictions, and some special counts collected by SANDAG. Average weekday traffic (AWDT) was derived from PeMS daily counts collected over the year 2016 and are therefore the most reliable count data source for model validation. Local jurisdiction traffic counts typically do not cover the entire year and therefore are subject to larger error than the PeMS counts.

As shown in Table 6, a total of 2,251 counts are available to use for highway validation. Out of those, 45% are from PeMS or Caltrans District 11 and 51% are gathered from local jurisdictions. About 4% counts are collected by SANDAG on toll facilities in the region.

TABLE 6: 2016 TRAFFIC COUNTS BY SOURCE

DATA SOURCE	FACILITY	NUMBER OF COUNTS	% COUNTS
PeMS	Freeway and Ramp	768	34%
Caltrans District 11	Freeway, Arterial, and Collector	253	11%
Local Jurisdiction	Arterial and Collector	1,142	51%
Other (SANDAG)	Freeway including toll Facility (I-15 and SR-125)	88	4%
Total		**2,251**	**100%**

Performance Measurement System (PeMS)

PeMS is a traffic count database maintained by Caltrans. The traffic data is collected in real-time from nearly 40,000 individual detectors spanning the freeway system across all major metropolitan areas of the State of California. The data collection method uses vehicle detectors, which are physical loops embedded in road pavement. The count database is available to the public through a web-based interface. Annually, SANDAG downloads hourly PeMS traffic counts for freeways in the San Diego region (Caltrans District 11).

The 2016 PeMS database has about 1500 vehicle detector stations (VDS) on the same number of freeway (also ramp) segments in District 11. Ideally, each station would have 8,783 records (hours) of counts for the entire year. However, some stations report Null values (partial or full). SANDAG removed such stations if null counts exceed 15% of the total count records for the station. This resulted in about 10% of the total stations removed from the count database.

Further, for each count station, SANDAG excludes weekend and holiday counts and calculates annual average weekday count by five model time periods (EA, AM, MD, PM, and EV). All eligible count stations were joined to about 800 model network links using automatic ArcMap procedures coupled with manual reviews.

Caltrans District 11

Every year, Caltrans provides SANDAG traffic counts from the Traffic Census Program. The counts are Annual Average Weekly counts and are available by five model time periods. SANDAG received traffic counts for about 270 locations for 2016.

Local Jurisdictions

SANDAG staff assembled and compiled 2016 traffic counts from local jurisdictions in the San Diego County that collect weekday daily two-way counts on major arterials and collectors. SANDAG staff matched the counts to the model network links. In cases where a count matched multiple links, the staff picked the link with estimated traffic flow matching the count most closely.

For 2016, 586 arterial counts offering sampling coverage of 2% of the total arterial network links are processed. About 90 of these counts were removed due to various reasons: weekend day count, Christmas holiday week counts, duplicate counts, and metadata inconsistency.

These counts are one-time 24-hour or 72-hour counts, thus presenting a challenge to use them as an average daily weekday count. This is because some locations on the arterial network are subject to high ADT variance depending on the time of year. For example, roads near a shopping mall experience greater use during the holiday months and roads near local beaches are subject to variances that corresponds to construction delays, special events or inclement weather. Because of the low sample rate and high degree of seasonal variance, caution is encouraged when using these counts.

Other

SANDAG manages two toll facilities in the region: the I-15 express lanes and the South Bay Expressway (SR-125). SANDAG obtained transactional counts for each facility from the Intelligent Transportation Systems Group, Operation Department. The raw data is annual average weekday transponders by 15-minute intervals and by each pair of entry plaza and exit plaza. SANDAG converts the gate-to-gate toll transponders data into toll counts by five model time periods at model network link level. The 2016 toll transponders data are matched to about 12 links on SR-125 and 22 links on the I-15 express lane facility.

Transit Boardings

Estimated transit boardings from the model are validated against 2016 daily transit ridership from the SANDAG Passenger Count Program.

In Fall 2016, there were 8,663 trips made by transit vehicles. Of which, 334 were not counted by the Passenger Count Program. For those 334 trips, 327 FY16 counts were pulled (as well as 7 FY15 counts for trips that were not counted in FY16 or FY17) and factored by MTS and NCTD farebox counts of each route. An example: Rt 20 trip #4 was missing from Fall 16 counts, but had 39 boardings in FY16, MTS reported that Rt 20 ridership dropped 11% from FY16 to FY17, so we factored down to 35 boardings for that trip in FY17.

3.3 TRAVEL TIME DATA (INRIX)

INRIX collects traffic related data from multiple sources, but mostly from GPS navigation devices and mobile phones carried in vehicles**,** which can anonymously provide location and speed information.

SANDAG purchases INRIX speed data annually. The raw data are travel speeds for each 5000 TMC (Traffic Message Channel) segments covering most of the freeways and about 70% of the arterials in the San Diego region. The data is available by one-minute interval through the year, though only the data from the month of October is used to calculate average speeds. The speeds are calculated for an average weekday (no weekends and holidays) by five model time periods.

To process the data, SANDAG created a correspondence between model link ids and the INRIX TMC ids. Due to difference in coverage, granularity and length, the automated process generated several erroneous matches which were manually reviewed and corrected. The review also removed suspicious records with INRIX speeds of less than 5 mph.

3.4 SUMMARY

This project utilizes various datasets to calibrate and validate the new version of the ABM. The observed datasets are for year 2016. The below is a summary of these datasets:

- Model Calibration
  - CT-RAMP (2016-17 HTS, 2015 Transit On-Board Survey)
  - Special Market Models (2015 Transit On-Board Survey, 2017 CBX intercept survey, 2017 beach intercept survey, Streetlight Location-Based Services data).
- Model Validation
  - Highway Traffic Counts (PeMS, Caltrans, local jurisdictions, and other)
  - Highway VMT (HPMS)
  - Transit Trips (Transit On-Board Survey)
  - Transit Boardings (Passenger Count Program)
- INRIX speed data

4.0 MODEL CALIBRATION

4.1 OVERVIEW

In model calibration, alternative-specific constants (ASCs) and other model parameters are iteratively adjusted until the model generates demand that reasonably matches travel patterns in observed data. Typically, models are calibrated according to the following procedure: first, create comparisons between observed data and estimated model results. Next, calculate ASC adjustments by calculating natural log of the ratio between the observed value and the estimated value for each alternative. Then, add the adjustments to the ASCs from the previous iteration. Next, run the model with the updated constants[13].

The remainder of this chapter presents and discusses various summaries of the comparisons between the model results and the observed data. The discussion is presented separately for resident models (CT-RAMP) and special market models. In the end, a summary of the chapter presents key takeaways from the discussions.

The present model calibration[14] relies on the 2016 base year. The calibration of the ABM system involved adjustments to the resident ABM (CT-RAMP) as well as other special market models (cross-border model, visitor model, airport model, and external model).

4.2 RESIDENT MODEL (CT-RAMP)

A web-based calibration tool, HTML visualizer, compares outputs from a CT-RAMP model run with the observed targets prepared from the observed datasets. The HTML visualizer presents various summaries comparing different CT-RAMP sub-model components. A list and description of those summaries is provided in the previous Chapter 3.1 Model Calibration.

This section presents and discusses the summaries from the HTML visualizer comparing the ABM outputs with the observed data. Note that the summaries label observed targets as HTS (2016 Household Travel Survey) and ABM results as SDABM16 (SANDAG Activity-Based Model 2016).

Overview

These set of summaries compare regional-level population and travel generation in the ABM with the observed data.

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[13] In CT-RAMP, the calibration ASCs are entered into the Utility Expression Calculator (UEC) spreadsheet and on separate line to distinguish calibration constants from the estimated constants.

[14] The present calibration process used no shadow pricing during the iterative adjustments of ASCs in CT-RAMP. However, after the calibration was finalized, the base year model is run with starting stable shadow pricing. The final model run also includes updated 4D's in the input mgra landuse file.

Synthetic Population Comparisons

The ABM relies upon a synthetic population that is representative of San Diego county residents. The synthetic population is generated by a software program developed by SANDAG staff. Several changes were made to the software tool as part of the regional model calibration effort. For more information about synthetic population refer to Appendix D. For more information about the HTS data refer to Chapter 3.0 Data.

The synthetic population is compared to households and persons from the expanded HTS. Since the HTS was expanded to match distributions from Census (2015 1-year ACS), these comparisons are similar to comparing the synthetic population to Census. Note that as the HTS is expanded to 2015 data while the ABM calibration base-year is 2016, the comparisons are focused on distribution rather than absolute values of the population.

The HTS data suggest about 1.11 million households in the region with the most households (32%) include 2 members and the least households (12%) include 5 or more members, Table 7 and Figure 3. In total, the synthetic population in the ABM has slightly more households (1.20M) than the HTS data (1.11M). The synthetic population generally matches the distribution of households by household size in HTS except that it has slightly fewer (-3%) households with 2 members and a little more (2%) households with 5 or more members.

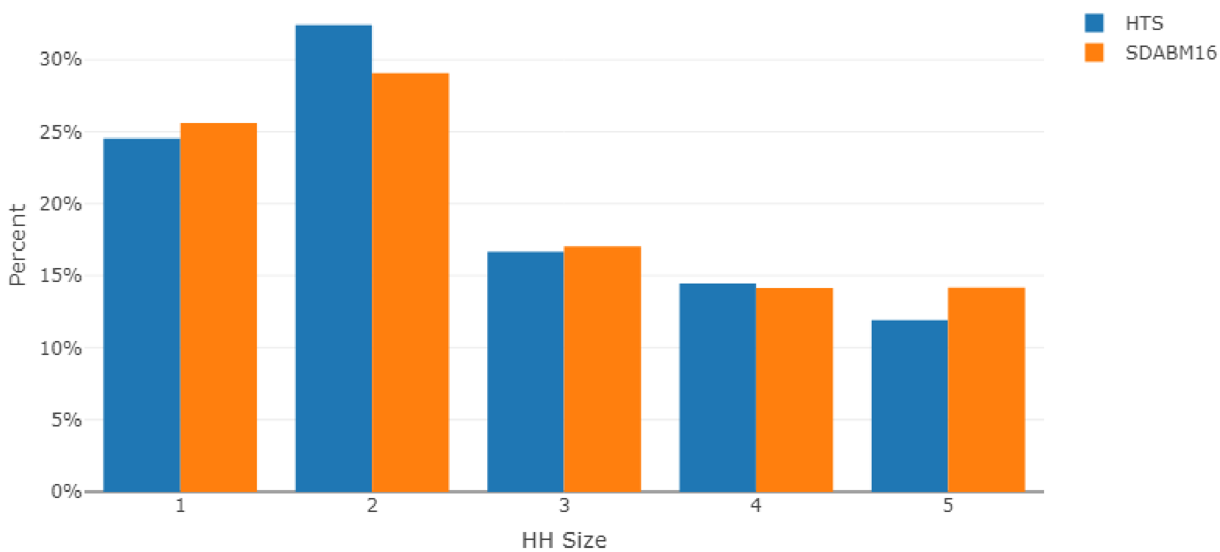


FIGURE 3: HOUSEHOLD SIZE DISTRIBUTION

TABLE 7: HOUSEHOLD SIZE DISTRIBUTION

HHSIZE	HTS	SDABM16	HTS	SDABM16	DIFF
1	273,347	305,987	25%	26%	1%
2	360,981	347,695	32%	29%	-3%
3	185,672	203,689	17%	17%	0%
4	161,164	169,043	14%	14%	0%
5	132,460	169,548	12%	14%	2%
Total	**1,113,624**	**1,195,962**	**100%**	**100%**	**0%**

According to the HTS, the population of the San Diego county is 2.92M in 2015. Of the total population 46% are workers (mostly full-time – 39%), 26% are students of some type, and 23% are either non-workers are retirees. Only 6% of the individuals are pre-school kids. See Table 8 and Figure 4 for comparisons.

More households in the ABM also means more population (12%) compare to the HTS. The ABM population by person type, Table 8 and Figure 4, generally show a reasonable match with the HTS distribution. However, it indicates smaller (-6%) share of full-time workers (part-time workers are 4% higher) and slightly higher share (3%) of non-workers. Also, population of university students is a little lower (-3%) in the synthetic population compared to the expanded survey.

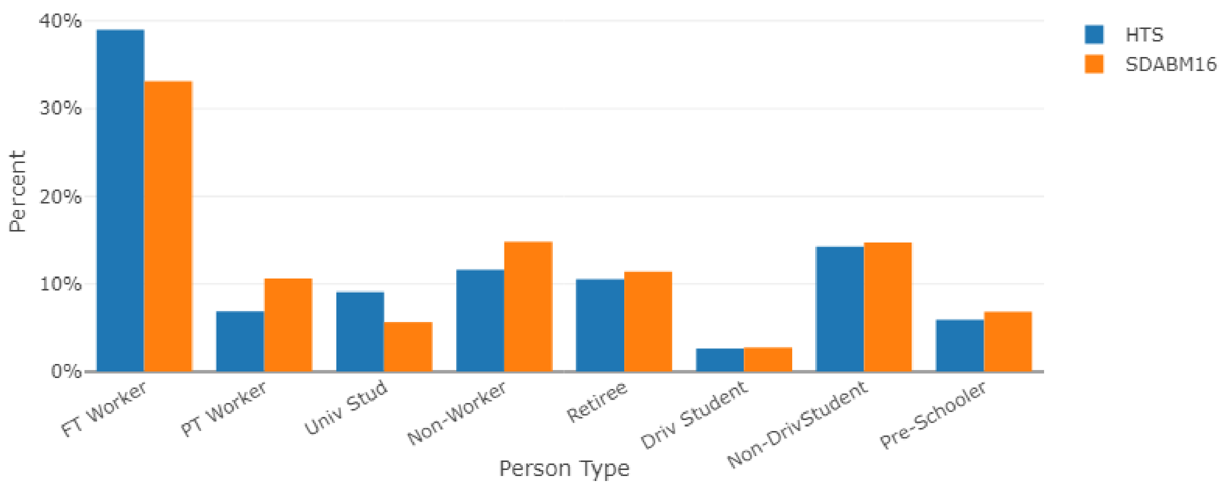


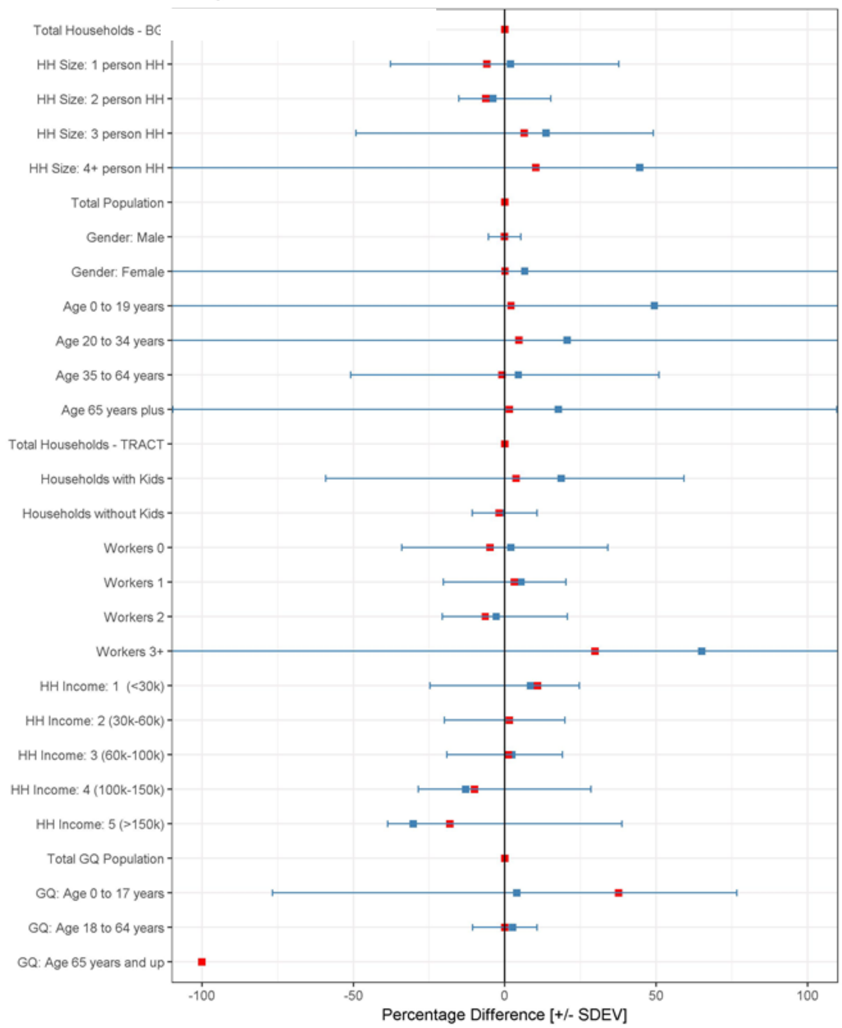
FIGURE 4: PERSON TYPE DISTRIBUTION

TABLE 8: PERSON TYPE DISTRIBUTION

PERTYPE	HTS	SDABM16	HTS	SDABM16	DIFF
FT Worker	1,138,936	1,083,539	39%	33%	-6%
PT Worker	201,243	348,928	7%	11%	4%
Univ Student	266,206	185,354	9%	6%	-3%
Non-Worker	340,120	484,648	12%	15%	3%
Retiree	308,537	373,359	11%	11%	1%
Driving-Age Student	77,580	90,940	3%	3%	0%
Non-Driving Student	416,152	482,008	14%	15%	0%
Pre-Schooler	173,765	223,356	6%	7%	1%
Total	**2,922,537**	**3,272,132**	**100%**	**100%**	**0%**

As part of the model calibration effort, the results of the population synthesizer were also compared to Census data at a geographic level. Two data sources were used for this effort; 2010 decennial census SF1 was used for household size, household type, gender, and age at block group level, and presence of kids in household and group quarters by age at the tract level. 2015 ACS 5-year data was used to compare number of workers in households and household income at the tract level. The controls are scaled at the regional level to match respective frequencies in 2015 ACS 1-year estimates. The controls are also scaled to match respective synthetic population at each level of geography they are being compared for. In the validation plot (Figure 5), dots are mean percentage difference and bars are standard deviation of percentage difference at the compared geography. As can be seen in the plot, the mean is close to observed for most variables, while the standard deviation indicates some variance at the geographic level for which the target is being compared.

FIGURE 5: SYNTHETIC POPULATION VALIDATION



Travel Rate Comparisons

The regional travel generated from the ABM is compared in terms of magnitude of travel (such as tours, trips, stops and VMT), as well as travel rates (tours per person, trips per person etc.).

As shown in Figure 6, the HTS suggest that on an average weekday, 2.92M residents of the San Diego region make 11.67M trips (result of 3.97M tours and 3.68M intermediate stops) thus generating a regionwide VMT (vehicle-miles travelled) of 48.18M. The ABM produces slightly higher estimates of trips - 12.73 million trips (4.58 million tours and 4.05 million stops) generating 55.11M VMT in the region.

FIGURE 6: OVERVIEW – AGGREGATE SUMMARIES

Regionwide travel rates are presented in Figure 7. As per the HTS data, an average resident of the San Diego region makes 3.7 trips (1.3 tours per person and 1.2 intermediate stops per person) on an average weekday. When calculated for all household members, this aggregates to 10.5 trips by all members of an average household in the region.

The travel rates from the ABM are slightly on the higher side. The model generates 3.9 daily trips per person (1.4 tours per person and 1.24 intermediate stops per person). With an average household size of 2.73, the ABM travel rate adds up to 10.64 trips for an average household.

The ABM generates slightly more trips than the HTS for several reasons. First, there are more households and persons in the ABM compared to the expanded HTS, since the HTS was expanded to 2015 data while the ABM calibration base-year is 2016.

Second, during the calibration process, it was discovered that the HTS under-estimates travel for school. We believe this is due to the use of proxy reporting for students; children under 15 years of age were not instrumented with the rMove GPS Smartphone App. Instead, it was expected that other household members would report their travel. However, it was discovered that the rate of students traveling to school in the HTS (~60%) is significantly lower than other travel surveys indicate (85-90%), suggesting that proxy reporting did not successfully capture travel for a significant portion of school trips. Furthermore, it was determined that the rate of workers going to work on the travel day was slightly lower than other household travel surveys. The rate of workers going to work was adjusted slightly higher based on this analysis.

Specific details of the adjustments are provided in the tour level summaries below. Note that the adjusted targets are not reflected in the calibration targets presented here. Therefore, the comparisons show a slightly higher travel rate in the ABM compared to the HTS.

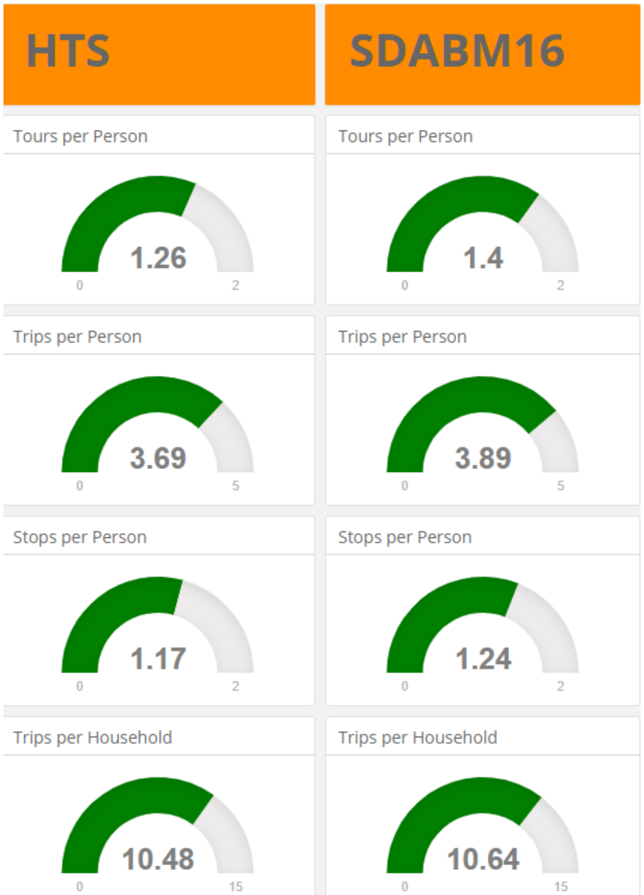


FIGURE 7: OVERVIEW – TRAVEL RATES

Long Term Choices

Long term travel choices are defined as the choices that are decided for a horizon period of more than a day. An individual's travel is generally organized around these choices. Owning a car (auto ownership) and choosing a location for work and school (work and school location choice) are considered long-term choices.

Auto Ownership

As presented in Table 9 and Figure 8, the HTS data suggests that 6% of the households in the region do not own a car. Most households (93%) own 3 or less vehicle with only 7% have 4 or more vehicles in the households. The ABM was calibrated to closely match the distribution of households by auto availability in the HTS data by adjusting alternative-specific constants.

TABLE 9: HOUSEHOLDS WITH AUTO AVAILABILITY

HHVEH	HTS	SDABM16	HTS	SDABM16	DIFF
0	63,477	66,691	6%	6%	0%
1	356,176	381,281	32%	32%	0%
2	437,225	470,935	39%	39%	0%
3	178,467	192,648	16%	16%	0%
4+	78,278	84,407	7%	7%	0%
Total	**1,113,624**	**1,195,962**	**100%**	**100%**	**0%**

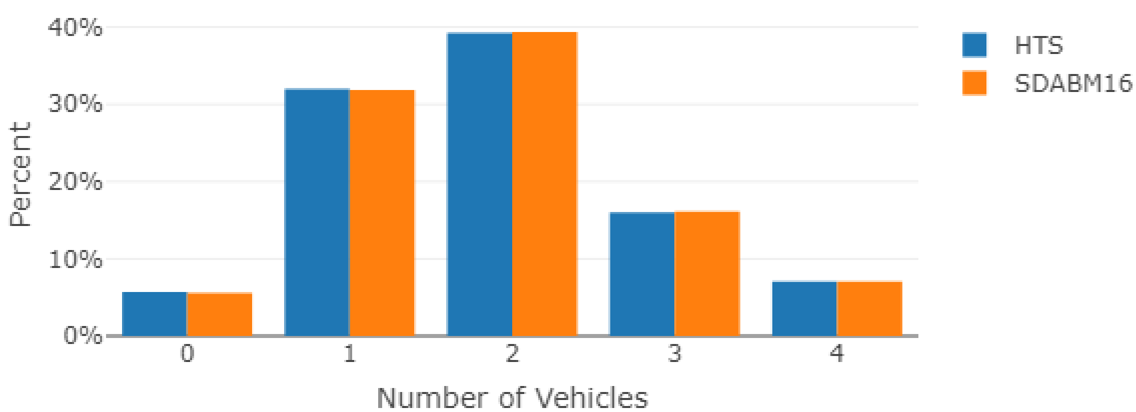


FIGURE 8: AUTO OWNERSHIP

Spatial distribution of 0-vehicle households is very vital to predict transit ridership in the region. Figure 9 shows a map comparing 0-vehicle households from the ABM and Census (2015 5-year ACS) at Census tract. The map displays absolute difference of the share of 0-vehicle household in the two datasets with a color code: a green color means positive difference (the ABM is higher than the Census) and a red color means negative difference (the ABM is lower than the Census). Higher intensity of a color indicates bigger difference. A good match (within 0.5%) with the Census share is symbolized with grey color.

The spatial distribution suggests that the auto ownership model in the ABM is lacking in putting 0-vehicle households in right areas. A comparison of household attributes at regional level suggested that compared to the Census data, the model is predicting more 0-vehicles for households with multiple drivers and fewer for one driver households. Also, the model is predicting more 0-vehicles for households with more than 2 members and fewer for one-member households. As seen in synthetic population comparisons, Figure 5, the inconsistency could be a result of differences in the synthetic population for households by household size and by workers. If the inconsistency persists after resolving the differences in synthetic population then it can be resolved by adjusting the auto ownership model by number of drivers in household and household size.

When looked at individual tracts, some Census tracts show significant differences. For example, as shown in Figure 10, couple census tracts near Encinitas exhibit that the model predicts very few 0-auto households but the Census reports significantly higher share of such households. A comparison of household attributes of the two tracts with adjacent census tracts where the model 0-auto household share is similar to the Census data, revealed a potential issue with the spatial distribution of workers in the synthetic population. The analysis found that the tracts that have smaller share of 0-vehicle households then Census are primarily different in terms of 0-worker households – significantly fewer 0-worker households than Census. This is consistent for the two Census tracts that are low in terms of 0-vehicle household shares. The workers distribution in adjacent tracts generally follow Census distribution so is the predicted 0-vehicle household share. The analysis of the two tracts in Encinitas points to a potential problem in generation of the synthetic population, also seen in synthetic population comparisons (Figure 5). An improved synthetic population generation process would more likely result in better predictions from the auto ownership model in the ABM.

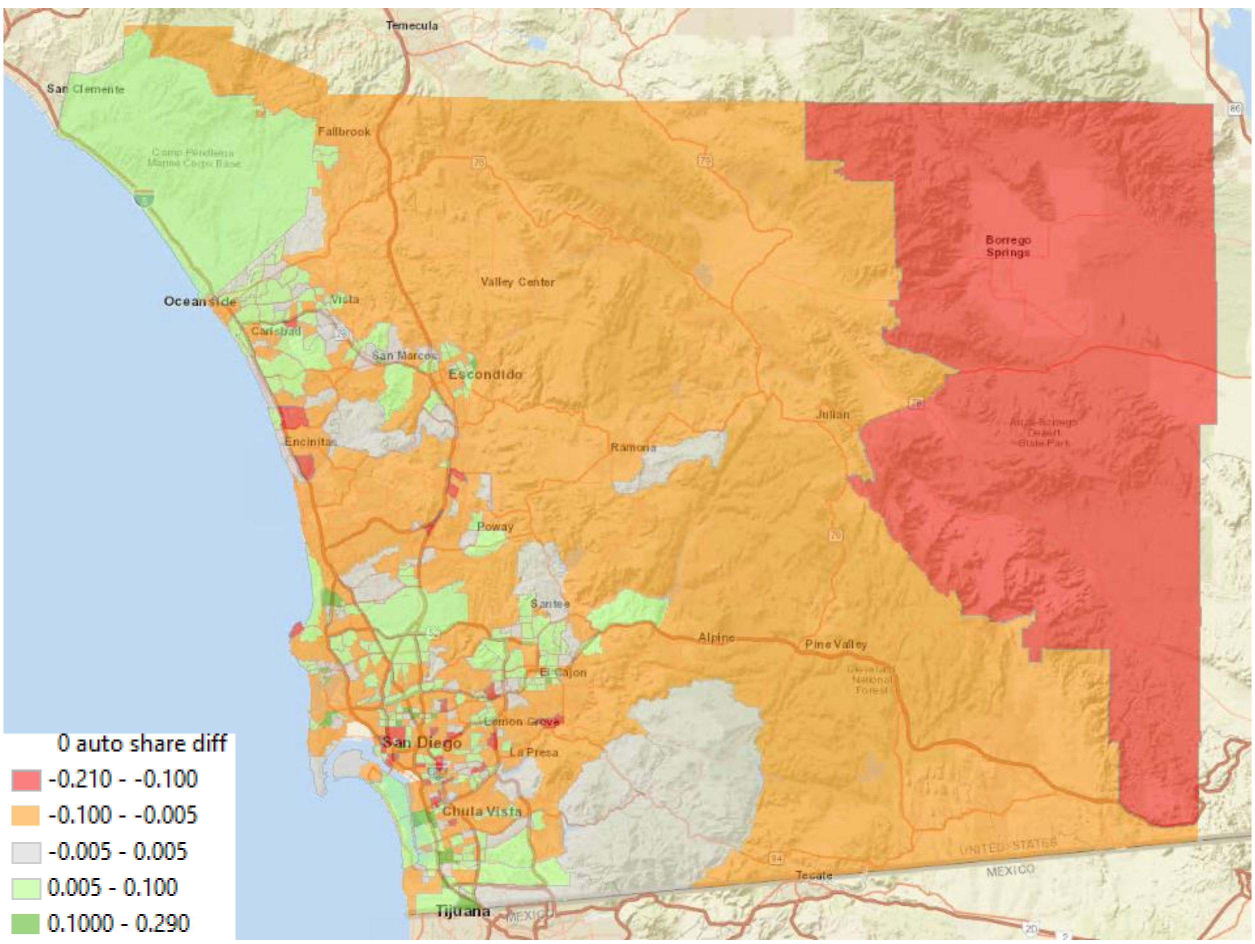


FIGURE 9: DIFF OF ESTIMATED AND OBSERVED 0-VEH HH SHARE (CENSUS TRACT)

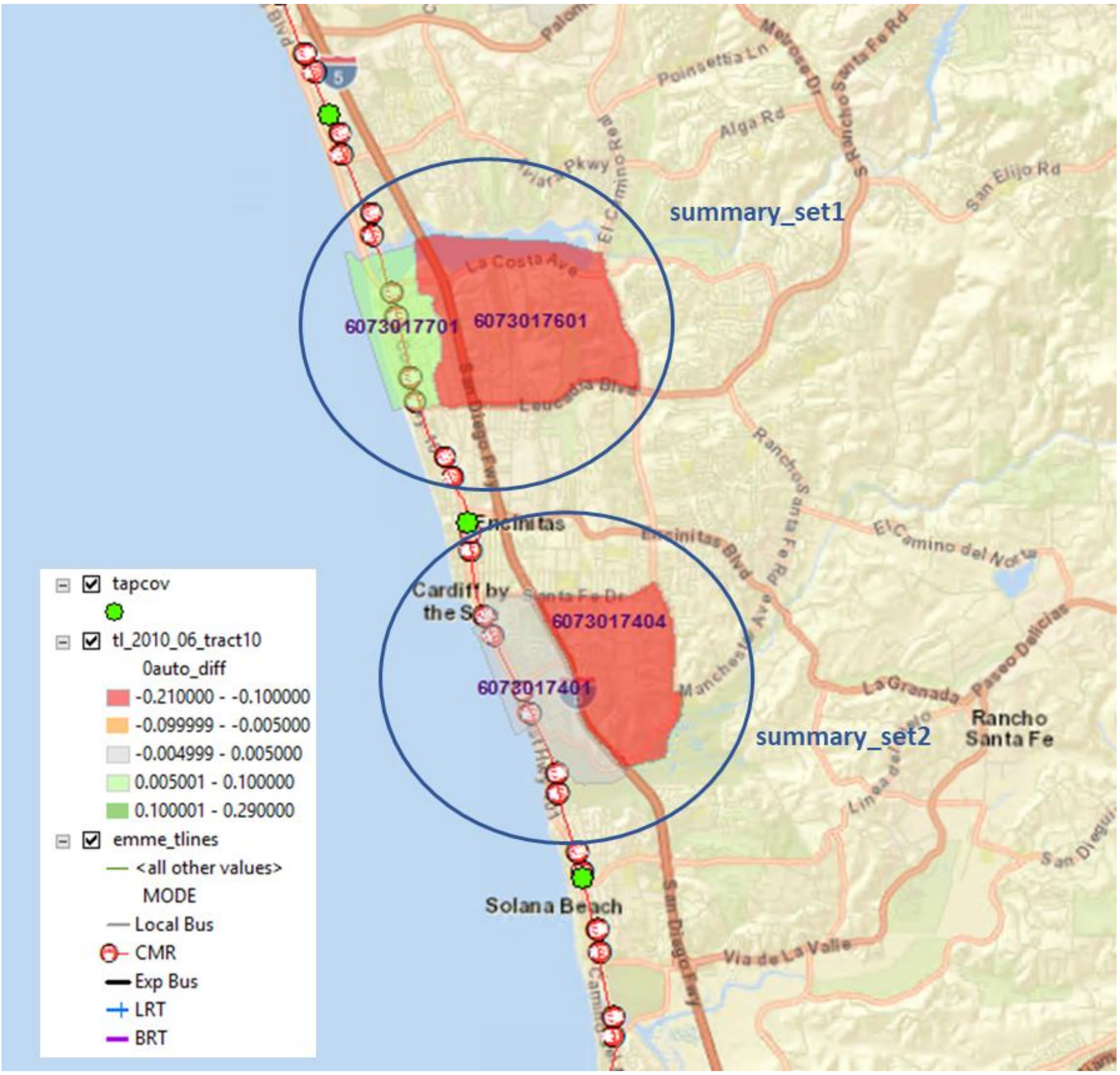


FIGURE 10: 0-VEH HH ANALYSIS – TWO CENSUS TRACTS IN ENCINITAS

Work from Home Choice

American Community Survey (ACS) has reported the means of transportation statistics annually since 2005. ACS reports that the proportion of workers that telework ranges approximately between 6% and 7.5% in the last 12-year period, except 2005 which shows a much lower percentage. Based on this trend, a target of 7.1% is recommended[15] for work from home share in 2016. The ABM is calibrated to match the target, Figure 11.

[15] See *Telework Assumptions, Future Mobility Research Program* submitted by WSP to SANDAG in 2018.

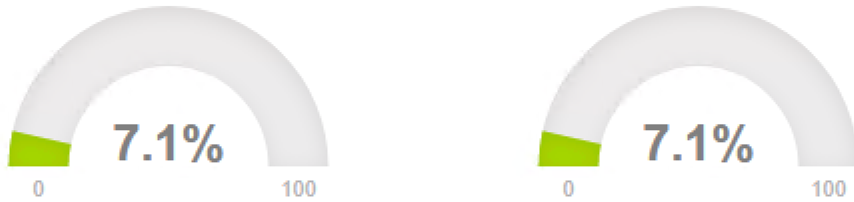


FIGURE 11: REGIONAL SHARE OF WORK FROM HOME (HTS VS SDABM16)

Working from home shares are also compared by workers' residence district, Figure 12 (see Appendix C for description of the districts). Note that the observed summaries by district are generated from the HTS data whereas the regional share target is provided by SANDAG. The HTS data is used just to compare distribution (share) of work from home across 8 districts in the San Diego region. The HTS indicate that the model significantly under-estimates the share of workers who work from home who live in district 1, and over-estimates the share of workers who work from home in districts 2 and 7. However, the differences could be due to survey bias; workers who work from home are more likely to be recruited for participation in a travel survey than workers who work at a remote location.

The ABM's estimate of the share is relatively consistent across districts (6.9% - 9.2%), but it reflects the effect of accessibility on the probability of working from home; workers who live further from their regular workplace are more likely to telecommute. The model was estimated from 2006 travel survey data in which worker occupation was not collected; it is possible that incorporating worker occupation as an explanatory variable would improve the model results, but it would also require the synthetic population to accurately represent worker occupation category spatially.

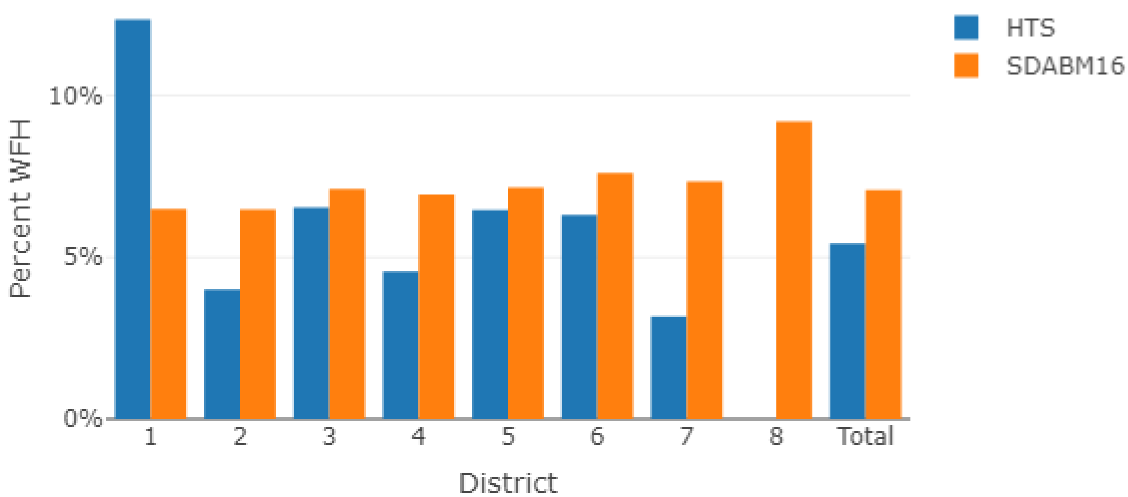


FIGURE 12: WORK FROM HOME BY DISTRICT

Mandatory Tour Location Choice

Table 56 presents a summary of average distance (tour length) between home and mandatory activity (work, university and school) location, regionally as well as by district (see Appendix C for description of the districts). The average observed home to work distance is 11.8 miles. The average home to university\college distance is 8.6 miles and the average home to school (K-12) distance is 4.3 miles). The model calibration adjusted constants in different distance bins to generate similar average tour lengths.

Average tour lengths by workers' residence district also show a reasonable match, except district 8 (East County). For workers living in the East County, the HTS suggest unreasonably far work locations (avg distance = 83.9 miles). The ABM generate a much more reasonable average work location distance (26.91 miles) for the workers in that district.

Similarly, home to university and school distances by student residence district also match reasonably well. The HTS data do not have any records of students in district 8 (East County), therefore, respective average distances are 0 in the targets.

Frequency distributions of home to work, university, and school distance are shown in Figure 13, Figure 14, and Figure 15 respectively. The HTS data distribution is generally lumpy due to lack of sample data in some distance bins. However, the ABM distributions are relatively smoother and generally follow the HTS distribution profiles.

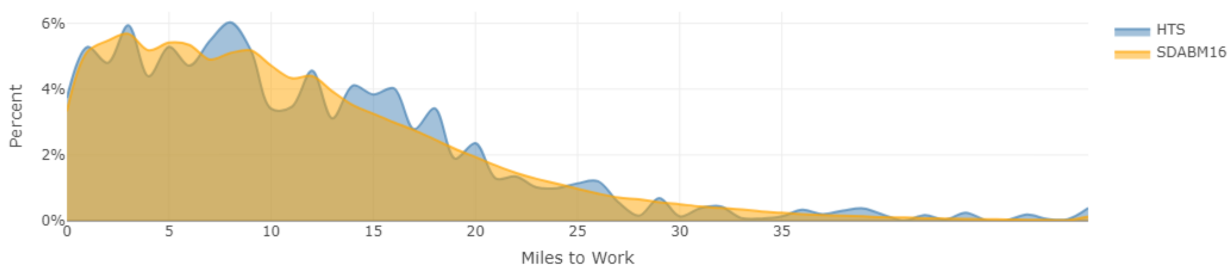


FIGURE 13: TRIP LENGTH FREQUENCY DISTRIBUTION - WORK

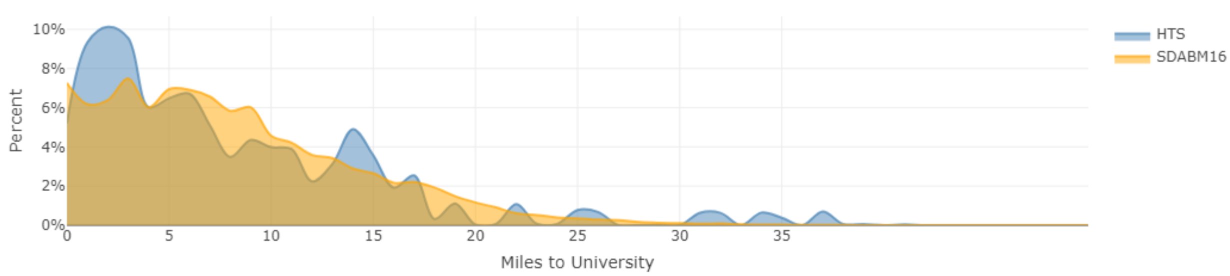


FIGURE 14: TRIP LENGTH FREQUENCY DISTRIBUTION – UNIVERSITY

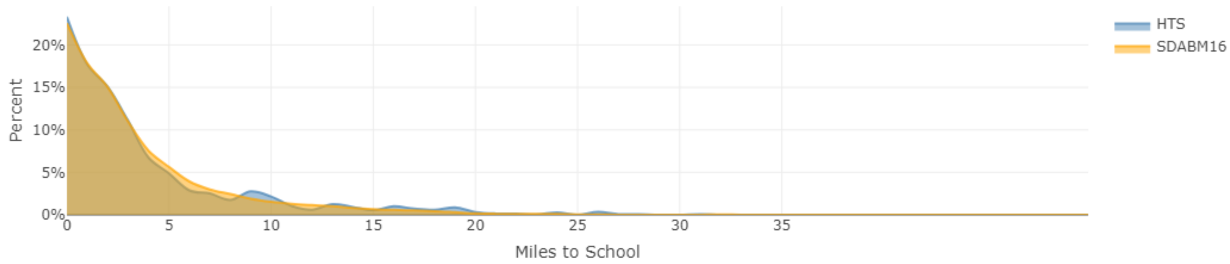


FIGURE 15: TRIP LENGTH FREQUENCY DISTRIBUTION - SCHOOL

Estimated versus observed district level summaries of worker travel (flow of workers) is compared by home district (row) to work district (column) (see Table 57, Table 58, and Table 59 in Appendix C for tabular summaries) are compared in a scatter plot, Figure 16. A point in the plot represents number of workers travelling in a home district to work district pair with observed workers on the x-axis and the corresponding workers produced in the ABM is on the Y-axis. The ABM exhibits a good allocation of workers with a R-squared value of 0.98.

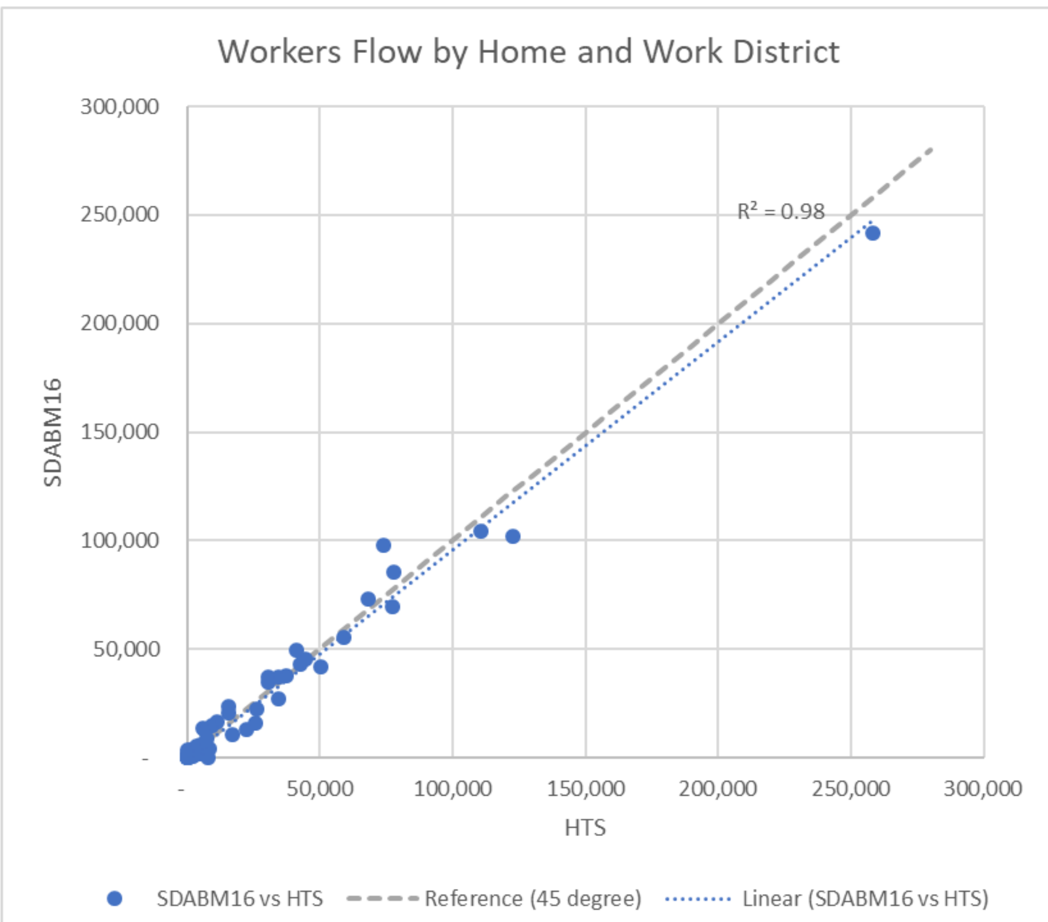


FIGURE 16: WORKERS FLOW BY HOME AND WORK DISTRICT

Tour Level Choices

Tour level choices include daily activity pattern generation, mandatory tour frequency, escorting children frequency, joint tour frequency, tour primary destination, tour time-of-day choice, and tour mode choice.

Coordinated Daily Activity Pattern Model

The coordinated daily activity pattern model (CDAP) determines each individual's daily activity pattern (DAP), as either Mandatory (M), Non-Mandatory (N), or stay at home (H). The activity pattern is Mandatory if the person undertakes at least one mandatory activity (work or school) during the day[16]. It is Non-Mandatory if the person did not go to work or school but participated in at least one non-mandatory activity (shopping, meal, social, recreation, etc.). If the person did not travel on the day and stayed home or was out of town, then the activity pattern is Home. Note that the activity pattern is M only if the mandatory activity resulted in person leaving the home. So, if the person is working/schooling at home then the activity pattern is N or H, depending on whether the person participated in non-mandatory activities or stayed at home.

The travel model was adjusted to match shares of M, N, and H patterns by person type by calibrating alternative-specific constants. Regionally, the ABM replicates the HTS daily activity patterns (Figure 17) in total, with slightly more persons with at least one travel activity (M and N), thus fewer persons who stay at home. The summary of activity pattern by person type (Table 61 and

[16] Currently CT-RAMP generate DAP as M for individuals working from home and schooling from home. The DAP for such individuals is recoded to N or H (depending on individuals' other travel) during creating summaries for comparisons.

Table 62) indicates a higher share of mandatory travel patterns for full-time workers (80% in the model compared to 75% in the HTS), somewhat lower rate of non-working adults staying home (26% in the model compared to 35% in the survey) and much higher rates of students going to school (90% to 93% in the model compared to the very low 65% to 67% in the survey). As discussed in calibration targets preparation (3.1 Model Calibration), the targets for full-time workers and non-working adults were adjusted slightly in calibration to generate more travel for these person types. The daily activity pattern distribution for students was left unchanged from the previous calibration due to suspected problems with proxy reporting described above.

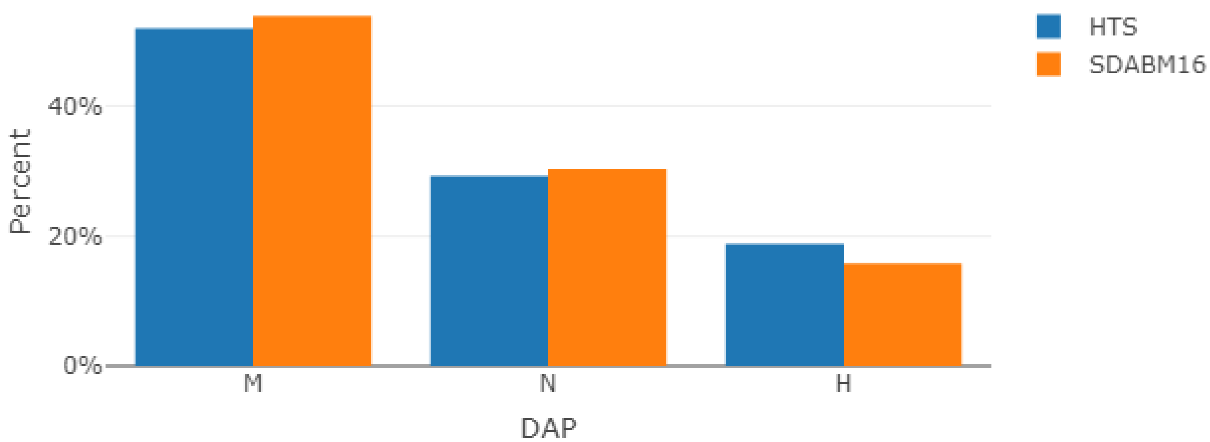


FIGURE 17: DAILY ACTIVITY PATTERN - TOTAL

Percentage of Households with a Joint Tour

A joint tour is defined as a tour where two or more members of a household travel together for all activities. The households with at least one joint tour are compared by household size in Figure 18 and Table 10. Naturally, joint activity participation increases with more members in the household. The ABM calibration adjusted constants by household size for joint tours to match the distribution in the HTS data.

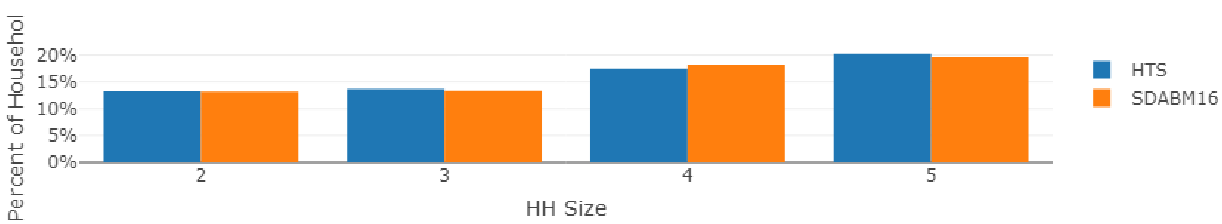


FIGURE 18: PERCENTAGE OF HOUSEHOLDS WITH A JOINT TOUR

TABLE 10: HOUSEHOLDS WITH A JOINT TOUR

	HTS				SDABM16			
HH Size	Joint	Total	Joint	Total	Joint	Total	Joint	Total
2	47,705	360,981	13%	100%	45,933	347,695	13%	100%
3	25,326	185,672	14%	100%	27,161	203,689	13%	100%
4	28,164	161,164	17%	100%	30,766	169,043	18%	100%
5	26,739	132,460	20%	100%	33,210	169,548	20%	100%
Total	**127,933**	**840,277**	**15%**	**100%**	**137,070**	**889,975**	**15%**	**100%**

Mandatory Tour Frequency

The mandatory tour frequency model predicts the exact number of mandatory tours by purpose for anyone assigned a Mandatory activity pattern (Figure 19). The distribution within mandatory tour frequency is also examined by person type in Table 63, Table 64, Table 65, and Table 66. The mandatory tour frequency is grouped into five categories: 1 work, 2 work, 1 school, 2 school, and mixed (1 work and 1 school).

According to the HTS data, most persons undertake either 1 work (61%) or 1 school tour (32%) on a given day. The ABM matches the observed frequency of work tours; however, it does not match the survey frequency for school tours due to suspected low rate of school travel in the HTS data.

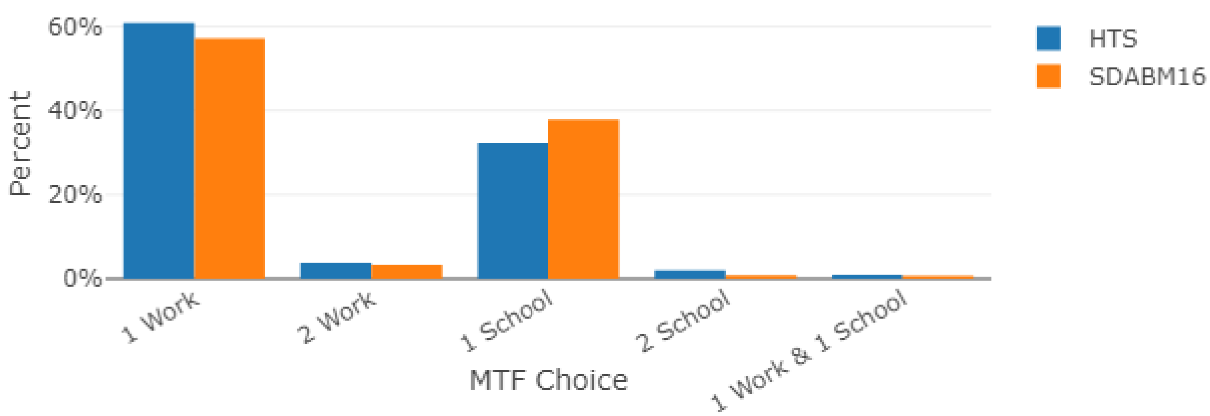


FIGURE 19: MANDATORY TOUR FREQUENCY – TOTAL

Individual Non-Mandatory Tour Frequency

The individual non-mandatory tour frequency model predicts the number of non-mandatory tours generated by anyone with an active (M or N) activity pattern. The overall distribution of non-mandatory tours by person with an active travel pattern is shown in Figure 20. The distribution of non-mandatory tours by person type is also examined in Table 67, Table 68, Table 69, and Table 70. For comparison purpose, 3 or more non-mandatory tours are grouped together in the last category - 3plus.

The HTS data indicates that 64% of the total persons do not make any non-mandatory tours in a day whereas the model estimates a lower share of persons (58%) with no non-mandatory tours due to the adjustment made to the share of non-workers who stay home. Otherwise, the frequency of non-mandatory tours by person type compares well.

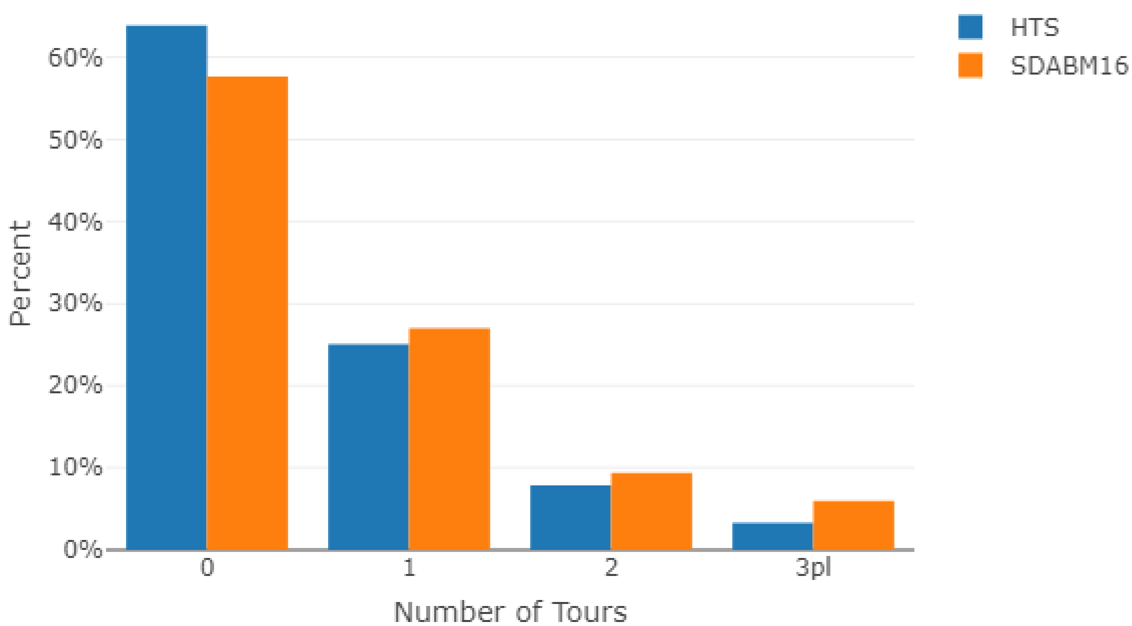


FIGURE 20 – PERSONS BY INDIVIDUAL NM TOURS - TOTAL

Total Tour Rate

Figure 21 summarizes the tour rate per person for active persons by person type. The comparison is consistent with the other summaries discussed above.

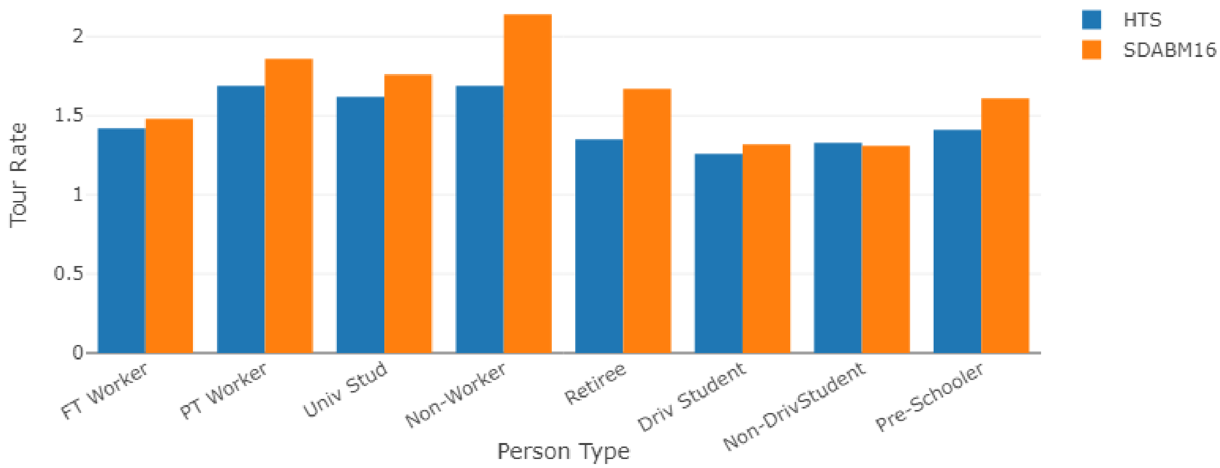


FIGURE 21: TOTAL TOUR RATE (ACTIVE PERSONS) BY PERSON TYPE

School Escort Model

The school escort model determines whether children are dropped-off at or picked-up from school, simultaneously with the driver responsible for chauffeuring the children, which children are bundled together on half-tours, and the type of tour (pure escort versus rideshare). The model is described in more detail in section 2.3 School escort model. The drop-off and pick-up behavior are inspected within various dimensions including type of student (driving-age or preschooler), type of driver (chauffeur) and type of escorting (pure escort, rideshare, or no escort).

Figure 22 and Figure 23 compare distribution of student school tours by escort type (no escort, ride share, and pure escort) and by direction (outbound and inbound). In a rideshare escort, the student is dropped off or picked up by a driver on their way to work or school or way back home. In pure escort, the student is dropped off of picked-up by a driver who is travelling specifically for the purpose of escorting the student, though the driver may make other non-escort stops. Further, the school tours are also compared by escortee type (non-driving age and preschooler) in Table 71 and Table 72. Note that the ABM allows escort school tours for driving age students, however, the HTS do not include escort tours for such students, thus they are excluded from comparisons. The ABM totals include driving age students as well.

The HTS indicates that most students do not require escort to school and when they do, the escort travel is mostly for the purpose of escorting the student (pure escort). Escort patterns are very similar regardless of direction. Mostly non-driving age students are dropped off or picked up as pure escort, whereas, escorting of preschooler is generally combined with mandatory travel (ride share). This is expected as generally a children's daycare (for preschooler) schedule is maintained around regular mandatory activity hours, while, there is very little control over the schedule of older kids' (non-driving age students) school, thus may require dedicated travel for escorting them.

The school escorting pattern in the ABM compares well with the HTS. In general, regardless of the direction (drop-off or pick-up), the ABM generates somewhat fewer escorting tours (pure escort or rider shares), thus more students are not being escorted to school. However, the highway validation indicates an over-estimate of multi-occupant vehicles, so we did not increase the escort participation model.

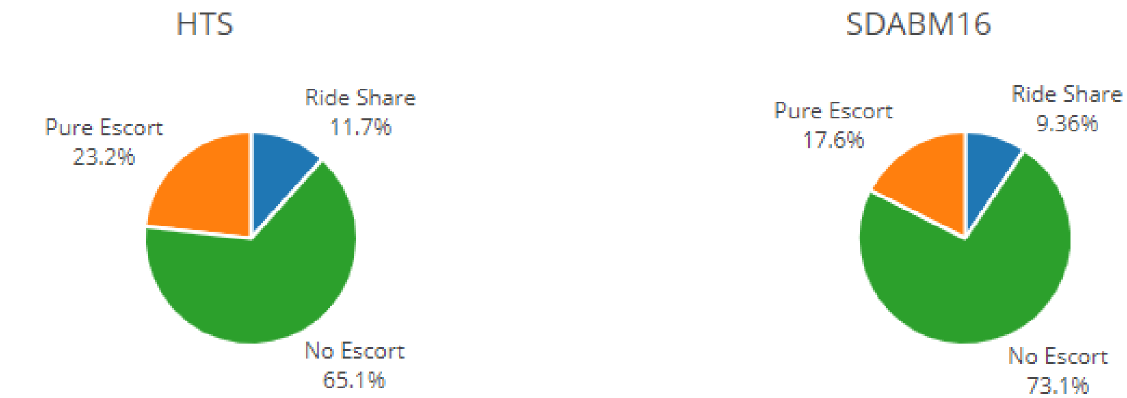


FIGURE 22: STUDENT SCHOOL HALF-TOURS BY ESCORT TYPE – OUTBOUND TOTAL

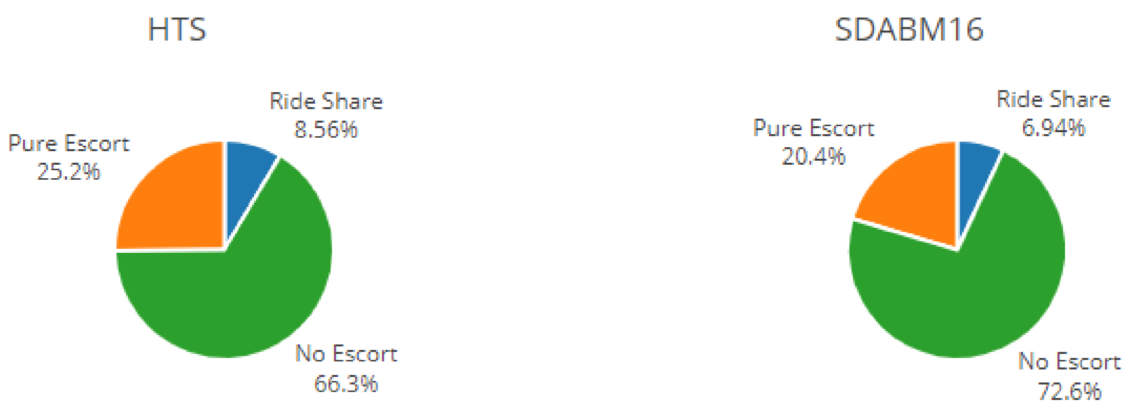


FIGURE 23: STUDENT SCHOOL HALF-TOURS BY ESCORT TYPE – INBOUND TOTAL

Also seen previously, the HTS data indicates that pure escort is the preferred escort method with 66.5% of the escort tours being pure escort (Figure 24, Figure 25, Table 73, and Table 74). Interestingly, even though full-time workers prefer to drop-off their kids to school on their way to work (ride share), their preference changes to pure escort for picking up the kids from school. Since part time workers have relatively more flexibility and more time, they prefer (54.6%) to do the pickups on their way back from work. University students are more flexible in terms of their class schedules and tend to make pure escort more often. As non-worker and retired drivers do not have to go to work or school, their escort travel is always pure escort.

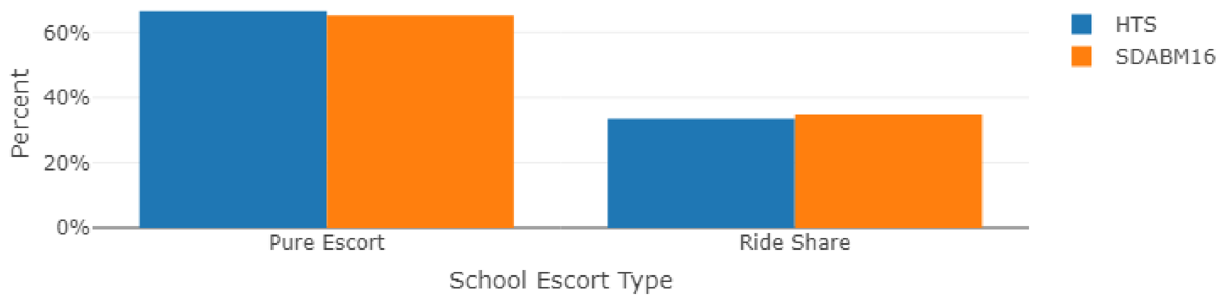


FIGURE 24: SCHOOL HALF-TOURS BY ESCORT TYPE – OUTBOUND TOTAL

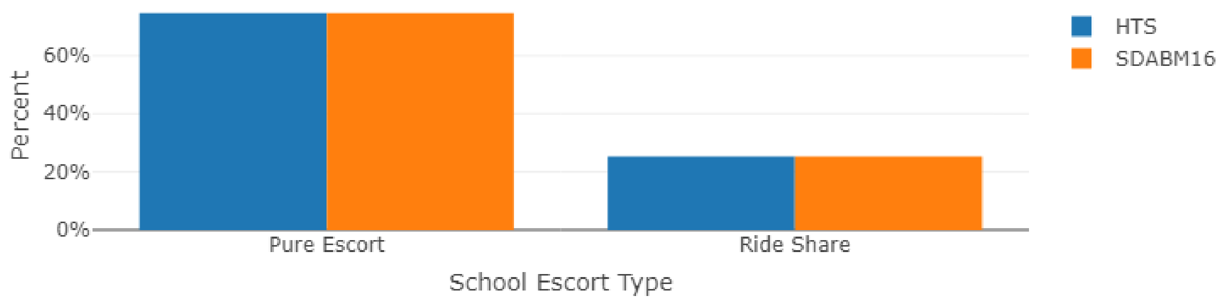


FIGURE 25: SCHOOL HALF-TOURS BY ESCORT TYPE – INBOUND TOTAL

The frequency of workers with both a work tour and children who go to school are compared by drop-off and pick-up escort type in Table 11, and Table 12. The HTS data indicates that workers during their commute prefer making escort travel only in one travel direction- either drop off while going to work or pick-up while returning home. For the other travel direction, the kids are probably either taking school bus or walking. 75% of the workers who make drop-off as pure escort, also do the pick-up as pure escort. In the ABM, pure escort tour in one direction is always a pure escort tour in the other direction as well. Otherwise, the ABM distribution of workers by type of escort tour is similar to the HTS.

TABLE 11: SHARE OF WORKERS WITH SCHOOL DROP OFFS AND PICKUPS - HTS

	PICKUP			
DROP OFF	RIDE SHARE	PURE ESCORT	NO ESCORT	TOTAL
Ride Share	35%	1%	64%	100%
Pure Escort	0%	75%	25%	100%
No Escort	5%	0%	95%	100%
Total	**7%**	**3%**	**90%**	**100%**

TABLE 12: SHARE OF WORKERS WITH SCHOOL DROP OFFS AND PICKUPS – SDABM16

	PICKUP			
DROP OFF	RIDE SHARE	PURE ESCORT	NO ESCORT	TOTAL
Ride Share	30%	11%	59%	100%
Pure Escort	0%	100%	0%	100%
No Escort	6%	2%	92%	100%
Total	**9%**	**3%**	**88%**	**100%**

Joint Tours

These summaries examine joint travel by household members. While the tour summaries provide a higher-level idea of households' participation in joint tours, the joint tour summaries explore joint tour participation in more detail by looking at joint tour frequency, party size, party composition (adults only, children only, or mixed), and household size.

Figure 26 and Table 75 presents the distribution of households by the frequency of joint tours. The distribution is compared among 20 joint frequency categories that are created using all possible combinations of joint tour frequency by purposes (shopping, maintenance, eating out, visiting, and other discretionary) with combinations limited to have maximum of 2 joint tours regardless of the purpose. Households with more than 2 joint tours for one purpose are placed in the 2 joint tours for that purpose.

The HTS data indicate that most (91%) of the households that participate in joint tours are making only one joint tour in a day and among them the visiting purpose is the least popular (4%) joint tour purpose. The ABM compares reasonably well with the HTS joint tour frequency although it underestimates households with only one eating out joint tour and overestimates households with 1 visiting joint tour.

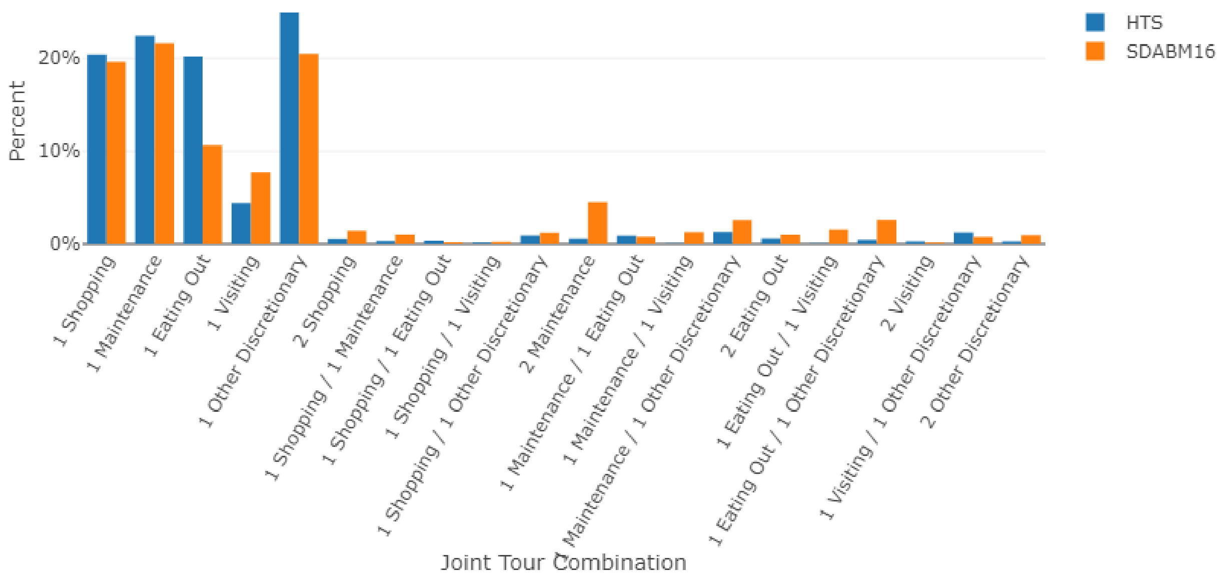


FIGURE 26: HOUSEHOLDS BY JOINT TOUR FREQUENCY

Table 76 summarize frequency of joint tours by the tour composition. A joint tour composition is defined as type of participating members and is categorized as all adult, all children, and mixed (both adults and children). According to the HTS data, the majority (57.6%) of joint tours involve all adults with 42.4% include both adult and children. There are few joint tours made only by children. This is reasonable as it is unlikely that only children will undertake a tour without supervision of an adult. The ABM generates a similar frequency of joint tours by tour composition.

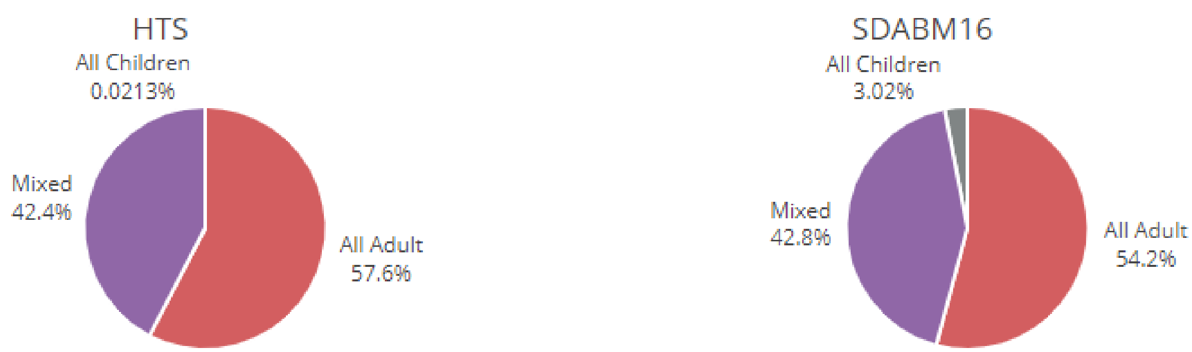


FIGURE 27: JOINT TOUR COMPOSITION

The HTS suggest that 78% of the joint tours are made by two members and only a handful (0.3%) of joint tours involve 5 or more members, Figure 28 and Table 77. The ABM generates a similar distribution of joint tours by party size.

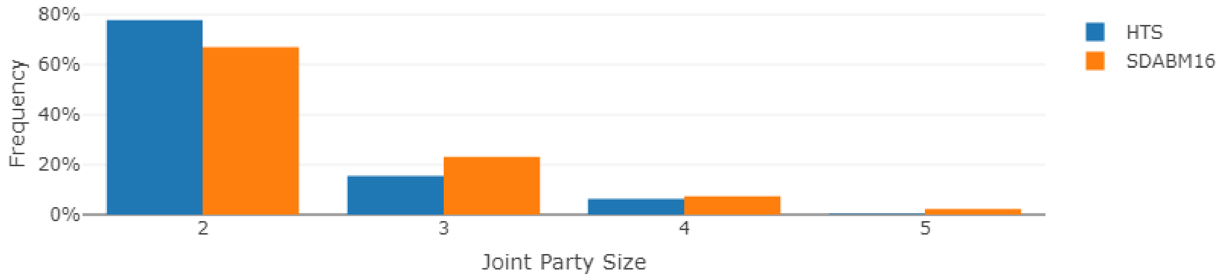


FIGURE 28: JOINT TOURS BY NUMBER OF HOUSEHOLD MEMBERS

In total, 15% of the joint tour eligible households (household size > 1) are observed to participate in joint tours in the HTS data (Figure 29). Also seen in the summary of joint tours by joint frequency (Figure 26 and Table 75), most participating households make only 1 joint tour in a day. According to the HTS, household participation in joint tour(s) increases with increase in household size (Table 78, Table 79, Table 80, and Table 81). Participating households increase from 13% to 20% when household size increases from 2 to 5 or more. The ABM distribution is similar to the HTS.

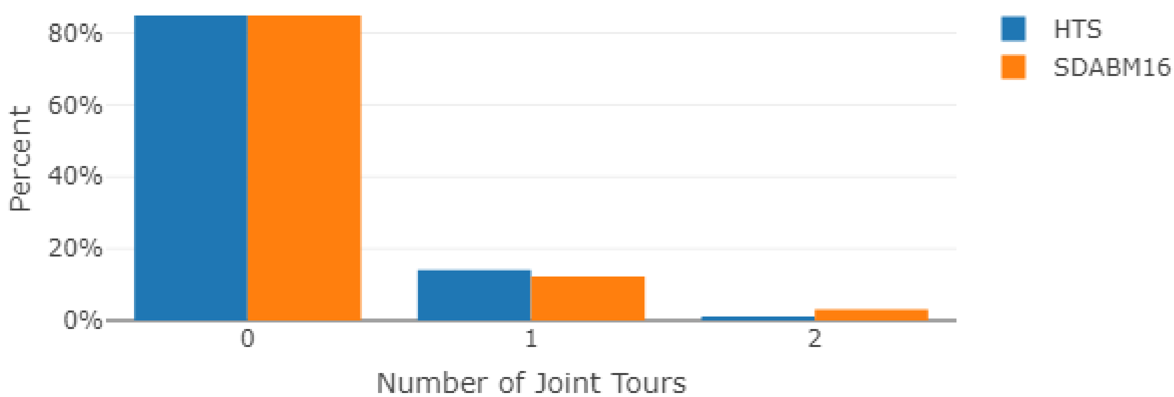


FIGURE 29: JOINT TOURS BY HOUSEHOLD SIZE

The distribution of joint tours by party composition (all adult, all children, and mixed) and by party size (2, 3, 4, and 5) are compared in Table 13, Table 14, Table 15, and Table 16. The HTS suggests that joint tours involving only adults mostly (99%) include 2 adults. If both adult and children are making joint tours, then more people participate in joint tours – 49% with party size of 2 and 50% with party size of 3 or 4. Only a few joint tours involve only children and all of them involve 2 children only.

The ABM distribution of joint tours is similar to the HTS except the joint tours by all children. The ABM generate more joint tours involving only children and majority (55%) of such tours has more than 2 children participating in them. However, given the issues with proxy reporting, we do not calibrate the participation models to reduce the size of joint tours with only children as it is likely that the survey under-represents this small travel market.

TABLE 13: JOINT TOUR FREQUENCY BY PARTY COMPOSITION AND SIZE - HTS

	JOINT PARTY SIZE				
PARTY COMPOSITION	2	3	4	5	TOTAL
All Adult	82,947	1,075	-	-	**84,023**
All Children	31	-	-	-	**31**
Mixed	30,460	21,575	9,238	498	**61,771**
Total	**113,439**	**22,651**	**9,238**	**498**	**145,825**

TABLE 14: JOINT TOUR FREQUENCY BY PARTY COMPOSITION AND SIZE – SDABM16

	JOINT PARTY SIZE				
PARTY COMPOSITION	2	3	4	5	TOTAL
All Adult	75,334	10,956	2,070	713	**89,073**
All Children	2,248	1,603	632	486	**4,969**
Mixed	32,656	25,502	9,593	2,642	**70,393**
Total	**110,238**	**38,061**	**12,295**	**3,841**	**164,435**

TABLE 15: JOINT TOUR SHARE BY PARTY COMPOSITION AND SIZE - HTS

	JOINT PARTY SIZE				
PARTY COMPOSITION	2	3	4	5	TOTAL
All Adult	99%	1%	0%	0%	**100%**
All Children	100%	0%	0%	0%	**100%**
Mixed	49%	35%	15%	1%	**100%**
Total	**78%**	**16%**	**6%**	**0%**	**100%**

TABLE 16: JOINT TOUR SHARE BY PARTY COMPOSITION AND SIZE – SDABM16

	JOINT PARTY SIZE				
PARTY COMPOSITION	2	3	4	5	TOTAL
All Adult	85%	12%	2%	1%	**100%**
All Children	45%	32%	13%	10%	**100%**
Mixed	46%	36%	14%	4%	**100%**
Total	**67%**	**23%**	**7%**	**2%**	**100%**

Non-Mandatory Destination Choice

The non-mandatory destination choice models choose a destination for the 'primary activity' on the tour. The primary activity for tours without a mandatory activity is chosen based on a set of fuzzy logic rules that assign a score to each activity on the tour based on activity purpose, activity duration, and distance from home (or work for work-based tours). A comparison of estimated versus observed distance between the tour origin and the primary destination is a useful comparison to ensure modeled travel distance is correct. This includes both average distance by purpose and the distribution of tours by tour length in one-mile increments. Based on this comparison, tour distance terms were adjusted in the model to improve goodness-of-fit between the estimated and observed tour length frequency distribution and the average tour length by purpose.

Overall, the frequency distribution of non-mandatory tours by distance in the ABM matches well with the HTS (Figure 30). The distributions by different non-mandatory tour purpose also compare well (Figure 78, Figure 79, Figure 80, Figure 81, Figure 82, and Figure 83). The sample size for joint tours in the HTS is smaller than that of individual tours; therefore, the joint tour length frequency distributions are somewhat lumpy and are not matched with the same accuracy as individual tours.

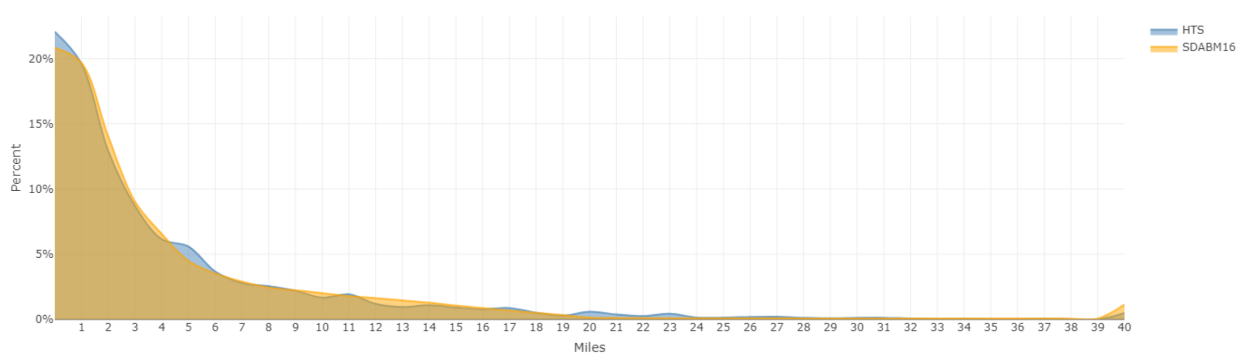


FIGURE 30: NON-MANDATORY TOUR LENGTH DISTRIBUTION

The HTS data observe that on average, non-mandatory tours are about 4.9 miles in distance. As expected, at-work tours are shorter than home-based tours, as a significant proportion of these tours are made for lunch trips that tend to be close to the place of work. Average tour lengths compare well with the HTS data, both total and by purpose (Table 17).

TABLE 17: AVERAGE NON-MANDATORY TOUR LENGTHS (MILES)

PURPOSE	HTS	SDABM16
Escorting	4.36	4.87
Individual Maintenance	4.78	5.01
Individual Discretionary	5.49	5.88
Joint Maintenance	7.43	6.62
Joint Discretionary	6.46	6.40
At-Work	3.41	3.45
Total	**4.91**	**5.15**

Time-of-Day Choice

The tour time-of-day choice model predicts the departure time from the tour origin and arrival time back at the tour origin in 40 half hour time bins. The first bin includes 3:00 AM to 5:00 AM and the last bin includes 12:00 PM to 3:00 AM. For both tour departure and arrival, the ABM distribution profile generally matches the HTS (see Figure 31 and Figure 32). Departure and arrival coefficients by time of day bins were adjusted to better match the distribution profiles.

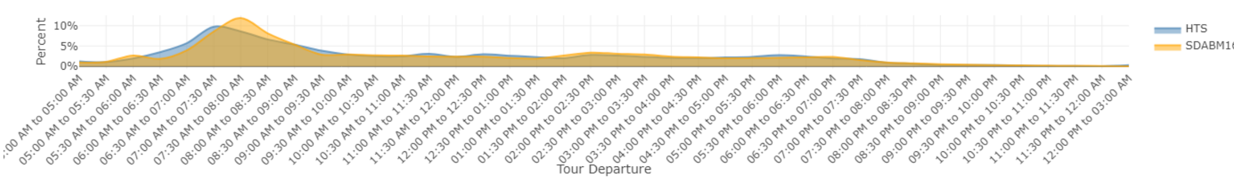


FIGURE 31: TOUR DEPARTURE PROFILE (30 MIN BINS)

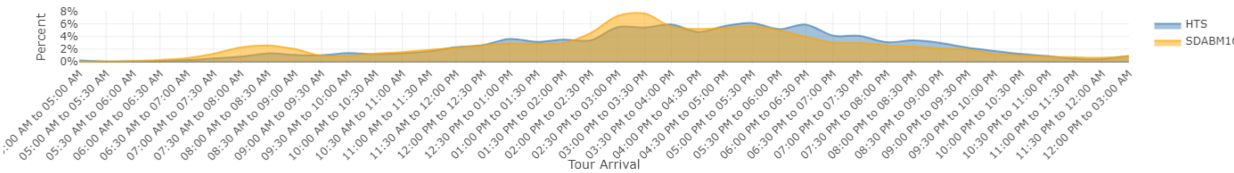


FIGURE 32: TOUR ARRIVAL PROFILE (30 MIN BINS)

A tour duration is calculated as a function of departure and arrival period. It includes travel time and time spent at the primary destination and all intermediate stops. A tour duration profile is constructed by dividing tour duration into half hour bins, where the first and last bin span multiple hours as explained above. As shown in Figure 33, the ABM generates a somewhat higher percentage of shorter tours than the HTS data. Otherwise, the ABM tour duration distribution generally follows the HTS.

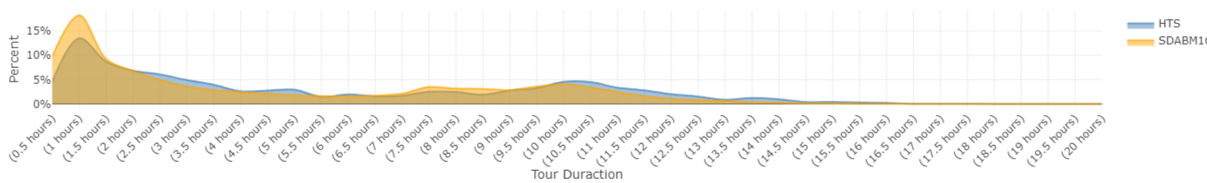


FIGURE 33: TOUR DURATION PROFILE (30 MIN BINS)

Comparison of the tour departure and arrival frequency distributions in five model time periods show that the ABM produce right number of tours departing within each skim time period. However, the distribution of tour arrivals indicates somewhat more tours arriving in the AM and MD period. This may be because of the increased number of school tours generated, and the school escort model predicting higher numbers of drop-offs of children at school than is shown in the observed data. Therefore, the arrival distribution was not calibrated to exactly match the observed distribution.

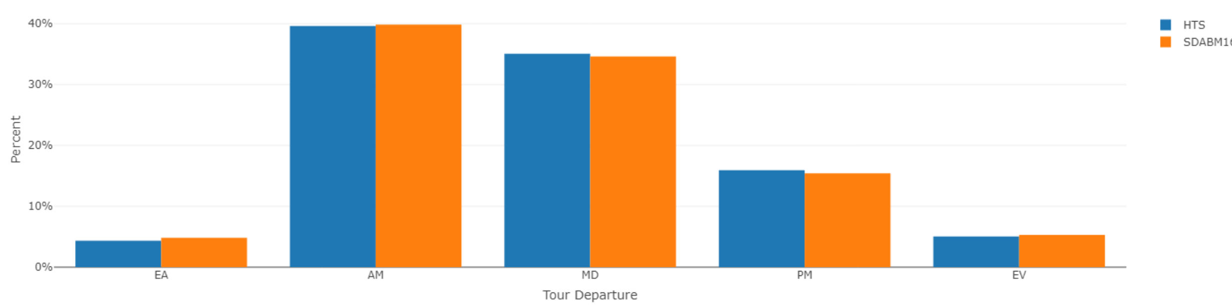


FIGURE 34: TOUR AGGREGATE DEPARTURE - TOTAL

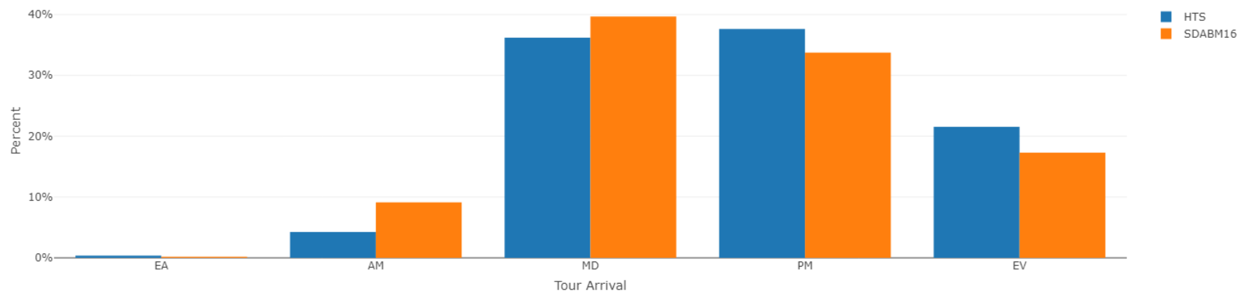


FIGURE 35: TOUR AGGREGATE ARRIVAL - TOTAL

Tour Mode

Tour mode is an abstract concept, defined as the main mode of travel used to get from the origin to the primary destination and back. The following 9 tour modes are available in the ABM: SOV, HOV2, HOV3, walk, bike/moped, walk-transit, PNR-transit, KNR-transit, and school bus. The tour mode is coded in the survey based on a set of rules that are dependent on the combination of trip modes used on the tour. The rules can be summarized as follows:

- Any tour with a transit trip is defined as a transit tour
    - Any transit tour with a PNR-transit trip is defined as a PNR-transit tour
    - Any transit tour with a KNR-transit trip is defined as a KNR-transit tour
    - Any transit tour with neither a PNR-transit trip or a KNR-transit trip is defined as a walk-transit tour
- Any tour with a bicycle trip is defined as a bicycle tour
- Any tour with an auto trip is defined as an auto tour
    - The highest occupancy mode of all auto trips on the tour is used to set the occupancy of the tour
- Remaining tours are walk tours

A similar set of rules is used in tour mode choice to constrain the availability of trip modes based on tour mode. These rules also influence the accessibilities used to choose the locations of intermediate stops on tours; for example, transit and walk accessibilities are used to choose stop locations on transit tours, rather than auto accessibilities.

The frequency of the tour mode is compared by household auto sufficiency and tour purpose. Auto sufficiency is defined as the availability of a vehicle to an adult member in the household. Three auto sufficiency categories are created based on number of autos and number of adults in the household: 0-auto, autos<adults, autos>=adults.

Note that during the tour mode choice calibration, the ABM tour mode choice structure is adjusted to address some special travel reported in the HTS. The original model did not allow SOV tours for individuals from 0-veh households, however, such SOV tours are available in the HTS data. Further investigation revealed that most of such travel in the survey are made using other household vehicles (people may have borrowed vehicle from parents, neighbor or friends) and only a small portion of the SOV trips from 0-vehicle households used rental cars or car share. This travel is represented in the ABM by allowing SOV tours for members of the 0-vehicle households and calibrating the corresponding constant to match the share (6%) in the HTS data.

After scaling the original HTS targets to accommodate transit targets from the transit on-board survey, the HTS targets are scaled one more time for tour mode calibration. Generally, a tour mode choice calibration aims to adjust the mode choice model so that the distribution of tours by mode is similar to observed share. Therefore, tour mode choice adjustments are made to alternative-specific constants to match observed mode shares. As transit tour targets are calculated directly from a transit on-board survey, the model needs to be calibrated to the same numbers. However, when calibrated using mode shares, the number of transit tours based on the share of transit mode in the HTS would result in a different number due to a different value of total tours in the ABM. For example, if a survey says that there are 100 transit tours among 10,000 total tours, then the transit share would be 1%. However, if the model is generating 12,000 total tours then calibrating the model to the survey transit share of 1% will result in 120 transit tours. Since we want to calibrate the model to match the absolute number of transit tours inferred from the on-board survey, we adjust observed tours by mode, keeping the transit tours constant but scaling other modes to match total tours in the model by purpose and auto sufficiency.

The summaries presented in this section include the final scaled calibration targets.

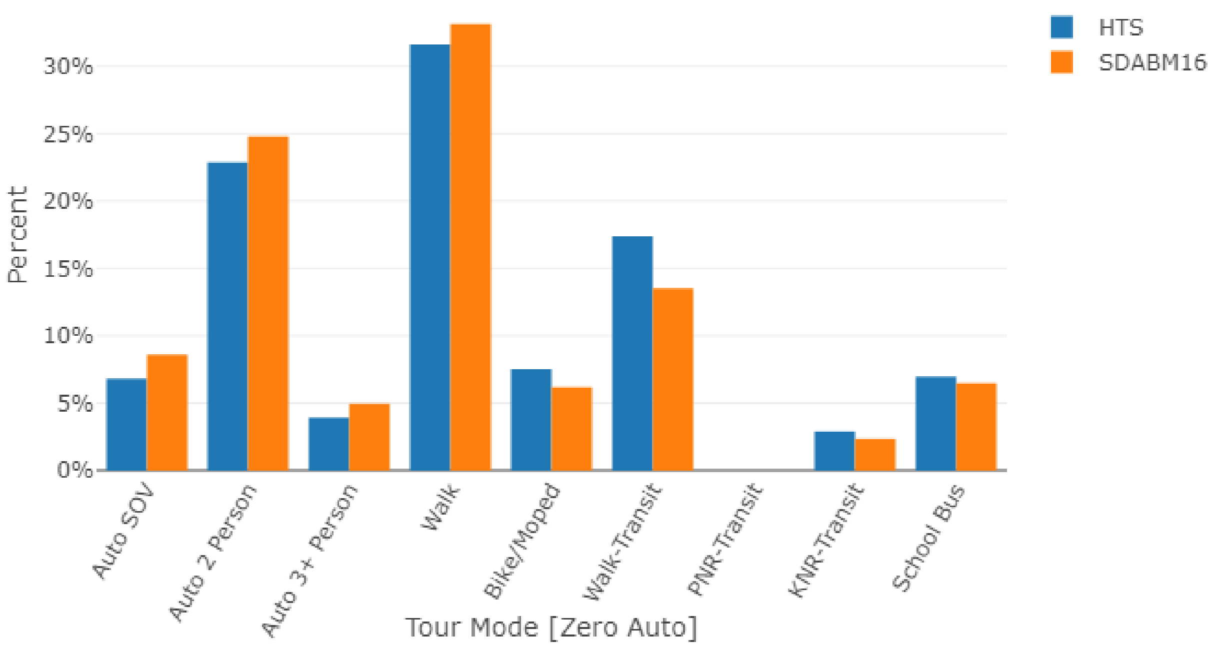


FIGURE 36: TOUR MODE – 0 AUTOS

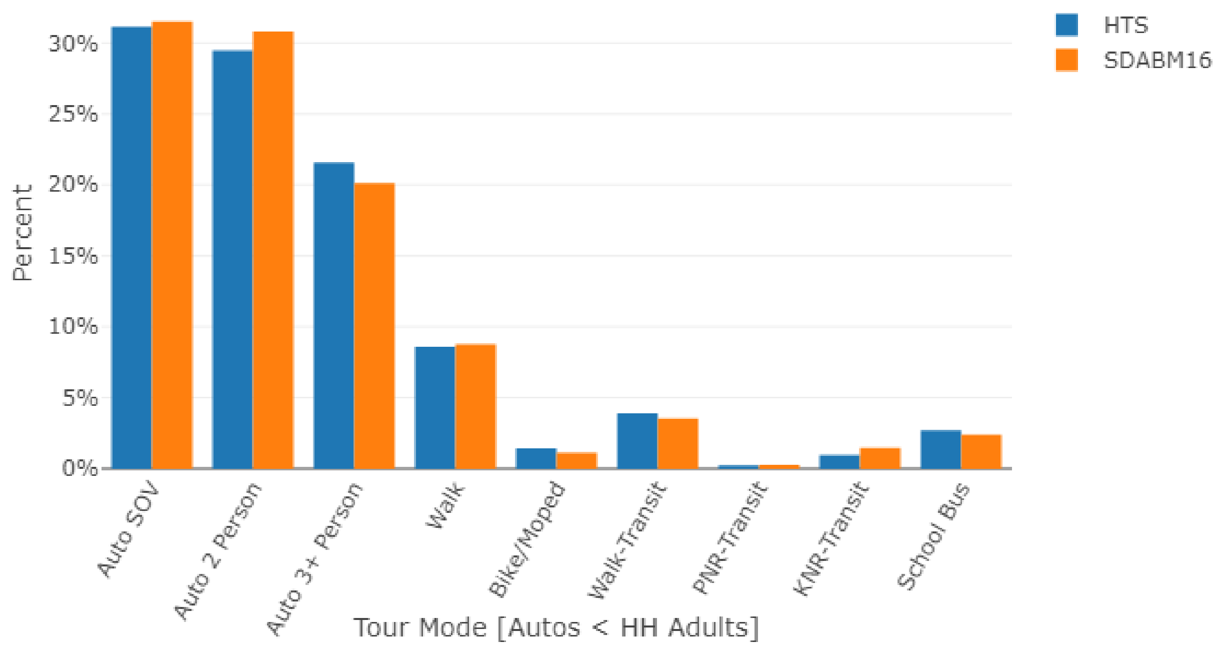


FIGURE 37: TOUR MODE – AUTOS < HH ADULTS

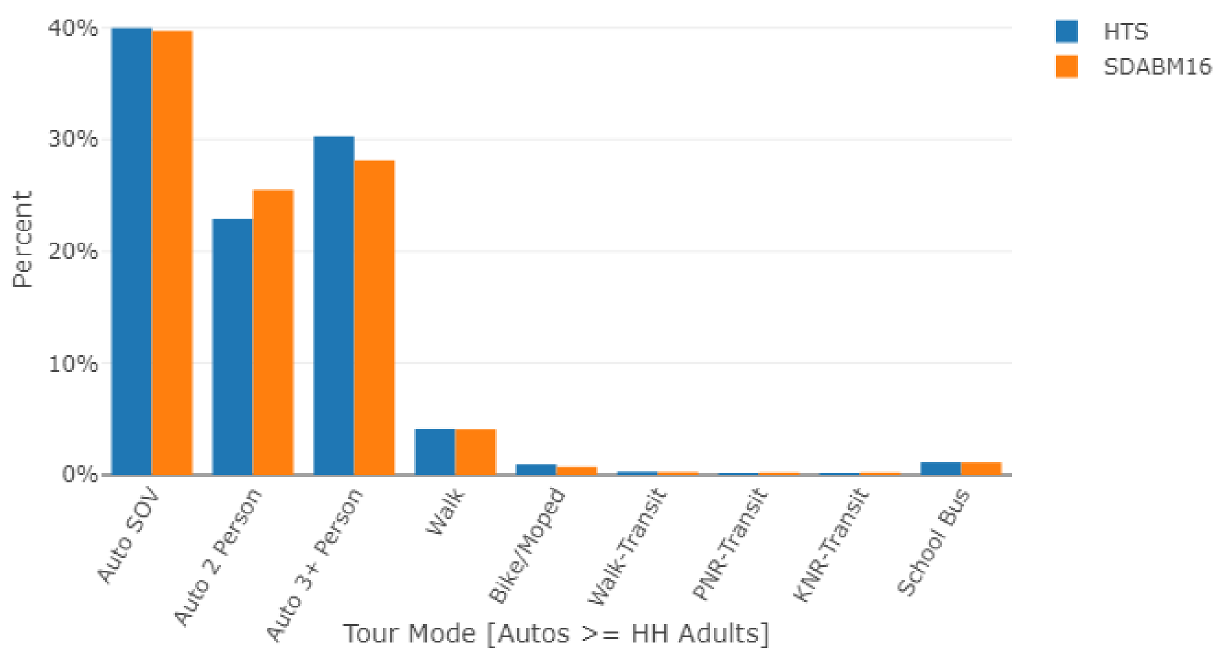


FIGURE 38: TOUR MODE – AUTOS >= HH ADULTS

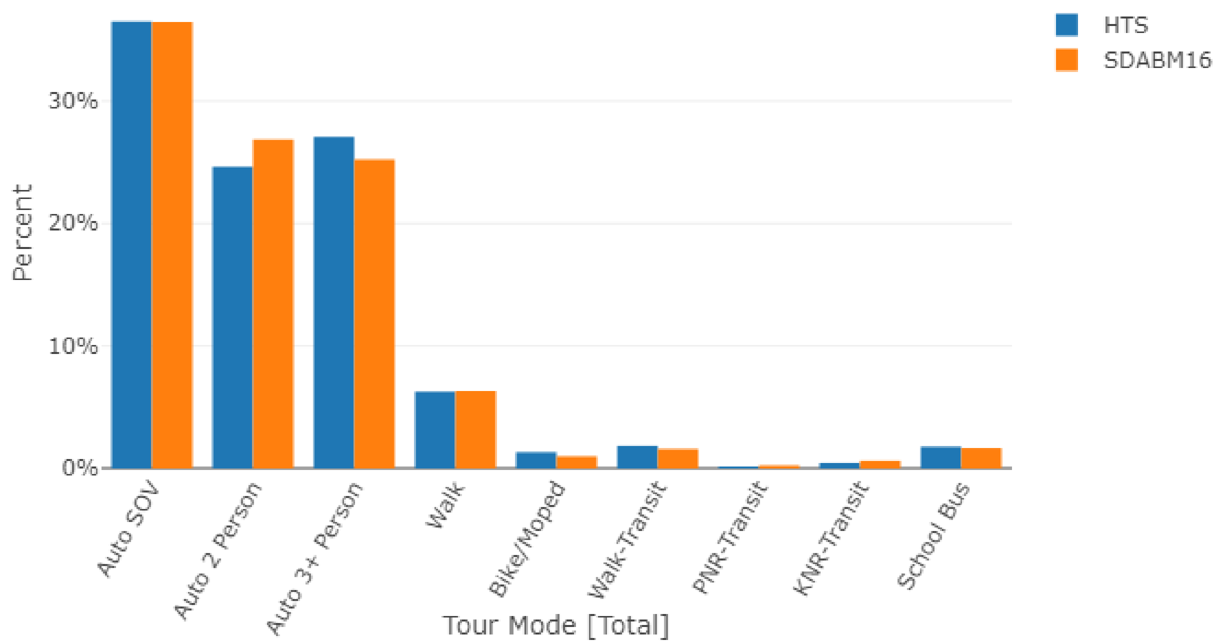


FIGURE 39: TOUR MODE – TOTAL

TABLE 18: TOUR MODE – TOTAL (HTS)

MODE	0 AUTO	AUTOS < ADULTS	AUTOS >= ADULTS	TOTAL	0 AUTO	AUTOS < ADULTS	AUTOS >= ADULTS	TOTAL
SOV	10,358	353,324	1,219,569	1,583,252	6.8%	31.1%	40.0%	36.5%
HOV2	34,836	334,265	699,865	1,068,966	22.9%	29.5%	22.9%	24.6%
HOV3	5,962	244,638	923,680	1,174,280	3.9%	21.6%	30.3%	27.1%
WALK	48,098	97,459	126,115	271,671	31.6%	8.6%	4.1%	6.3%
BIKE	11,439	16,278	28,758	56,475	7.5%	1.4%	0.9%	1.3%
WLK TRN	26,452	44,239	8,452	79,143	17.4%	3.9%	0.3%	1.8%
PNR TRN	0	2,717	4,541	7,258	0.0%	0.2%	0.1%	0.2%
KNR TRN	4,392	10,912	4,659	19,962	2.9%	1.0%	0.2%	0.5%
SCHBUS	10,588	30,611	34,920	76,119	7.0%	2.7%	1.1%	1.8%
Total	**152,125**	**1,134,442**	**3,050,559**	**4,337,126**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

TABLE 19: TOUR MODE – TOTAL (SDABM16)

MODE	0 AUTO	AUTOS < ADULTS	AUTOS >= ADULTS	TOTAL	0 AUTO	AUTOS < ADULTS	AUTOS >= ADULTS	TOTAL
SOV	13,046	357,448	1,211,672	1,582,166	8.6%	31.5%	39.7%	36.5%
HOV2	37,732	349,607	778,374	1,165,713	24.8%	30.8%	25.5%	26.9%
HOV3	7,542	228,215	858,628	1,094,385	5.0%	20.1%	28.1%	25.2%
WALK	50,430	99,595	124,705	274,730	33.2%	8.8%	4.1%	6.3%
BIKE	9,396	12,630	20,997	43,023	6.2%	1.1%	0.7%	1.0%
WLK TRN	20,553	40,118	8,029	68,700	13.5%	3.5%	0.3%	1.6%
PNR TRN	0	3,023	6,898	9,921	0.0%	0.3%	0.2%	0.2%
KNR TRN	3,566	16,607	6,705	26,878	2.3%	1.5%	0.2%	0.6%
SCHBUS	9,860	27,199	34,551	71,610	6.5%	2.4%	1.1%	1.7%
Total	**152,125**	**1,134,442**	**3,050,559**	**4,337,126**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Overall, the tour mode shares in the ABM match the HTS shares reasonably well (Figure 39). The comparison within the auto sufficiency categories is also similar, Figure 36, Figure 37, and Figure 38. As shown in Table 18 and Table 19, the HTS observed an overall tour mode share of 36.5% by drive-alone (SOV) and 24.6% and 27.1% by shared-ride 2 and shared-ride 3 respectively. 2.5% of the tours use some form of transit mode with the most (1.8%) use walk to transit. The non-motorized tour modes (walk and bike) make up for 7.6% of the tours in the region.

In addition to adjusting alternative-specific constants by mode, several distance-based and destination-based coefficients were adjusted in tour mode choice to better match transit trips to parking constrained areas (initially there were too few transit trips to downtown San Diego compared to the transit on-board survey). The final district level coefficients add 40 minutes and 80 minutes of benefit to transit tours with a primary destination in downtown San Diego for walk-transit and drive-transit tours respectively. These coefficients were also present in the initial model but their utility contribution was adjusted to better match observed data.

After calibration, it was also found that the model over-estimated short transit trips, according to both on-board survey comparisons and comparisons of passenger-miles of transit summarized from transit assignment results compared to SANDAG’s transit passenger count program. Distance coefficients were adjusted to better match the distribution of transit tours by access mode and distance. Figure 40, Figure 41, and Figure 42 show the comparisons of tour length by distance for walk-transit, PNR-transit, and KNR-transit tours respectively after calibration of the utility adjustment function. The utility functions penalize short walk-transit tours by adding a disutility for tours at 0 length equal to 200 minutes of disutility, with a slope of -133 per mile which results in no penalty at 1.5 miles. For example, the disutility for a walk-transit tour that is 0.5 miles would be (200 + -133 * 0.5 =) 133 minutes. At one mile, the disutility would be 67 minutes, and the penalty is 0 for tours of 1.5 mile length. The penalty for PNR-transit tours starts at 45 minutes of disutility and goes to 0 at 18 miles, where the penalty for KNR-transit tours starts at 50 minutes of disutility and goes to 0 at 10 miles.

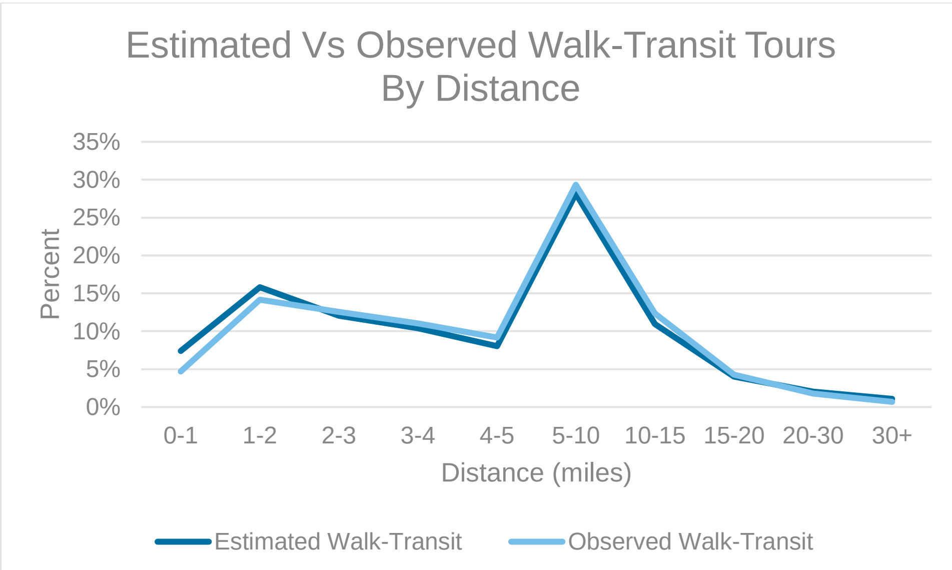


FIGURE 40: ESTIMATED VERSUS OBSERVED WALK-TRANSIT TOURS BY DISTANCE

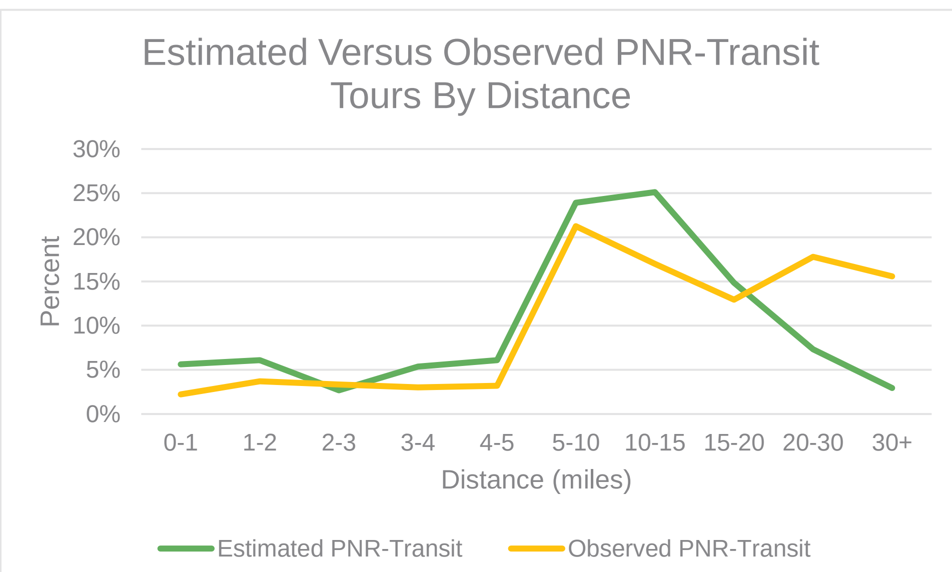


FIGURE 41: ESTIMATED VERSUS OBSERVED PNR-TRANSIT TOURS BY DISTANCE

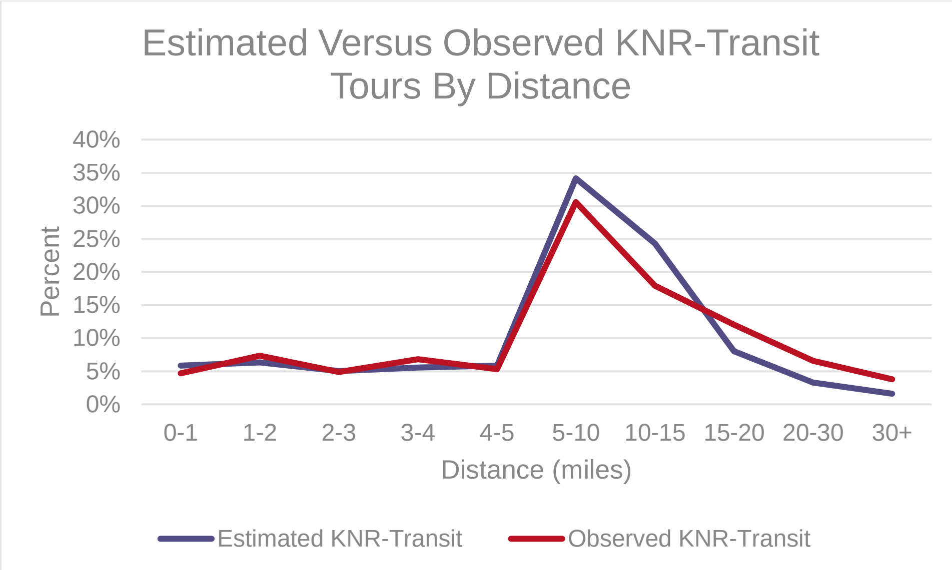


FIGURE 42: ESTIMATED VERSUS OBSERVED KNR-TRANSIT TOURS BY DISTANCE

Trip Level

After tours are generated, CT-RAMP models stops on tours; these are out-of-home activities that are made on a tour in addition to the primary destination. The final number of trips generated are function of the number of tours and the number of stops made on tours. Trip level summaries include stop frequency, stop purpose, stop time-of-day, stop location choice and trip mode choice. There are logit choice models for number of stops, stop location choice, and trip mode choice. Stop purpose and timing are determined using a Monte Carlo selection from lookup tables of probabilities constructed from HTS data.

Stop Frequency

The stop frequency model predicts the number of stops on each tour in both the outbound direction (from tour origin to tour destination) and inbound direction (returning to tour origin). Stop frequency models are segmented and results are summarized by tour purpose.

As described in 3.1 Model Calibration, the ABM in its present form allow a maximum of three intermediate stops in each direction (outbound or inbound) of a tour but the HTS contain significant tours with intermediate stops higher than three. To account for these missing stops in the ABM, the HTS targets are adjusted in such a way that equivalent number of stops from the tour frequencies sum up to the total number of stops regionwide.

Calibrating the ABM to these scaled targets result in more tours with higher number of stops (3plus) in each direction, Figure 43, and Figure 44.

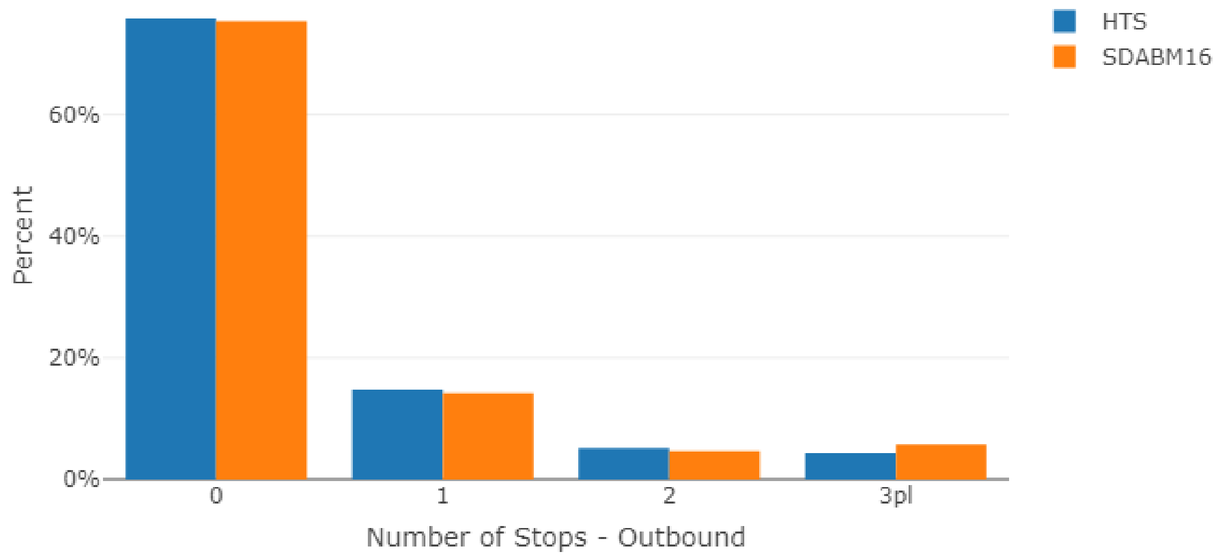


FIGURE 43: STOP FREQUENCY – OUTBOUND TOTAL

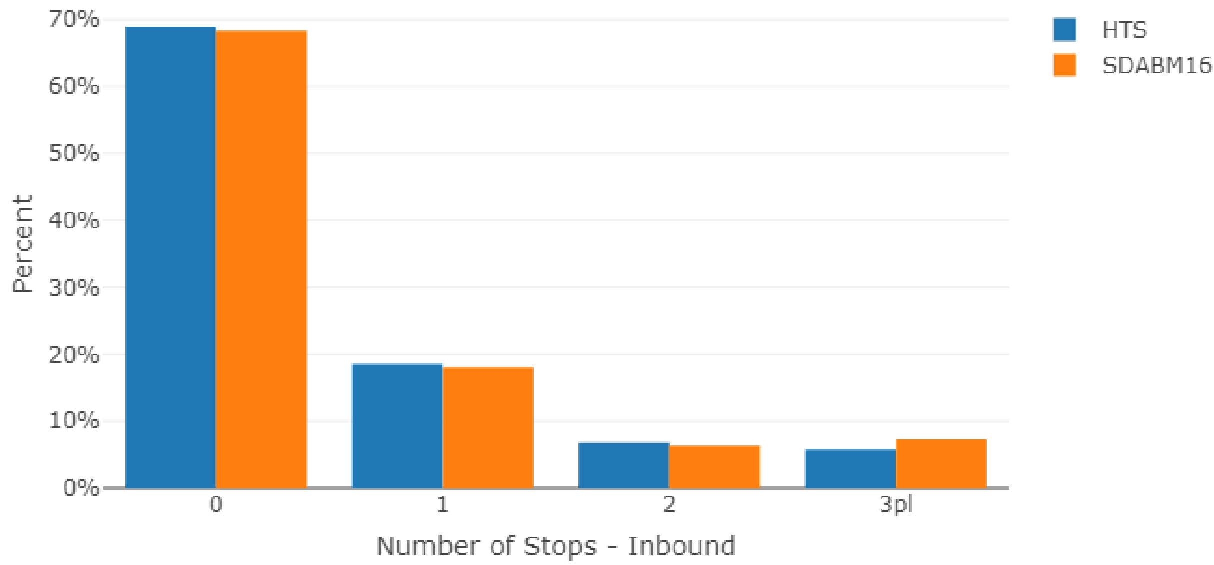


FIGURE 44: STOP FREQUENCY – INBOUND TOTAL

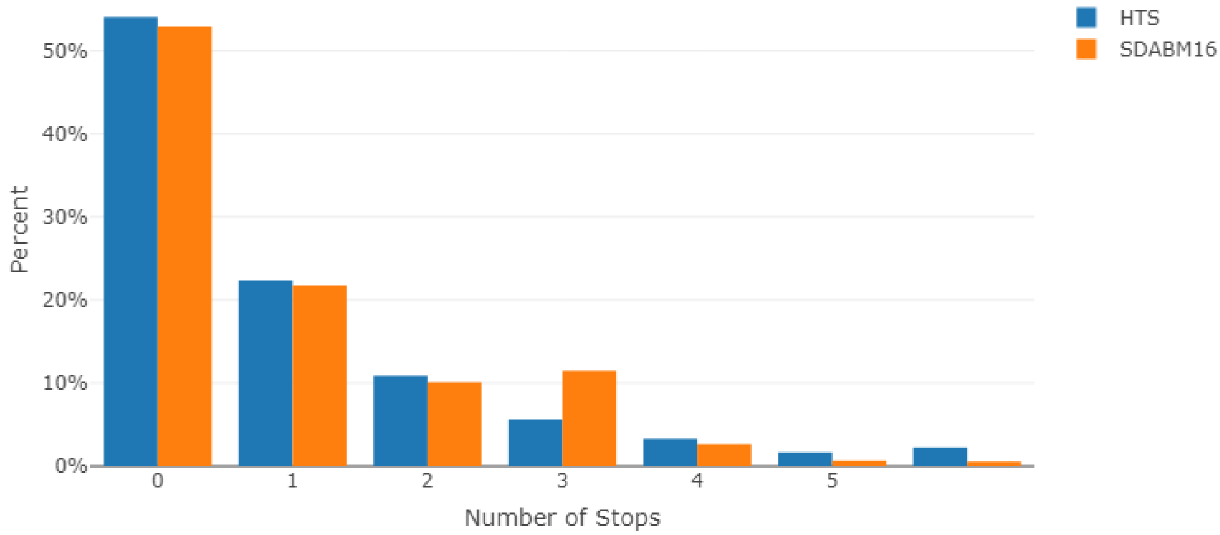


FIGURE 45: STOP FREQUENCY - TOTAL

Stop Location Choice

The stop location choice model predicts the stop location for each stop on the tour. If needed, the model can be calibrated to match the observed out of direction distance by tour purpose. Out of direction distance is defined as the extra distance to the destination as a result of traveling through the stop location. For stops in the outbound direction, it is based on the distance between the last known location (the tour origin or previous outbound stop) and the tour primary destination. For stops in the inbound direction, it is based on the distance between the last known location (the tour primary destination or previous inbound stop) and the tour origin. The out of direction distance is a measure of how far an individual is travelling to participate in intermediate stop activities.

Overall, the ABM distribution matches the HTS well, but results in intermediate stops that are somewhat longer than the HTS (Figure 46 and Table 82). Regionally, the ABM generate stops that results in an average out of distance of 4.3 miles compared to 3.1 miles in the HTS. In general, the average distance is higher for all purposes, with school and at-work stop distances being significantly higher. We did not calibrate this model to match the observed distribution perfectly because assignment results indicated an under-estimate of traffic. Decreasing intermediate stop trip length further would decrease goodness-of-fit of assignment results.

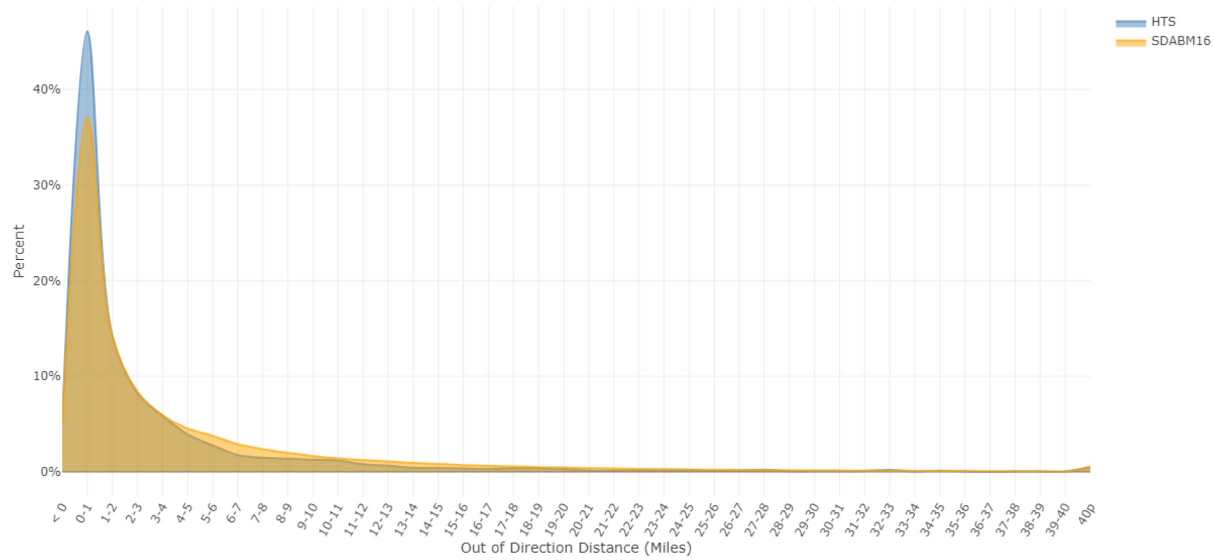


FIGURE 46: STOP LOCATION OUT OF DIRECTION DISTANCE - TOTAL

Time-of-Day Choice

The model currently implements departure time of a stop on the tour as a Monte Carlo choice of time period from distributions generated from survey data. The entire day is divided into 40 half-hour bins. The first bin includes 3:00 AM to 5:00 AM and the last bin includes 12:0 PM to 3:00 AM. Appendix B describes the process of creating stop departure time distribution from the HTS data.

The ABM is updated with new stop departure time distributions created from the HTS. As the ABM determine stop departures based on distribution from the survey data itself, the stop departure profile from the ABM output is likely to follow the survey stop departure profile. However, the ABM profile appear to differ, showing more stops in the morning (AM) period and fewer stops during the mid-day (MD) period, Figure 47, Figure 47, Figure 48, Figure 49, and Figure 50. This is because, also discussed in the daily activity pattern, the HTS exhibit significantly lower mandatory travel for full-time workers and this necessitated updating calibration targets to have increased mandatory travel for full-time workers. The ABM is calibrated to these boosted targets. However, the increased targets are not reflected in the survey stop departure profile, thus giving the impression of the ABM generating more stops departing in the AM peak period and less stops departing in the MD period. An analysis of traffic assignment results by period indicates that the model generally matches the diurnal distribution in the counts.

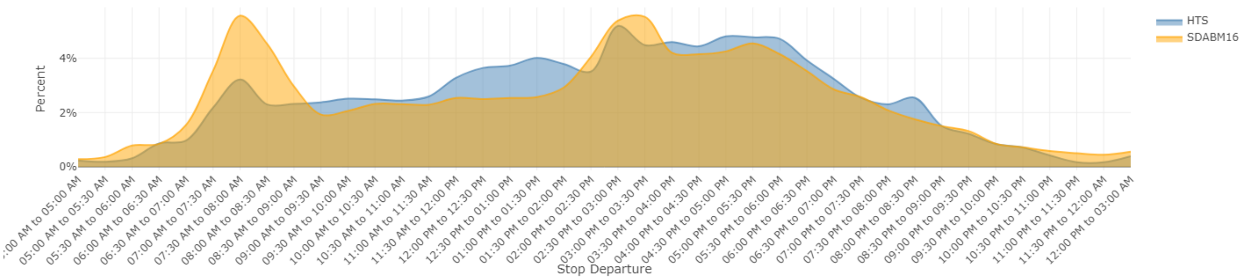


FIGURE 47: STOP DEPARTURE PROFILE (30 MIN BINS)

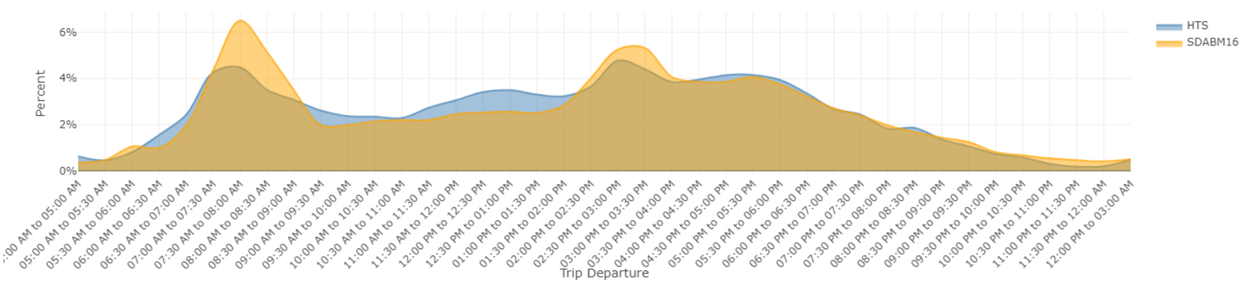


FIGURE 48: TRIP DEPARTURE PROFILE (30 MIN BINS)

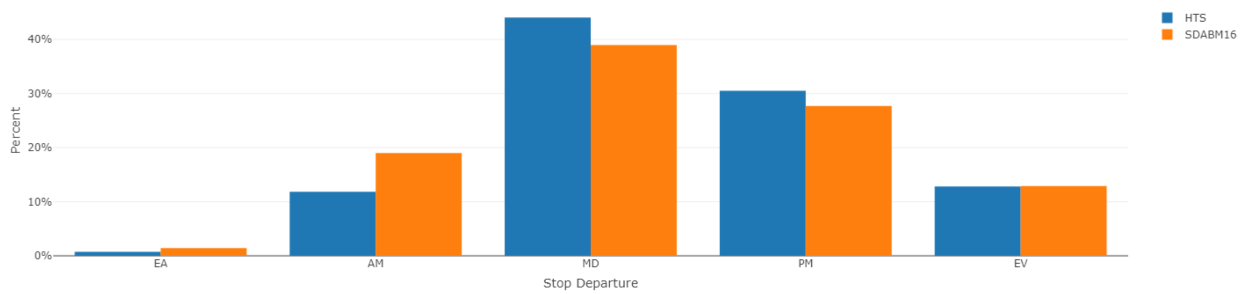


FIGURE 49: AGGREGATE STOP DEPARTURE (MODEL TIME PERIODS)

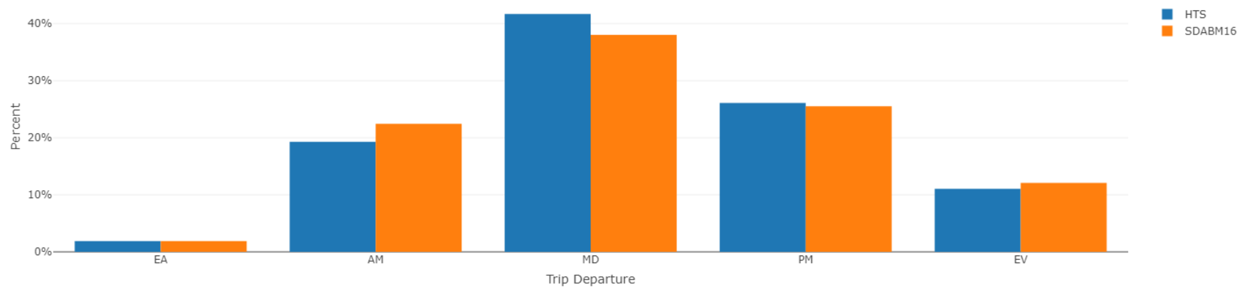


FIGURE 50: AGGREGATE TRIP DEPARTURE (MODEL TIME PERIODS)

Trip Mode Choice

Trip mode targets are prepared from the HTS data and updated with transit trip targets from the transit on-board survey. Other mode targets are appropriately scaled to keep the total trips by purpose the same, similar to the process described above for creation of tour mode choice targets. This ensures that the absolute number of expanded transit trips from the transit on-board survey is matched in calibration.

The calibration process involved adjustment of alternative-specific constants to match observed trips by trip mode and tour mode within each tour purpose. The trip mode choice model can be thought of as a 'mode switching' model, in which the tour mode constrains which modes are available for trips on tours. Overall, the ABM generates a trip mode distribution which is very similar to observed (Figure 51, Table 20, and Table 21). Both datasets indicate that on an average weekday, 47% trips in the region are drive alone and 42% are shared-ride (SR2 and SR3), approximately 1.6% of San Diego County resident trips are made by transit, and 8% are made by a non-motorized mode (walk or bike).

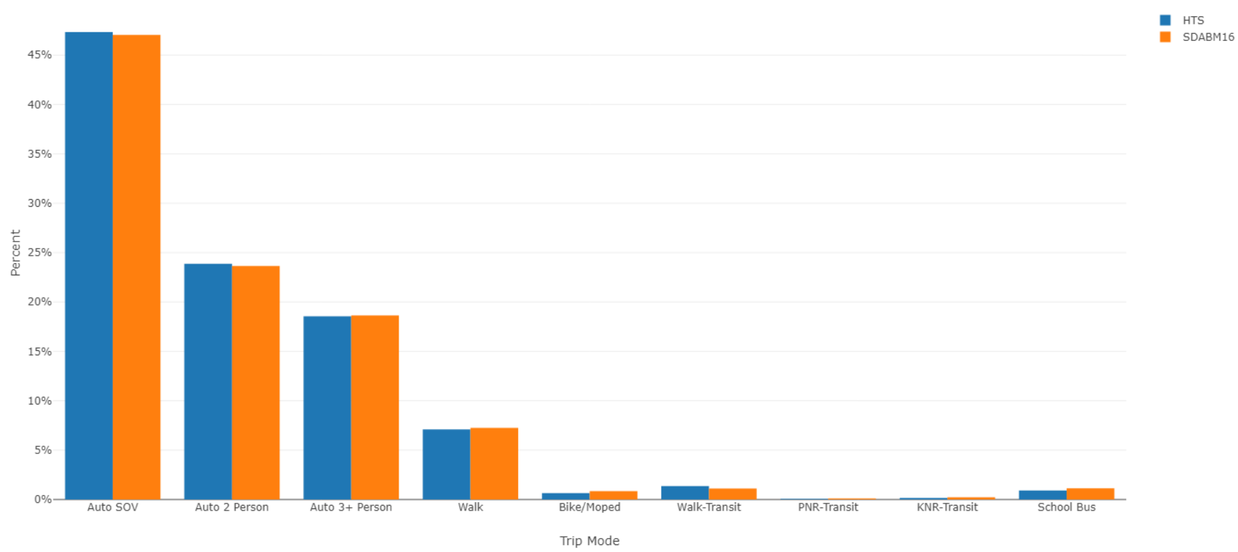


FIGURE 51: TRIP MODE – TOTAL

TABLE 20: TRIP MODE CHOICE – TOTAL (HTS)

TRIP MODE	SOV	HOV2	HOV3	WALK	BIKE	WLK TRN	PNR TRN	KNR TRN	SCHBUS	TOTAL
SOV	100.0%	24.3%	9.9%	0.0%	11.1%	0.0%	17.9%	0.0%	0.5%	47.3%
HOV2	0.0%	72.5%	17.2%	0.0%	8.0%	2.3%	21.6%	23.8%	6.1%	23.9%
HOV3	0.0%	0.2%	70.7%	0.0%	1.9%	0.7%	7.5%	11.4%	12.8%	18.6%
WALK	0.0%	3.0%	2.2%	100.0%	2.9%	7.2%	7.2%	18.2%	0.2%	7.1%
BIKE	0.0%	0.0%	0.0%	0.0%	76.1%	0.1%	0.5%	0.0%	0.0%	0.6%
WLK TRN	0.0%	0.0%	0.0%	0.0%	0.0%	89.3%	10.5%	16.2%	0.0%	1.4%
PNR TRN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	34.7%	0.0%	0.0%	0.1%
KNR TRN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	30.3%	0.0%	0.2%
SCHBUS	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	80.5%	0.9%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

TABLE 21: TRIP MODE CHOICE – TOTAL (SDABM16)

TRIP MODE	SOV	HOV2	HOV3	WALK	BIKE	WLK TRN	PNR TRN	KNR TRN	SCHBUS	TOTAL
SOV	100.0%	23.7%	9.8%	0.0%	0.0%	0.0%	13.2%	0.0%	0.0%	47.0%
HOV2	0.0%	72.1%	17.1%	0.0%	0.0%	5.4%	13.7%	29.3%	0.0%	23.6%
HOV3	0.0%	1.0%	70.7%	0.0%	0.0%	2.2%	8.0%	12.7%	0.0%	18.6%
WALK	0.0%	3.3%	2.4%	100.0%	0.0%	16.7%	4.0%	7.3%	0.0%	7.2%
BIKE	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.8%
WLK TRN	0.0%	0.0%	0.0%	0.0%	0.0%	75.7%	6.0%	9.6%	0.0%	1.1%
PNR TRN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	55.1%	0.0%	0.0%	0.1%
KNR TRN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	41.2%	0.0%	0.2%
SCHBUS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	1.1%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Transit Best Path Calculator

The transit best path calculator is used to find and rank the all available transit paths for a given origin, destination, time period, and access/egress mode. The best transit path utility equations are used to rank the available transit paths and calculate a transit logsum for use in trip and tour mode choice models across the best paths. If transit is selected as the chosen trip mode, the best transit path utilities for the chosen access/egress mode are input to a logit choice model from which the boarding and alighting TAP is chosen for the trip. The transit best path calculator is used by all model components including the resident CT-RAMP model, the internal-external model, the overnight visitor model, the Mexican resident travel model, the San Diego Airport model and the Cross-Border express model. Therefore, the ability of the transit best path calculator to appropriately rank transit paths based on their utility is fundamental to the ability of the model to replicate the characteristics of transit trips observed in the on-board survey.

A number of adjustments were made to the best transit path utility calculations to improve the goodness-of-fit between the chosen boarding and alighting TAP pair and observed transit trips. First, it was clear from initial model runs that the number of transit boardings per trip was too high. Initial runs resulted in a boarding rate (boardings/trips) of 2.0 or more, whereas the transit on-board survey suggests a transit boarding rate of 1.2. The low transfer rate observed in the on-board survey suggests that transit travelers in San Diego County are very transfer-averse. This could be partly due to the fare policy in which the passenger must pay for each transit boarding unless using a transit pass (no transfer tickets are given). It may also be due to increased competition from Transportation Networking Companies and the increased availability of flex-car options.

A set of transfer penalties was introduced into the best transit path calculator to reduce the rate of transfers in the model. The transfer penalties are formulated as a continuous function of transfers (transfers is a continuous variable due to the use of a stochastic path-builder in EMME). There are different transfer penalties for walk-transit versus drive-transit, as shown in Figure 52. The transfer penalty function results in a good match of estimated to observed transfers (Figure 53, Figure 54, and Figure 55).

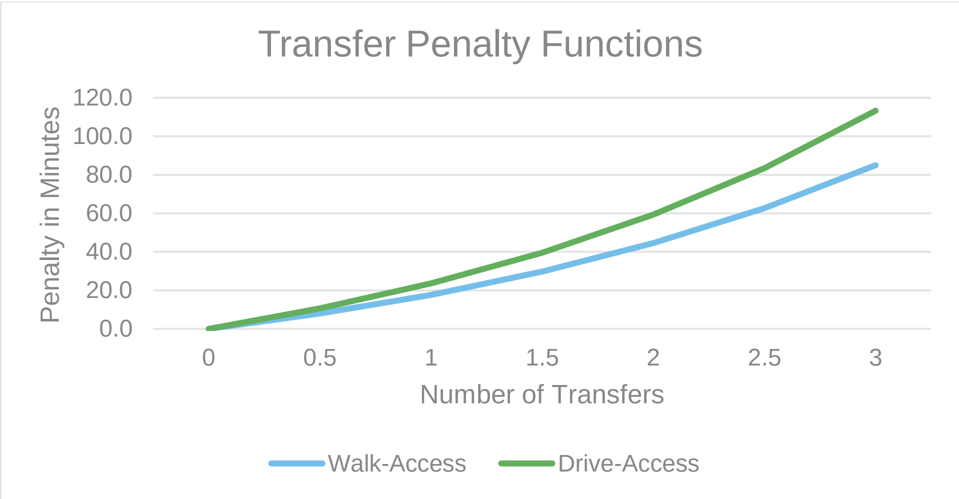


FIGURE 52: TRANSIT TRANSFER PENALTY FUNCTION

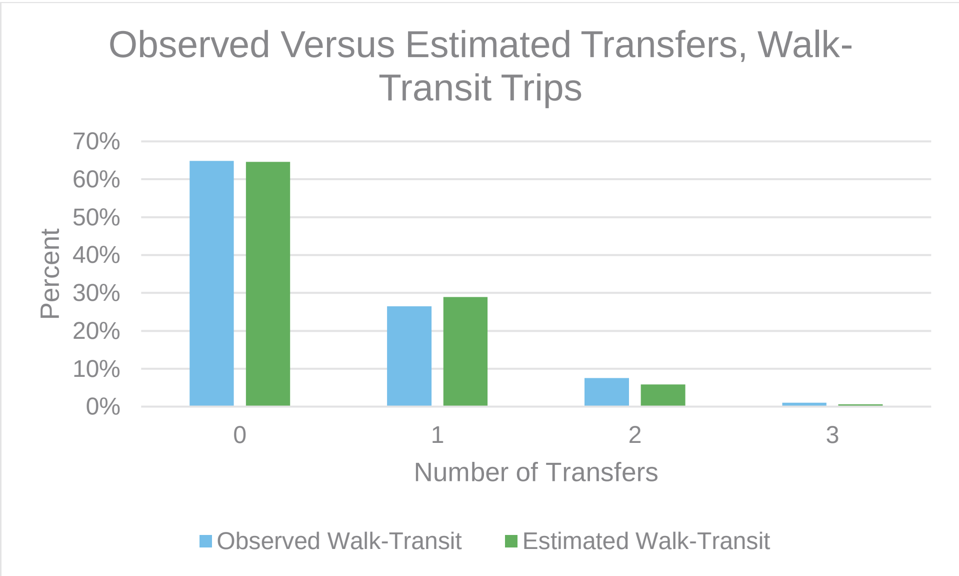


FIGURE 53: OBSERVED VERSUS ESTIMATED WALK-TRANSIT TRIPS BY NUMBER OF TRANSFERS

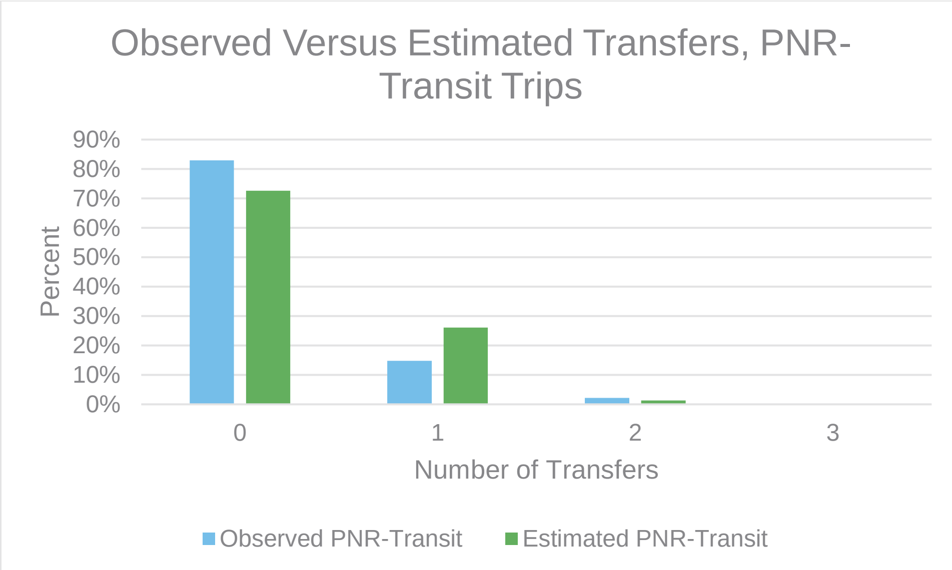


FIGURE 54: OBSERVED VERSUS ESTIMATED PNR-TRANSIT TRIPS BY NUMBER OF TRANSFERS

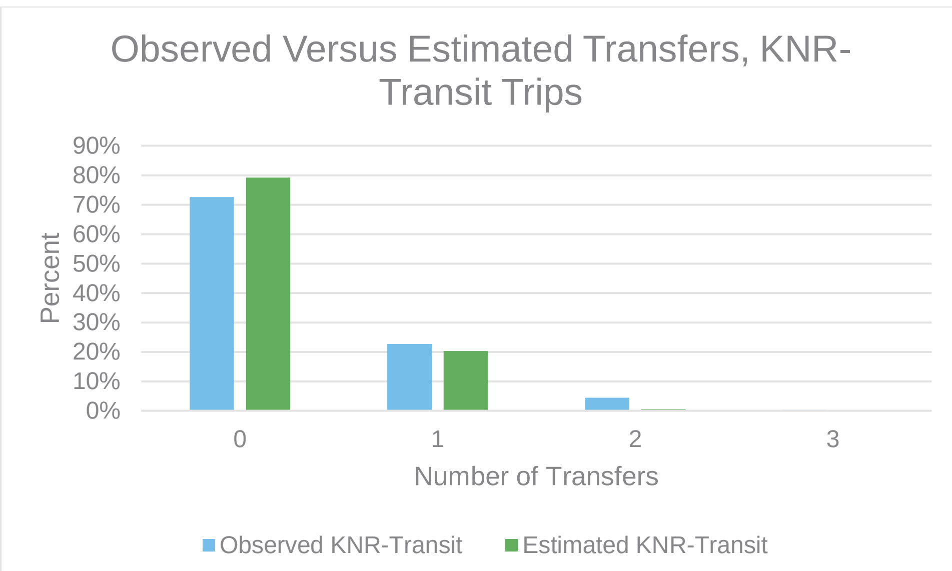


FIGURE 55: OBSERVED VERSUS ESTIMATED KNR-TRANSIT TRIPS BY NUMBER OF TRANSFERS

Generally, transit passengers are familiar with transit lines and park-and-ride lots close to home, and less familiar as distance to home increases. Transit passengers tend to select initial boarding locations close to home, and would tend to drive a short distance compared to the overall origin-destination distance. A common issue in modeling drive-transit is the ability of the model to understand the disutility of driving a long way from home. A common way to address this issue is to introduce a term in the model that measures the ratio of the drive distance to the overall trip distance. This term (shown in Figure 56) was added to the SANDAG model in calibration to improve goodness-of-fit. It is applied to boarding (or alighting) locations that are more than 30% of the distance from home compared to the OD distance. The results of the calibration are shown in Figure 57.

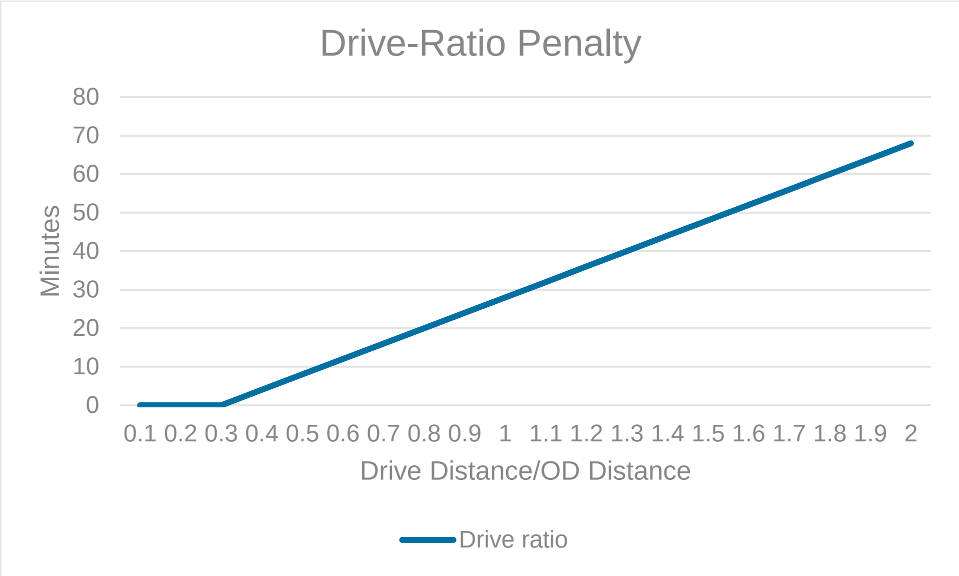


FIGURE 56: DRIVE RATIO PENALTY

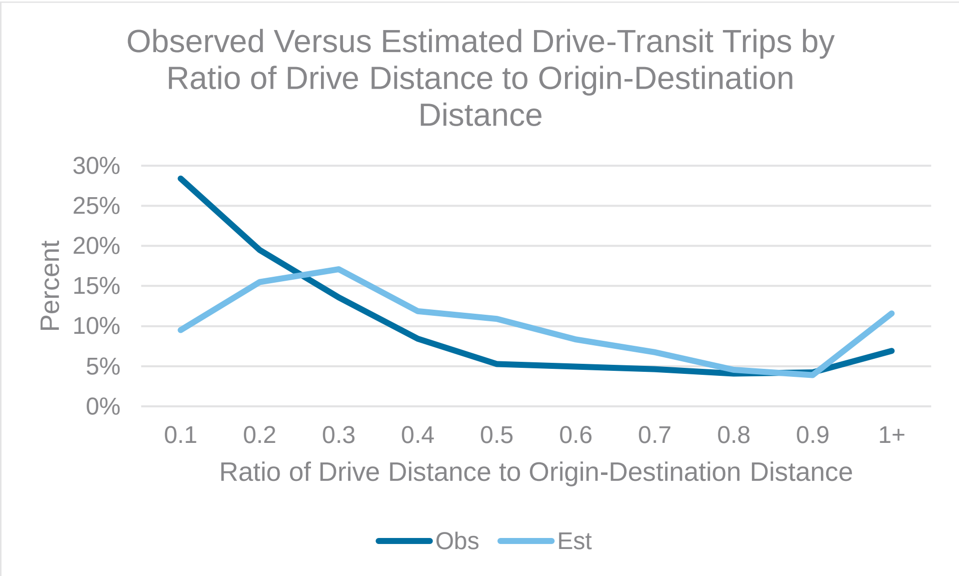


FIGURE 57: OBSERVED VERSUS ESTIMATED DRIVE-TRANSIT TRIPS BY DRIVE ACCESS RATIO

In order to match transit trips by transit technology (bus, bus rapid transit, light-rail, and commuter rail), a set of transit technology constants are calibrated. The final constants (compared to local bus) are worth 10 minutes of benefit for bus rapid transit and 17 minutes for light-rail transit. The initial application of the parameters distorted the number of transfers. Thus they are adjusted such that if there are required transfers on the transit path, 1/3 of the constant benefit is applied.

Commuter rail ridership was particularly difficult to match and required significant analysis and experimentation. The analysis included tracing transit paths and utilities for specific records in the on-board survey data in an attempt to determine why the model under-estimated observed commuter rail ridership (approximately 5k boardings on Coaster as shown below). The tracing of transit records led to some adjustments in path-finding parameters used in EMME, including the introduction of timed transfers for commuter rail stations, a revised first wait and transfer wait time function, and a longer walk-access/egress distance than previously allowed. However, these changes only partially improved assignment results on commuter rail. Next, the best transit path commuter rail constants by access mode were calibrated to better match ridership. However, this resulted in a significant distortion of commuter rail trips by trip length. Ultimately a set of commuter rail constants (Figure 58) were introduced that vary by time spent on commuter rail. If commuter rail service is modified in the future, the constants should be re-evaluated, or converted to a distance-based function.

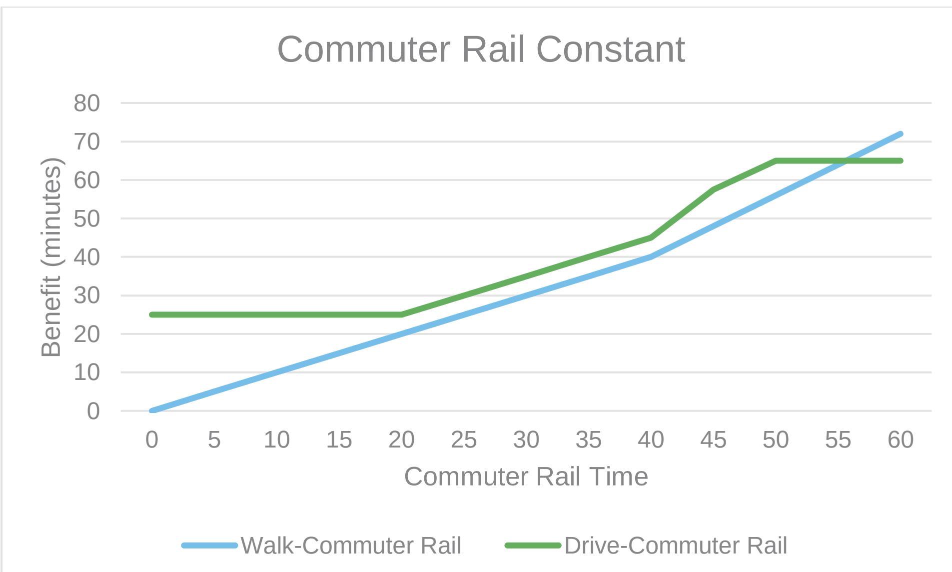


FIGURE 58: COMMUTER RAIL CONSTANTS

4.3 SPECIAL MARKET MODELS

This section describes adjustments made to special market models, including the Mexican resident travel model, the internal-external travel model, the overnight visitor travel model, and the San Diego airport travel model.

Cross-border Model

The cross-border model predicts travel made by Mexican residents in and out of the San Diego county. The US-Mexico border currently has three active port of entry/exit (POE): San Ysidro, Otay mesa, and Tecate. Two more POEs, Otay Mesa East (OME) and Jacumba, are planned to open in 2025 and 2040 respectively.

SANDAG maintains a border crossing/entry database using data sources from Customs and Border Protection, U.S. Dept of Homeland Security. The database provided 2016 northbound crossings by port of entry and crossing mode. The northbound crossings made by Mexican residents were derived using the share from the 2010-2011 SANDAG cross border survey - 81% of the total north bound crossings. The distribution of crossing by purpose in the 2012 cross -border model informed the calibration target for the 2016. The model calibration adjusted alternative-specific constants for POEs in destination choice and for purpose in tour mode choice.

The calibrated model shows a good match of crossings by POE, mode, and purpose with the observed targets – see Figure 59, Figure 60, and Figure 61.

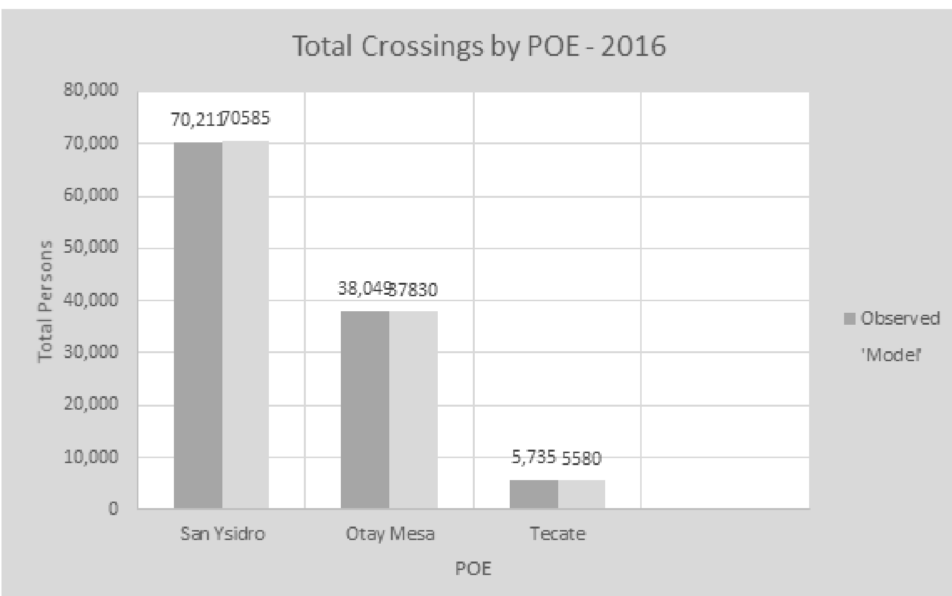


FIGURE 59: NORTHBOUND MEXICAN RESIDENT CROSSINGS BY POIINT OF ENTRY AT THE US-MEXICO BORDER

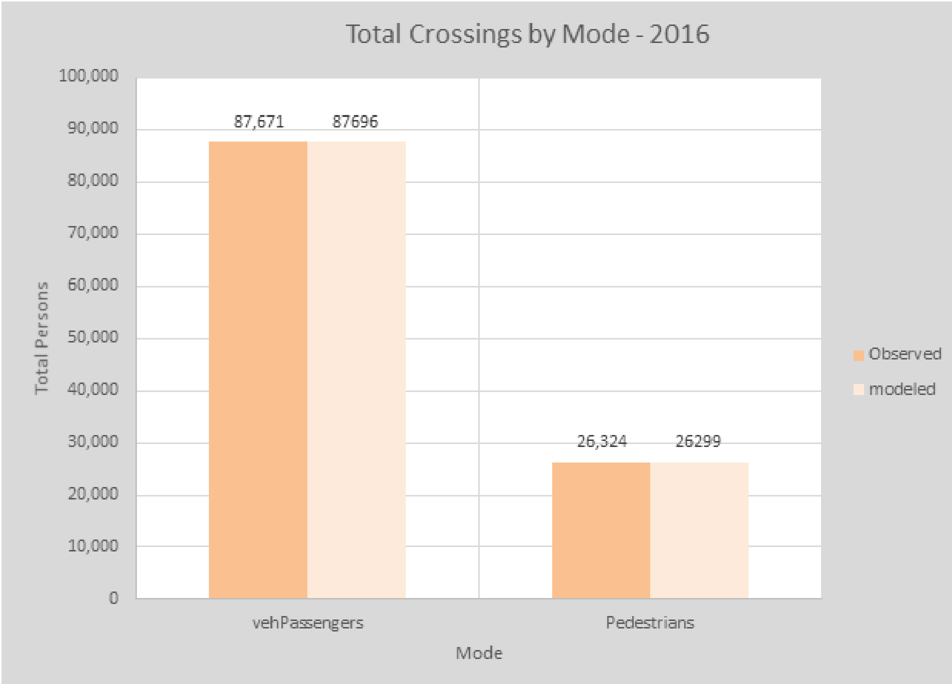


FIGURE 60: NORTHBOUND MEXICAN RESIDENT CROSSINGS BY MODE AT THE US-MEXICO BORDER

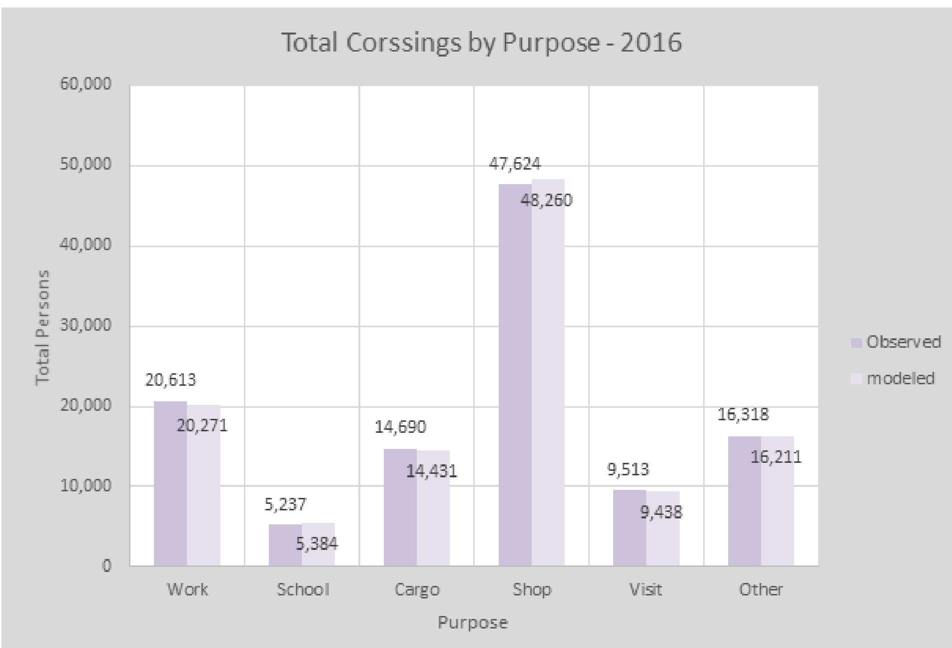


FIGURE 61: NORTHBOUND MEXICAN RESIDENT CROSSINGS BY PURPOSE AT THE US-MEXICO BORDER

External Model

SANDAG staff updated the external to internal trip input file[17] using 2006-2010 Census Residence to Workplace flows data[18]. The trip file specifies trips by purpose (work and non-work) and external station. The following assumptions were made in updating the input file:

- Residents of Riverside, San Bernardino, Kern, and Ventura Counties use the I-15 cordon
- Residents of Orange, Los Angeles, and Ventura Counties use the I-5 cordon
- A telework rate of 12% (7% work from home and 5% occasional telework) applied to the Census data

However, a comparison of VMTs before and after the update showed only minor differences.

San Diego Airport Model

The San Diego Airport air passenger ground access model was adjusted to match observed on-board survey trips (approximately 450).

Visitor Model

The visitor model was adjusted to match observed on-board survey transit trips (approximately 4,000).

[17] externalInternalControlTotalsByYear.csv
[18] https://www.census.gov/data/tables/2010/demo/metro-micro/commuting-employment-2010.html

5.0 MODEL VALIDATION

A model validation tests the model's predictive capabilities before it is used to produce forecasts. There are two types of model validation; static validation, which compares model outputs against independent data that was not used to build the travel model, and dynamic validation, in which model inputs are systematically varied to assess the reasonableness of model responses. The static validation process compares outputs from model assignment with observed data. Model parameters are adjusted until the model outputs fall within an acceptable range of error.

In the assignment step, model demand (e.g. trips by time period, mode, and vehicle class\value-of-time) are loaded on to network. In highway assignment, the output includes vehicle flows on every link (road) in the highway network and for transit assignment, the output includes the number of boardings on each route. These are compared to observed traffic counts and observed transit ridership respectively. The two observed datasets (traffic counts and transit boardings) used in the present model validation are described in Chapter 3.0 Data.

The remaining of this chapter presents and discusses validation summaries for the highway and the transit system in the San Diego region. The two transportation systems are discussed separately.

5.1 HIGHWAY

As recommended by the FHWA and Caltrans, this report calculates the following four validation criteria to compare estimated traffic flows with the observed traffic counts:

1. **Gap** - difference between estimated flow and observed traffic count divided by the observed traffic count. It provides a general context for the relationship (i.e. high or low) between model flows and counts.
2. **Percent of links with volume-to-count (gap) within Caltrans deviation allowance**
3. **Correlation coefficient or R-squared** - estimates the correlation (strength and direction of the linear relationship) between the traffic count and the estimated traffic flow from the model. R-squared is square of the correlation coefficient. It is a statistical measure of how close the data are to the fitted regression line. R-squared is always between 0 and 1; a value of 0 indicates that the model explains none of the variability of the response data around its mean and a value of 1 indicates that the model explains all the variability of the response data around its mean.
4. **Percent root-mean squared error (PRMSE)** - square root of the estimated flow minus the observed traffic count squared divided by the number of traffic counts. It measures of accuracy of the entire model, representing the average error between observed and estimated traffic flow on a link.

The FHWA also specify thresholds for the above measures (except gap). The recommended thresholds are presented in Table 22.

TABLE 22: VALIDATION GUIDELINES

VALIDATION MEASURE	THRESHOLD
Percent of links with volume-to-count within Caltrans deviation allowance (Caltrans)	>=75%
Correlation coefficient (FHWA)	>=0.88
PRMSE (FHWA)	<40%

*Source: The Travel Model Validation and Reasonableness Checking Manual, II Second Edition, September 2010.

The subsequent sections discuss highway validation by:

- Region
- Road class
- Volume group
- PMSA
- Key freeway corridors
- RMSE comparison

Region

As described in Chapter 3.0 Data, the observed traffic count database used in this model validation effort encompass 2,251 links on the highway network. As presented in Table 23, the total real traffic across these links sum up to 67.6 million vehicles. On the same links, the ABM produce a comparable estimate of traffic volume (66.8 million vehicles) and is only 1.2% lower than the total observed vehicle count. According to the HPMS[19], on an average weekday in year 2016, the roadway travel in the San Diego region resulted in 83.76 million vehicle miles of travel (VMT). The estimated traffic flows from the ABM produce a daily regionwide VMT value of within 0.4% of the observed estimate from the HPMS.

Table 23: Highway Validation - Region

MEASURE	OBSERVED	SDABM16	DIFF	% DIFF
Traffic Volume	67,561,805	66,775,789	(786,016)	-1.2%
VMT*	83,763,007	83,397,515	(365,492)	-0.4%

Note: Observed VMT is from the HPMS estimate of the total VMT in the San Diego region for year 2016

[19] Highway Performance Monitoring System

A scatter plot in Figure 62 compares the estimated traffic flows with the observed traffic counts regionally. Points in the scatter plot are links where traffic counts are available. A point represents observed traffic count on the X-axis and the corresponding estimated flow on the Y-axis. The scatter plot includes several measures/guidelines assessing accuracy of the model flows with respect to the observed traffic counts.

First, the plot includes a 45-degree line representing a virtual scenario of perfect match between traffic counts and estimated flows. The 45-degree line is useful in quickly identifying overestimation (flow>count) or underestimation (flow<count) of a flow. A highway validation aims to make most points as close to this line as possible. An ideal validation would have all count locations on the 45-degree line. However, perfect match for all count locations is almost impossible to achieve due to various reasons such as error in traffic counts, simulation errors in the model etc. Acknowledging this fact, Caltrans rather provides recommendations on maximum (high and low) deviations of an estimation flow from the corresponding traffic count value. The scatter plot displays these Caltrans high and low deviations as dotted lines above and below the 45-degree line respectively. Lastly, a linear regressed line of all points is also added to the plot. Slope of the regressed line measures regional match between the estimated flows and the traffic counts - a slope of less than 1 means underestimation regionwide and more than 1 indicates overestimation. The plot also displays a R-squared value representing goodness of fit of all data points.

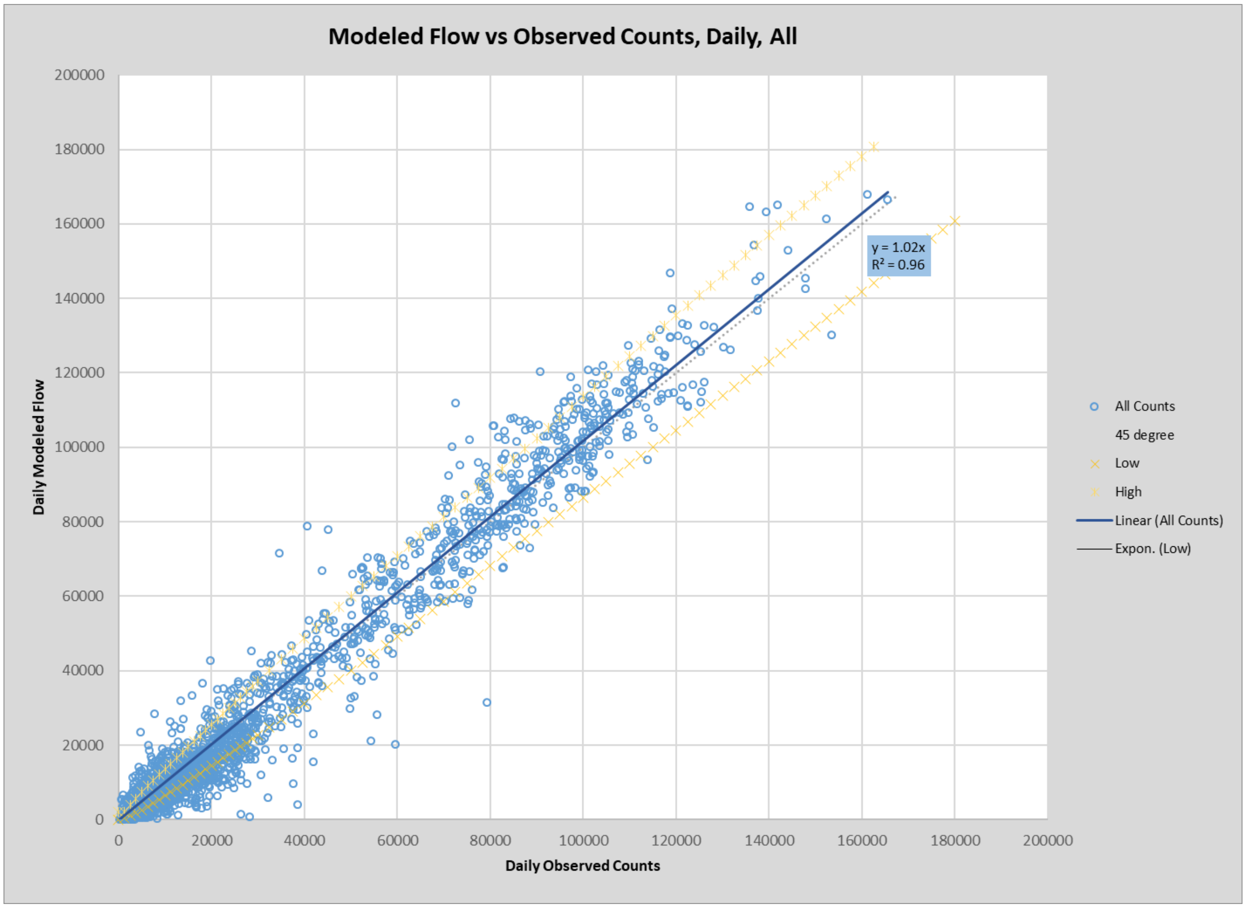


FIGURE 62: DAILY ESTIMATED FLOWS VS OBSERVED COUNTS – REGION

As displayed in the scatter plot, Figure 62, the linear regressed line has a slope of 1.02 and R-squared value of 0.96. The slope indicates a good balance of links with underestimation and overestimation. The r-squared value is close to 1.0 indicating that the fitted regressed line represents the data well.

Note that the model validation necessitated boosting of the commercial vehicle demand in the model system. The increase in the commercial vehicle demand was needed to achieve the same validation level as the previous version of the ABM. After exhausting the scope of increase in travel in the resident and other special market models, the lack of travel in the region was discovered to be caused by low CVM demand in the new ABM. The current version of the ABM has a new disaggregate commercial vehicle model (CVM) and the previous CVM validation effort[20] observed that the new disaggregated model generates significantly lower levels of commercial vehicle travel compared to the aggregated model used in earlier versions of the ABM and relatively low VMT for light commercial vehicle travel compared to other regions. This resulted in an under-estimate of overall VMT previously, and this relationship was also found in early model runs of ABM2, though not as significant as previous under-estimates due to the higher rate of travel in the resident models as a result of calibrating to the new HTS

[20] See *Activity-Based Model and Commercial Vehicle Model Validation Report*, dated October 31, 2016

data. Further, the proliferation of TNCs, internet shopping, and for-hire services such as food delivery suggests that the CVM may need to be updated based on emerging trends that did not exist when the CVM survey data was collected. The light truck commercial vehicle demand in the mid-day period is increased by a factor of 2.0, boosting the share of CVM VMT from 7% to 10% of the regional VMT. This percentage is still consistent with the FHWA analysis of VMT from commercial vehicles for other regions and was therefore felt to be a reasonable model adjustment.

A few additional findings were made based on an investigation of the commercial vehicle model that should be noted for future applications:

- The current CVM uses[21] a sample rate of 1.0; that is, the CVM is run once and the results are used in assignment. It is also possible to run the CVM multiple times (previous efforts used a sample rate of 10) and average the results. An investigation revealed that use of a smaller scale factor in the disaggregate CVM model results in a slightly lower travel rate. However, running the model multiple times consumes valuable runtime, so the decision was made to use the lower sample rate.
- A comparative analysis of inputs from different years revealed counterintuitive results for travel rates in the disaggregate commercial vehicle model. The travel rate with 2016 inputs was found to be lower than the travel rate with 2012 inputs as used in the CVM validation effort, despite higher employment in 2016. This should be tested further, especially for future year model runs.

Appendix G provides more details of the investigation into the commercial vehicle demand and magnitude of the increase in commercial vehicle demand.

Road Class

As shown in the scatter plots, Figure 62 and Figure 63, barring some big outliers, most of the count locations appear close to the 45-degree line and within the Caltrans recommended deviation range. To quantify, Table 24 presents a summary of links in various gap ranges and by road class. It shows that regionally links with a positive gap value has an average gap value of 33% and the links with a negative gap value has an average gap value of -27%. Due to higher number of links (59%) of negative gap values, the regional gap value is calculated as very small (-2%). The small value suggests a good match of the estimated flows and the traffic counts regionally. The match is also good across the four road classes.

In general, an expectation is to have fewer links as the gap value increase. The regional pattern of links in different gap ranges follows the expected pattern and show most links in the smallest gap range and fewer links in higher ranges. However, the road classes aside freeway (ramps, arterials, collectors) have more underestimated links with bigger negative gap values. This results in more links with a negative gap value regionwide, thus suggesting that spatially the region is more underestimated then overestimated. Also, percent of links with volume-to-count (gap) within Caltrans deviations are calculated as 67%, thus falling a little short of the FHWA

[21] Using a scale factor of 1 provides significant run time savings over using a scale factor 10.

recommended threshold of at least 75%. By road class, again, freeway facilities are doing better by exceeding the recommended threshold with 81% links within the Caltrans deviations, but other road classes, especially arterial and collector, fall very well short of the threshold. In summary, the estimated freeway flows from the model compare well with the traffic counts but the flows on arterial and collector do not match counts as well. This point to the difference in quality of the traffic counts on different road classes.

As noted in Chapter 3.0 Data, the traffic counts are obtained from various sources and the quality of the counts vary by the source. The freeway and ramp traffic counts come from Performance Measurement System (PeMS) and Caltrans Traffic Census, which are proven to be more reliable estimate of an average weekday travel, whereas, the traffic counts on arterials and collectors are obtained from local jurisdictions, which are more error prone as they are one-time 24-hour or 72-hours count, thus presenting a challenge to use them as an average daily weekday count. Because of the low sample rate and high degree of seasonal variance, the traffic counts on arterials and collectors are less reliable. Furthermore, the traffic assignment on lower volume facilities is more influenced by the aggregation bias caused by the size of TAZs and subject to higher variances due to uncertainty in the model. Because of these issues we would expect that the percent error in lower volume facilities to be higher than higher volume facilities.

The PRMSE value of 22% for all count locations is well within the recommended value (<40%). Moreover, PRMSE value for each road classes, except collector, also satisfies the recommendation. The Collectors are low volume facilities and are therefore hard to match with traffic counts. For smaller counts, even a small difference between estimated flow and traffic count could result in a big PRMSE value.

The correlation coefficient between the estimated flows and the traffic counts is 0.98 and is well above the recommended threshold (>0.88). Like the PRMSE values, the correlation coefficient for freeway locations is better than the recommended value but the other relatively lower speed facilities are not doing that well. Again, more likely due to suspect quality of traffic counts on those facilities.

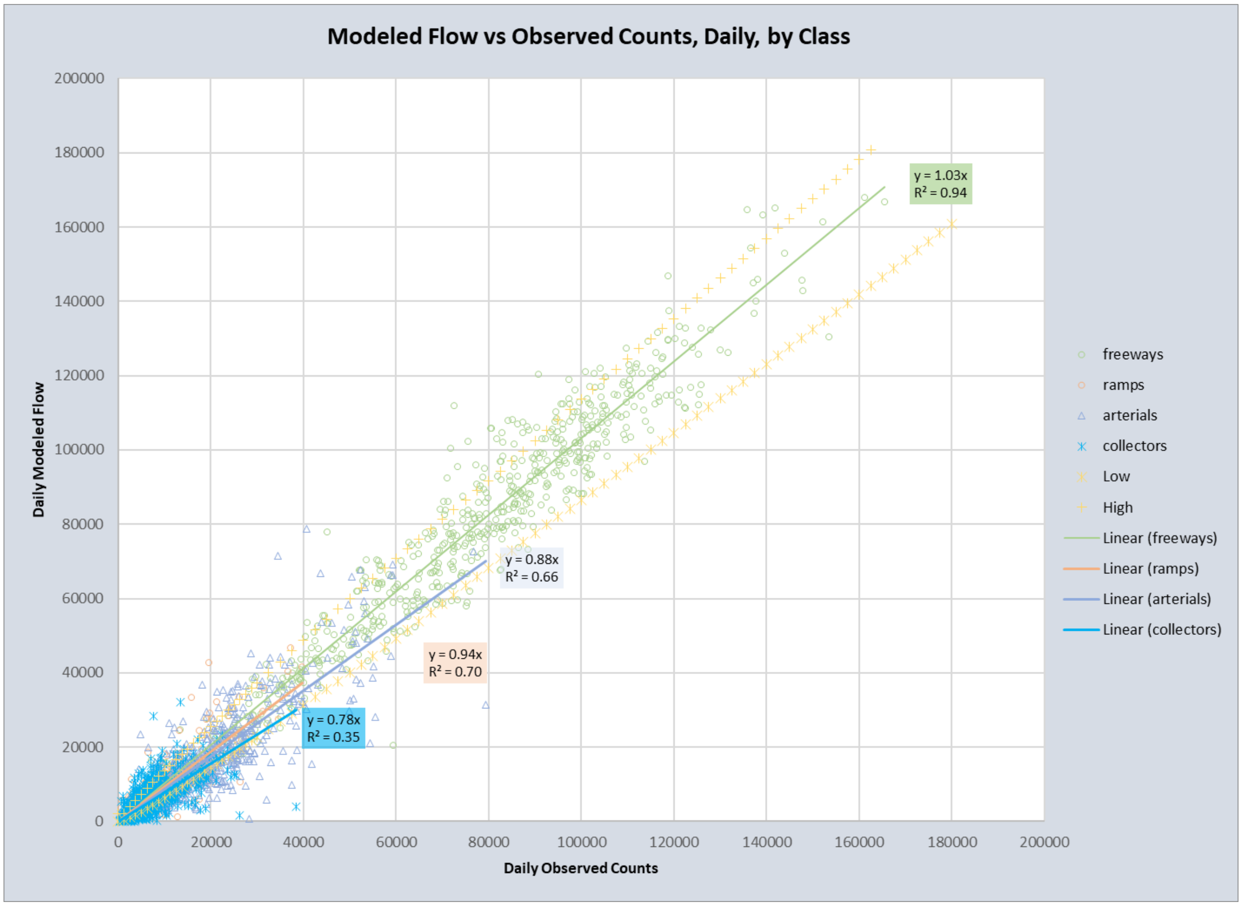


FIGURE 63: DAILY ESTIMATED FLOWS VS OBSERVED COUNTS – BY ROAD CLASS

TABLE 24: DAILY ESTIMATED FLOWS VS OBSERVED COUNTS – BY ROAD CLASS

	FREEWAY		RAMP		ARTERIAL		COLLECTOR		ALL	
	Count	%	Count	%	Count	%	Count	%	Count	%
Number of Links within Gaps										
>=100%	1	0%	12	3%	13	2%	34	6%	60	3%
50%~100%	6	1%	25	6%	25	4%	63	11%	119	5%
30%~50%	13	2%	34	8%	27	5%	30	5%	104	5%
20%~30%	31	5%	27	6%	22	4%	26	4%	106	5%
10%~20%	104	16%	26	6%	40	7%	33	6%	203	9%
0%~10%	199	31%	41	9%	57	10%	35	6%	332	15%
0%~-10%	190	30%	49	11%	86	15%	52	9%	377	17%
-10%~-20%	60	9%	64	15%	76	13%	54	9%	254	11%
-20%~-30%	13	2%	70	16%	84	14%	50	8%	217	10%
-30%~-50%	14	2%	68	16%	91	16%	97	16%	270	12%
<-50%	1	0%	22	5%	62	11%	124	21%	209	9%
total links	632	100%	438	100%	583	100%	598	100%	2251	100%
positive links	354	56%	165	38%	184	32%	221	37%	924	41%
negative links	278	44%	273	62%	399	68%	377	63%	1327	59%
-10% ~ +10%	389	62%	90	21%	143	25%	87	15%	709	31%
-20% ~ +20%	553	88%	180	41%	259	44%	174	29%	1166	52%
-30% ~ +30%	597	94%	277	63%	365	63%	250	42%	1489	66%
Average of Gaps										
Positive	12%		42%		35%		60%		33%	
Negative	-10%		-26%		-28%		-40%		-27%	

	FREEWAY	RAMP	ARTERIAL	COLLECTOR	ALL
	Count %	Count %	Count %	Count %	Count %
All	2%	0%	-8%	-3%	-2%
Percent Root Mean Square Error (PRMSE), Trend Line Slope and R-Squared					
PRMSE	12%	38%	37%	59%	22% **(<40%)**
Correlation	97%	84%	81%	64%	98% **(>=88%)**
Slope	1.03	0.94	0.88	0.78	1.02
R-squared	94%	70%	66%	40%	97%
Links Within/Outside Caltrans Acceptable Deviation					
Within	515	329	342	319	1505
Outside	117	109	241	279	746
Acceptable %	81%	75%	59%	53%	67% **(>75%)**

*Note: numbers in parenthesis are the FHWA's recommended thresholds.

PMSA

The summaries, Table 25, compare the estimated traffic flow and the observed traffic count by 8 pseudo MSAs in the San Diego region (see Appendix C for description and a map of the districts). The comparison generally shows reasonable gaps and PRMSE values across all links within a PMSA. The average gaps are generally within 11%. However, the model flows in the East County exhibit larger overestimation overall (average gap=18%); 17% of the links are overestimated by a gap of more than 100%, resulting in a relatively large RMSE value (58%) for the links in the district. However, due to the relatively low number of count locations (41) in the district, it is difficult to make any conclusions from these results. The slope of the regression line is close to 1.0 for all districts.

TABLE 25: DAILY ESTIMATED FLOWS VS OBSERVED COUNTS – BY MSA

	CENTER CITY		CENTRAL		NORTH CITY		SOUTH SUBURBAN		EAST SUBURBAN		NORTH COUNTY WEST		NORTH COUNTY EAST		EAST COUNTY		ALL	
	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
Number of Links within Gaps																		
>=100%	3	4%	10	2%	26	4%	5	3%	4	1%	1	1%	4	2%	7	17%	60	3%
50%~100%	5	6%	40	7%	44	7%	4	2%	8	2%	2	1%	10	5%	6	15%	119	5%
30%~50%	5	6%	26	5%	41	6%	5	3%	12	4%	9	5%	4	2%	2	5%	104	5%
20%~30%	6	8%	20	4%	46	7%	4	2%	13	4%	6	3%	10	5%	1	2%	106	5%
10%~20%	5	6%	57	10%	70	11%	11	7%	25	7%	11	6%	23	11%	1	2%	203	9%
0%~10%	6	8%	86	16%	123	18%	17	10%	37	11%	37	19%	26	12%	0	0%	332	15%
0%~-10%	6	8%	87	16%	114	17%	29	18%	63	18%	42	21%	31	15%	5	12%	377	17%
-10%~-20%	9	12%	62	11%	59	9%	20	12%	46	13%	28	14%	25	12%	5	12%	254	11%
-20%~-30%	6	8%	48	9%	49	7%	20	12%	51	15%	22	11%	20	9%	1	2%	217	10%
-30%~-50%	15	19%	64	12%	49	7%	26	16%	47	14%	25	13%	37	17%	7	17%	270	12%
<-50%	11	14%	53	10%	44	7%	22	13%	36	11%	14	7%	23	11%	6	15%	209	9%
total links	77	100%	553	100%	665	100%	163	100%	342	100%	197	100%	213	100%	41	100%	2251	100%

	CENTER CITY		CENTRAL		NORTH CITY		SOUTH SUBURBAN		EAST SUBURBAN		NORTH COUNTY WEST		NORTH COUNTY EAST		EAST COUNTY		ALL	
	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
-10% ~ +10%	12	16%	173	31%	237	36%	46	28%	100	29%	79	40%	57	27%	5	12%	709	31%
-20% ~ +20%	26	34%	292	53%	366	55%	77	47%	171	50%	118	60%	105	49%	11	27%	1166	52%
-30% ~ +30%	38	49%	360	65%	461	69%	101	62%	235	69%	146	74%	135	63%	13	32%	1489	66%
positive links	30	39%	239	43%	350	53%	46	28%	99	29%	66	34%	77	36%	17	41%	924	41%
negative links	47	61%	314	57%	315	47%	117	72%	243	71%	131	66%	136	64%	24	59%	1327	59%
Average of Gaps																		
Positive	41%		30%		35%		40%		27%		17%		34%		96%		33%	
Negative	-33%		-28%		-24%		-31%		-27%		-24%		-29%		-37%		-27%	
All	-4%		-3%		7%		-11%		-11%		-10%		-6%		18%		-2%	
Percent Root Mean Square Error (PRMSE) and Trend Line Slope																		
RMSE	35%		21%		21%		26%		23%		14%		28%		58%		22%	

	CENTER CITY		CENTRAL		NORTH CITY		SOUTH SUBURBAN		EAST SUBURBAN		NORTH COUNTY WEST		NORTH COUNTY EAST		EAST COUNTY		ALL	
	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
Slope	1.05		1.03		1.04		0.97		0.96		1.00		1.00		1.02		1.02	

Volume Group

The summaries in Table 26 compare the estimated traffic flows and the traffic count in 11 volume groups that are formed based on the range of the observed traffic counts. Each volume group consists a traffic range of 10k with the first group as less than 10k and the last group as more than 100k. Generally, links with lower volumes show larger gaps and PRMSE values. This is not surprising given that lower volume links are more likely to be collectors or arterials and as previously discussed have more error. Further, the slope of the regressed line for the lower volume links (<40k) indicate underestimation on those links. This concurs with the observations from the comparisons by road class where arterials and collectors showed underestimation overall.

TABLE 26: DAILY ESTIMATED FLOWS VS OBSERVED COUNTS – BY VOLUME GROUP

	<10K		10K-20K		20K-30K		30K-40K		40K-50K		50K-60K		60K-70K		70K-80K		80K-90K		90K-100K		>100K		ALL	
GAP	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
Number of Links within Gaps																								
>=100%	52	6%	7	1%	0	0%	1	1%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	60	3%
50%~100%	99	12%	13	3%	3	1%	0	0%	3	5%	0	0%	0	0%	1	1%	0	0%	0	0%	0	0%	119	5%
30%~50%	57	7%	21	4%	14	6%	3	3%	1	2%	2	3%	0	0%	3	4%	2	3%	1	1%	0	0%	104	5%
20%~30%	42	5%	15	3%	12	5%	5	5%	6	11%	10	13%	1	2%	4	5%	8	10%	1	1%	2	1%	106	5%
10%~20%	44	5%	31	6%	15	6%	12	13%	8	14%	17	22%	12	22%	15	18%	11	14%	21	27%	17	13%	203	9%
0%~10%	62	7%	42	8%	24	10%	19	20%	13	23%	11	14%	10	19%	27	32%	23	29%	33	43%	68	51%	332	15%
0%~-10%	88	10%	62	12%	41	17%	16	17%	13	23%	23	29%	20	37%	23	27%	31	39%	18	23%	42	31%	377	17%
-10%~-20%	89	11%	69	14%	33	13%	18	19%	8	14%	4	5%	11	20%	9	11%	5	6%	3	4%	5	4%	254	11%
-20%~-30%	71	8%	84	17%	41	17%	11	11%	1	2%	7	9%	0	0%	2	2%	0	0%	0	0%	0	0%	217	10%
-30%~-50%	117	14%	100	20%	44	18%	4	4%	2	4%	3	4%	0	0%	0	0%	0	0%	0	0%	0	0%	270	12%
<-50%	126	15%	54	11%	18	7%	7	7%	1	2%	2	3%	0	0%	1	1%	0	0%	0	0%	0	0%	209	9%
total links	847	100%	498	100%	245	100%	96	100%	56	100%	79	100%	54	100%	85	100%	80	100%	77	100%	134	100%	2,251	100%

	<10K		10K-20K		20K-30K		30K-40K		40K-50K		50K-60K		60K-70K		70K-80K		80K-90K		90K-100K		>100K		ALL	
GAP	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
-10% ~ +10%	150	18%	104	21%	65	27%	35	36%	26	46%	34	43%	30	56%	50	59%	54	68%	51	66%	110	82%	709	31%
-20% ~ +20%	283	33%	204	41%	113	46%	65	68%	42	75%	55	70%	53	98%	74	87%	70	88%	75	97%	132	99%	1,166	52%
-30% ~ +30%	396	47%	303	61%	166	68%	81	84%	49	88%	72	91%	54	100%	80	94%	78	98%	76	99%	134	100%	1,489	66%
positive	356	42%	129	26%	68	28%	40	42%	31	55%	40	51%	23	43%	50	59%	44	55%	56	73%	87	65%	924	41%
negative	491	58%	369	74%	177	72%	56	58%	25	45%	39	49%	31	57%	35	41%	36	45%	21	27%	47	35%	1,327	59%
Average of Gaps																								
Positive	60%		27%		20%		15%		17%		16%		10%		12%		12%		9%		7%		33%	
Negative	-35%		-30%		-26%		-22%		-14%		-15%		-8%		-9%		-5%		-5%		-5%		-27%	
All	5%		-15%		-13%		-7%		3%		1%		-1%		3%		4%		5%		3%		-2%	
Percent Root Mean Square Error (PRMSE) and Trend Line Slope																								
RMSE	53%		37%		30%		27%		24%		20%		11%		15%		12%		10%		8%		22%	
Slope	0.97		0.84		0.87		0.93		1.03		1.00		0.99		1.03		1.04		1.05		1.03		1.02	

Key Freeway Corridors

Highway corridor performance is an important metric for regional stakeholders. The examination of model results by highway corridor helps establish a travel model's precision in regional planning applications. The list of examined corridors is presented in Table 27.

TABLE 27: KEY FREEWAY CORRIDORS

CORRIDOR	FREEWAY
North-South	I-5, I-5HOV, I-15, I-15HOV I-805, SR-67, SR-125, and SR-163
East-West	I-8, SR-52, SR-54, SR-56, SR-78, SR-94, and SR-905

The model flows on freeway corridors are compared by four corridor directions (NB, SB, EB, and WB) for daily as well as two peak time periods (AM and PM).

Table 28 compares daily flows on all key freeway corridors by direction. Overall, the flows match well with the observed counts - slope is 1.03 and the average gap is 2%. The flows by direction also compare well.

Table 29 compares all key freeway corridors by direction and in the AM peak period. Overall, the slope of 1.16 and the average gap of 22% indicate overestimation of traffic flows in the AM period. The overestimation is consistent across the four corridor directions. The SB and the EB directions of the corridors are overestimated the most with the slopes of 1.20 and 1.26 respectively and the average gaps of 28% for both. The NB and the WB directions are doing well with the slopes (1.12 for both) relatively closer to 1 and the average gaps (17% for both) smaller in magnitude. Comparisons of key freeway corridors (results are too long to include) by direction provide more insight into SB and EB overestimations. Generally, all corridors in the south bound direction show significant overestimation, except I-15 HOV which is underestimated. The east bound direction is similarly overestimated as well, except SR-54 and SR905 which are doing well.

Table 30 compares all key freeway corridors by direction and in the PM peak period. Overall, the slope of 1.12 and the average gap of 11% indicate overestimation of traffic volume in the PM period. The overestimation is consistent across the four corridor directions. The NB direction of the corridors is overestimated the most with the slope of 1.22 and the average gap of 20%. Other directions are doing well with slopes relatively closer to 1.0 and average gaps smaller in magnitude. Comparisons at corridor level (results are too long to include) by direction show that overestimation in the north bound direction is generally on all corridors, except I-15 HOV which is slightly underestimated.

Detailed validation plots showing validation of daily flows by count locations on the I-5, I-15, and I-805 corridors are shown in Figure 64, Figure 65, Figure 66, Figure 67, Figure 68, Figure 69, Figure 70, and Figure 71. Appendix F provides similar plots for other key freeway corridors.

Note that this effort improved validations on HOV corridors by assigning speeds on HOV links to the same as the parallel general-purpose links and adding[22] time penalty of 30 seconds on HOV connectors to represent the discomfort of merging into and out of HOV lanes, particularly for short trips.

[22] These changes are automated in python scripts.

TABLE 28: KEY FREEWAY CORRIDORS BY DIRECTION – DAILY

	NB		SB		WB		EB		ALL	
GAP RANGE	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
Number of Links within Gaps										
>=40%	4	2%	3	2%	0	0%	2	2%	9	1%
30%~40%	2	1%	3	2%	3	2%	2	2%	10	2%
20%~30%	11	6%	8	4%	8	6%	4	4%	31	5%
10%~20%	31	16%	39	20%	18	14%	16	15%	104	17%
0%~10%	70	35%	78	39%	23	18%	27	26%	198	32%
0%~-10%	58	29%	39	20%	56	45%	37	36%	190	30%
-10%~-20%	16	8%	11	6%	15	12%	16	15%	58	9%
-20%~-30%	4	2%	7	4%	2	2%	0	0%	13	2%
-30%~-40%	0	0%	7	4%	0	0%	0	0%	7	1%
<=-40%	4	2%	4	2%	0	0%	0	0%	8	1%
total	200	100%	199	100%	125	100%	104	100%	628	100%
-10%~10%	128	64%	117	59%	79	63%	64	62%	388	62%

	NB		SB		WB		EB		ALL	
GAP RANGE	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
-20%~20%	175	88%	167	84%	112	90%	96	92%	550	88%
-30%~30%	190	95%	182	91%	122	98%	100	96%	594	95%
Positive	118	59%	131	66%	52	42%	51	49%	352	56%
Negative	82	41%	68	34%	73	58%	53	51%	276	44%
Average of Gaps										
Positive	11%		11%		12%		12%		12%	
Negative	-9%		-14%		-7%		-7%		-9%	
All	3%		3%		1%		2%		2%	
Percent Root Mean Square Error (PRMSE) and Trend Line Slope										
RMSE%	11%		13%		11%		10%		12%	
Slope	1.04		1.05		0.99		1.01		1.03	

TABLE 29: KEY FREEWAY CORRIDORS BY DIRECTION - AM

	NB		SB		WB		EB		ALL	
GAP RANGE	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
Number of Links within Gaps										
>=40%	32	16%	63	32%	7	6%	26	25%	128	20%
30%~40%	17	9%	21	11%	8	6%	16	15%	62	10%
20%~30%	29	15%	40	20%	21	17%	19	18%	109	17%
10%~20%	30	15%	28	14%	40	32%	24	23%	122	19%
0%~10%	42	21%	24	12%	42	34%	12	12%	120	19%
0%~-10%	34	17%	3	2%	7	6%	4	4%	48	8%
-10%~-20%	11	6%	1	1%	0	0%	2	2%	14	2%
-20%~-30%	5	3%	7	4%	0	0%	0	0%	12	2%
-30%~-40%	0	0%	9	5%	0	0%	1	1%	10	2%
<=-40%	0	0%	3	2%	0	0%	0	0%	3	0%
total	200	100%	199	100%	125	100%	104	100%	628	100%
-10%~10%	76	38%	27	14%	49	39%	16	15%	168	27%

	NB		SB		WB		EB		ALL	
GAP RANGE	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
-20%~20%	117	59%	56	28%	89	71%	42	40%	304	48%
-30%~30%	151	76%	103	52%	110	88%	61	59%	425	68%
Positive	150	75%	176	88%	118	94%	97	93%	541	86%
Negative	50	25%	23	12%	7	6%	7	7%	87	14%
Average of Gaps										
Positive	26%		35%		18%		30%		28%	
Negative	-8%		-29%		-5%		-11%		-14%	
All	17%		28%		17%		28%		22%	
Percent Root Mean Square Error (PRMSE) and Trend Line Slope										
RMSE%	24%		32%		16%		34%		27%	
Slope	1.12		1.20		1.12		1.26		1.16	

TABLE 30: KEY FREEWAY CORRIDORS BY DIRECTION – PM

	NB		SB		WB		EB		ALL	
GAP RANGE	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
Number of Links within Gaps										
>=40%	25	13%	14	7%	9	7%	3	3%	51	8%
30%~40%	31	16%	14	7%	6	5%	4	4%	55	9%
20%~30%	46	23%	19	10%	13	10%	15	14%	93	15%
10%~20%	34	17%	34	17%	11	9%	31	30%	110	18%
0%~10%	25	13%	32	16%	29	23%	31	30%	117	19%
0%~-10%	18	9%	44	22%	33	26%	17	16%	112	18%
-10%~-20%	12	6%	22	11%	14	11%	3	3%	51	8%
-20%~-30%	3	2%	8	4%	5	4%	0	0%	16	3%
-30%~-40%	0	0%	8	4%	2	2%	0	0%	10	2%
<=-40%	6	3%	4	2%	3	2%	0	0%	13	2%
total	200	100%	199	100%	125	100%	104	100%	628	100%
-10%~10%	43	22%	76	38%	62	50%	48	46%	229	36%

	NB		SB		WB		EB		ALL	
GAP RANGE	COUNT	%	COUNT	%	COUNT	%	COUNT	%	COUNT	%
-20%~20%	89	45%	132	66%	87	70%	82	79%	390	62%
-30%~30%	138	69%	159	80%	105	84%	97	93%	499	79%
Positive	161	81%	113	57%	68	54%	84	81%	426	68%
Negative	39	20%	86	43%	57	46%	20	19%	202	32%
Average of Gaps										
Positive	28%		22%		20%		16%		23%	
Negative	-15%		-14%		-12%		-4%		-13%	
All	20%		6%		6%		12%		11%	
Percent Root Mean Square Error (PRMSE) and Trend Line Slope										
RMSE%	30%		22%		17%		15%		24%	
Slope	1.22		1.07		1.02		1.10		1.12	

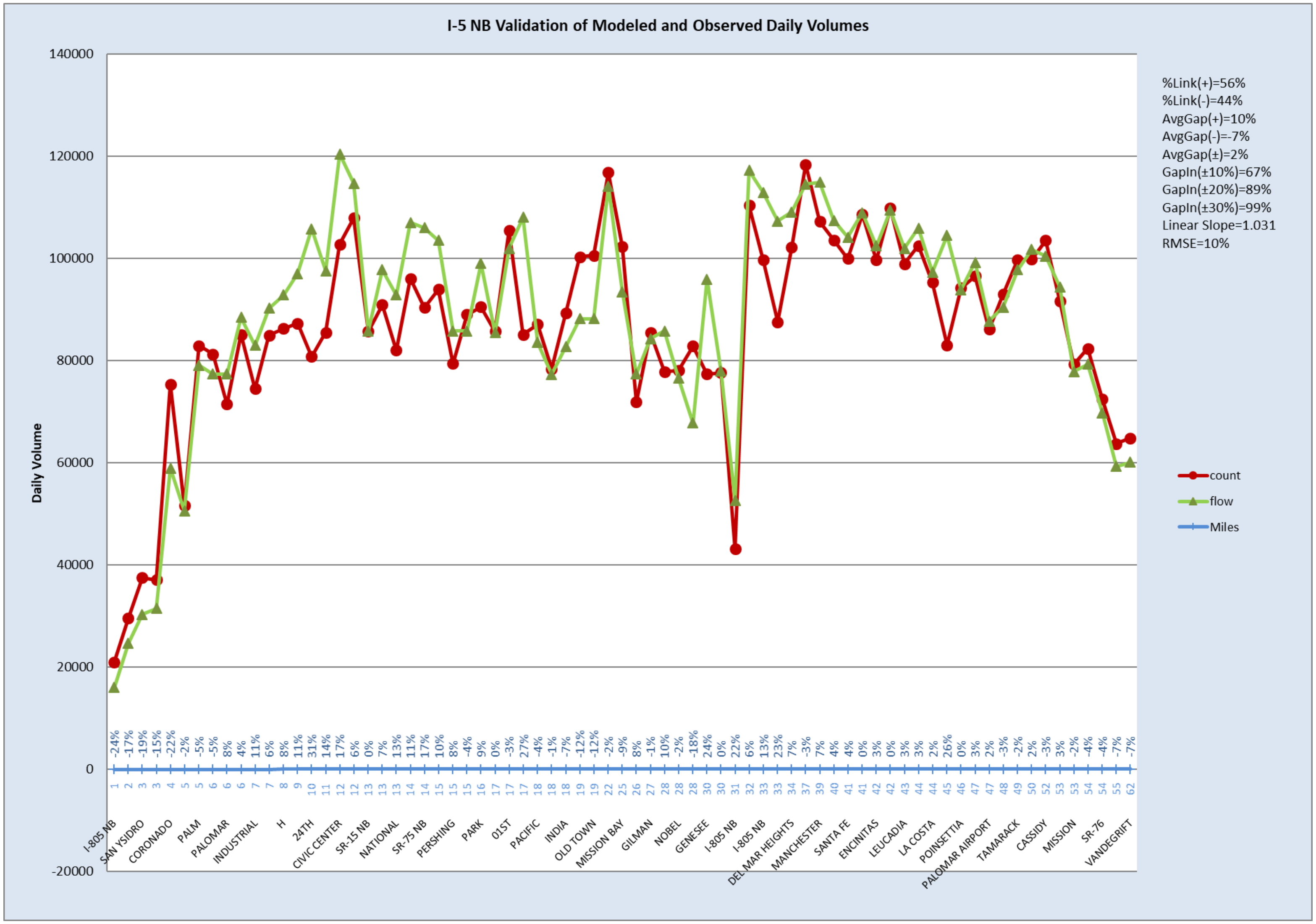


FIGURE 64: KEY CORRIDOR VALIDATION - I-5 NB

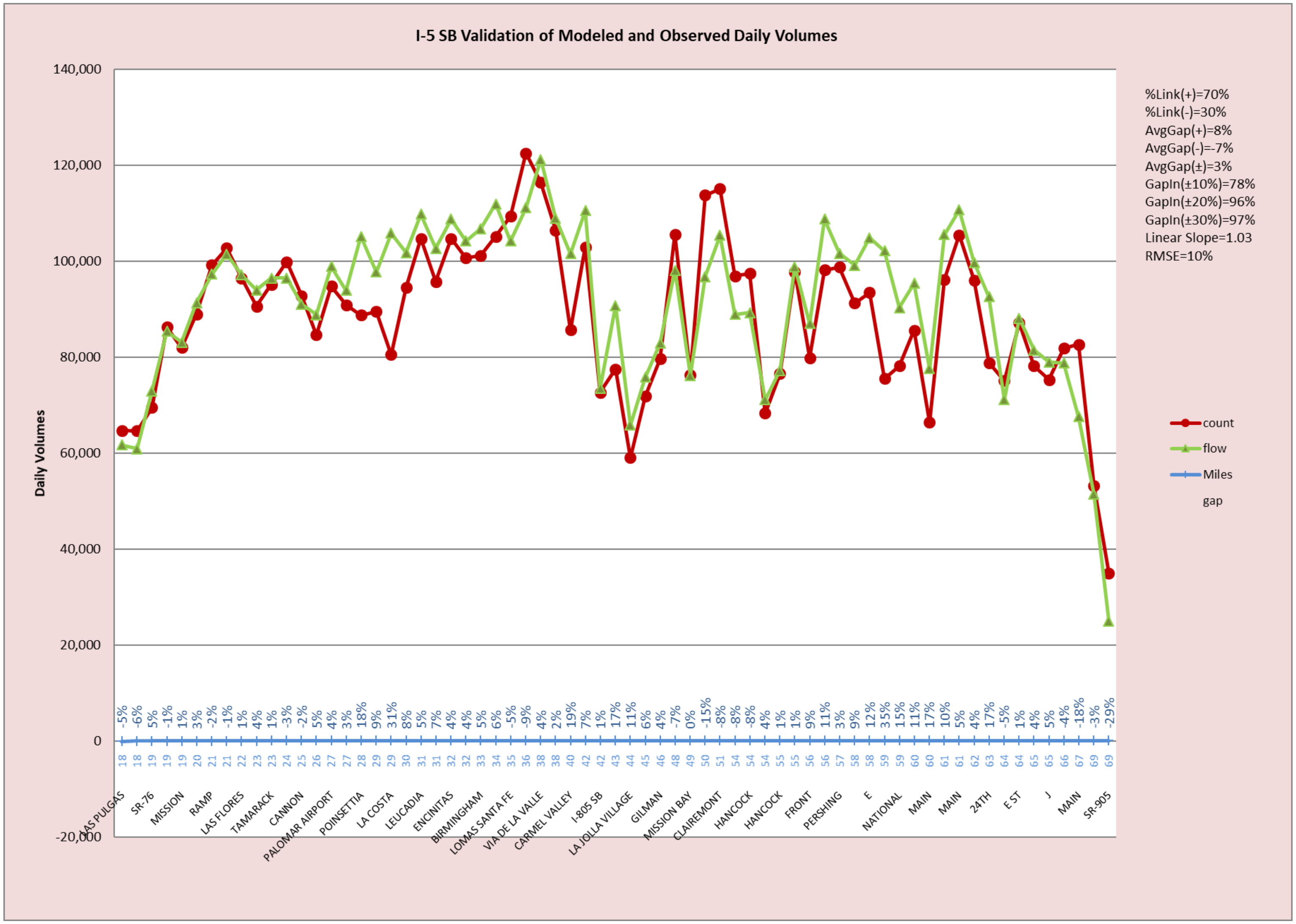


FIGURE 65: KEY CORRIDOR VALIDATION - I-5 SB

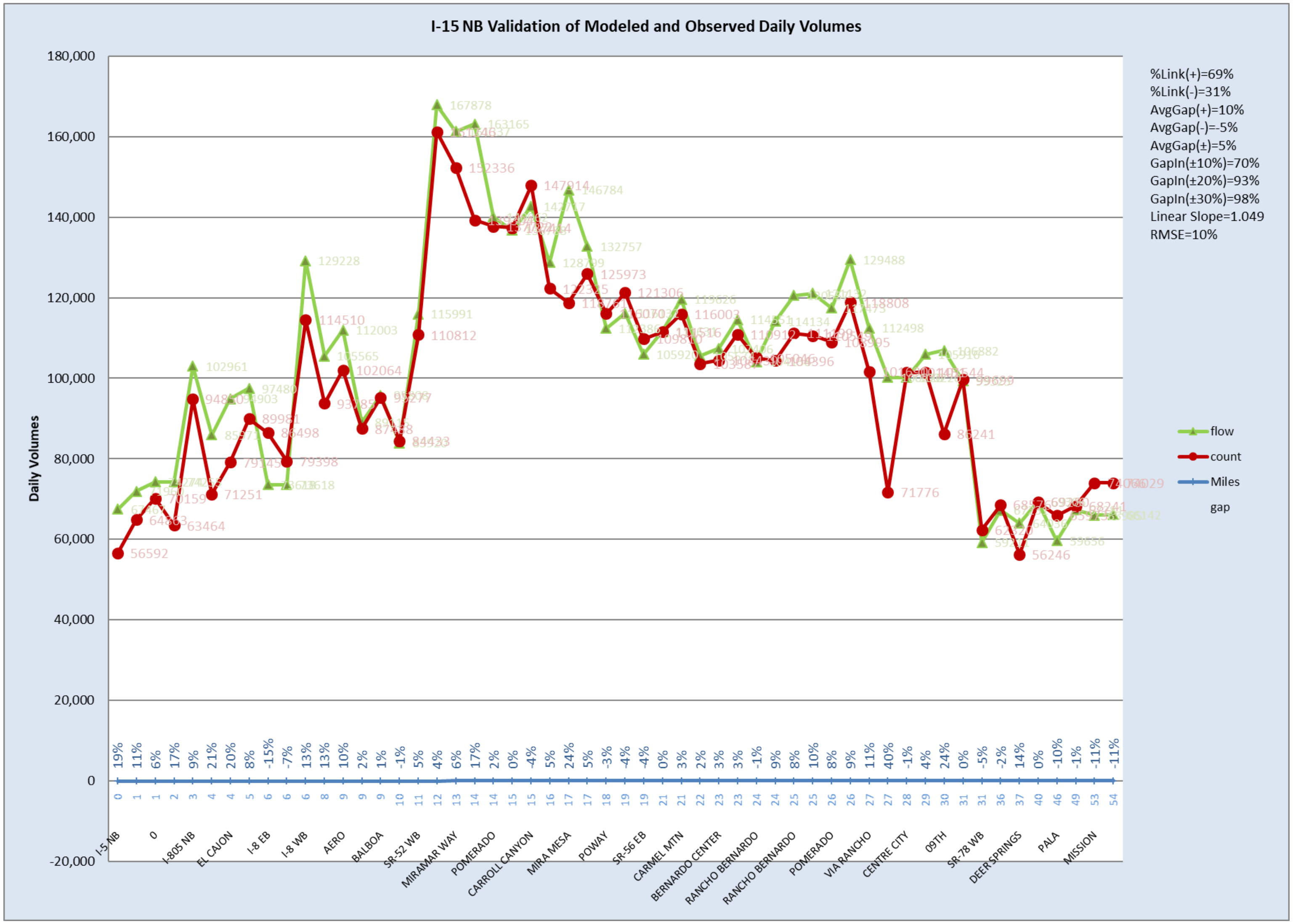


FIGURE 66: KEY CORRIDOR VALIDATION - I-15 NB

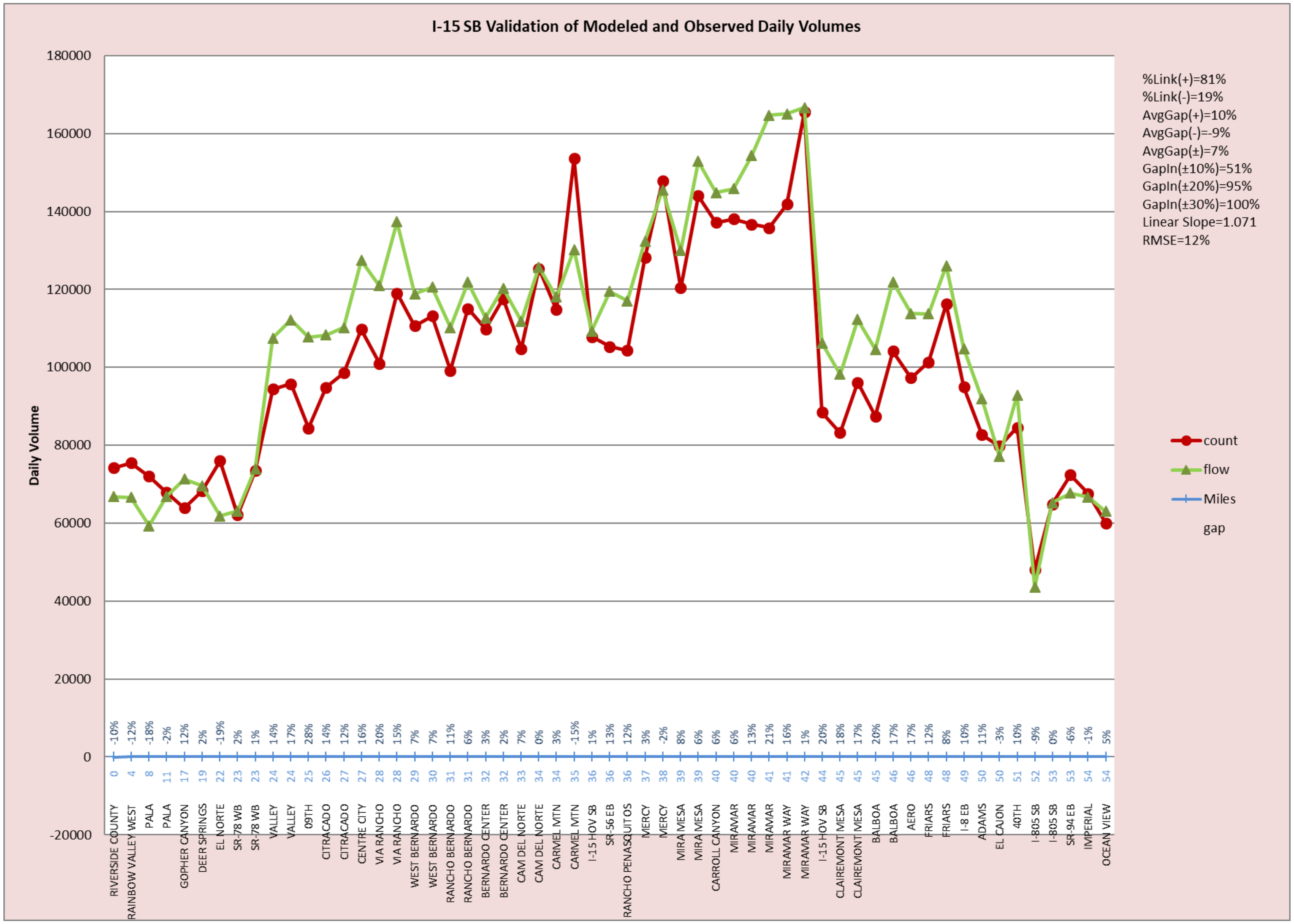


FIGURE 67: KEY CORRIDOR VALIDATION - I-15 SB

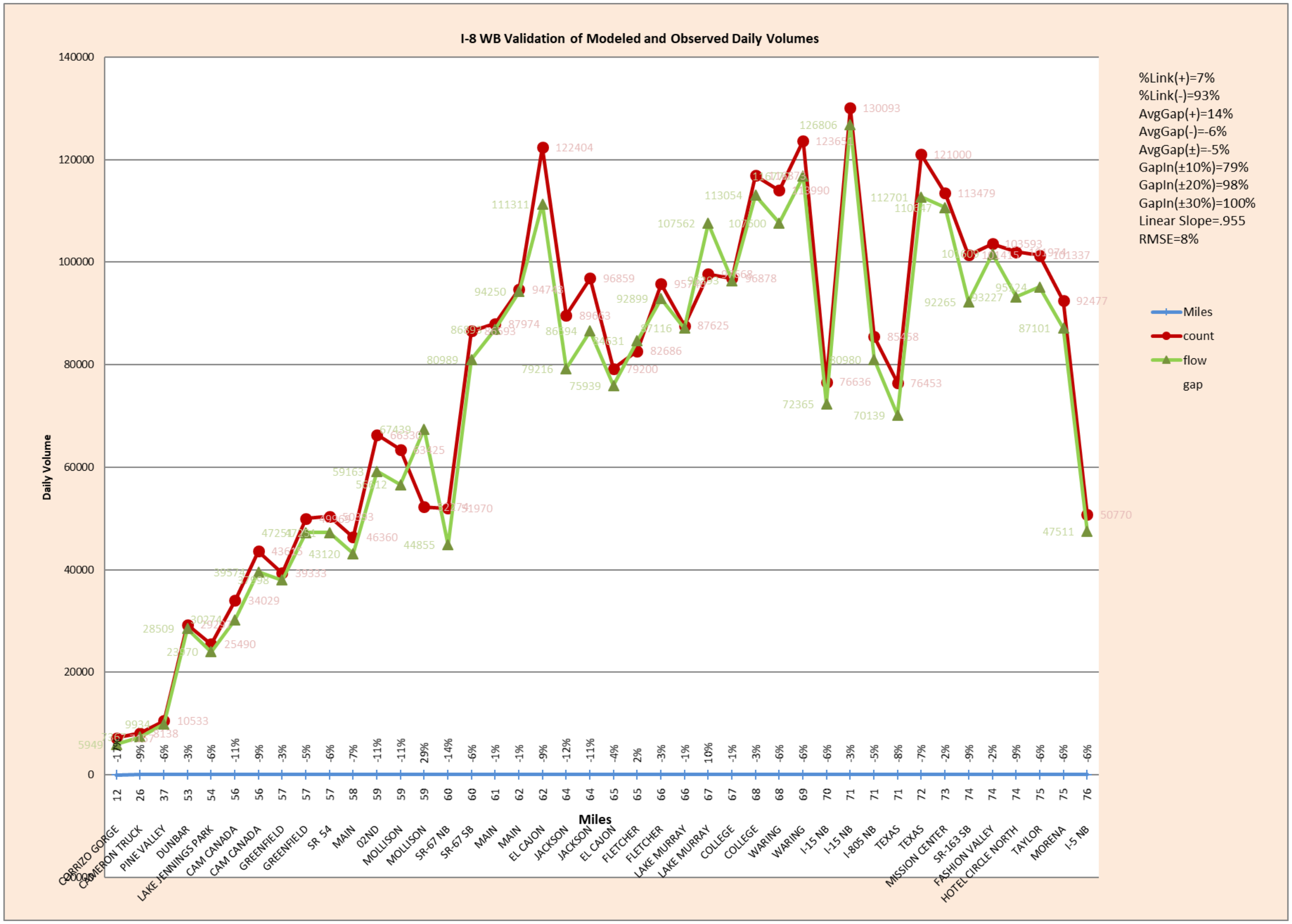


FIGURE 68: KEY CORRIDOR VALIDATION - I-8 WB

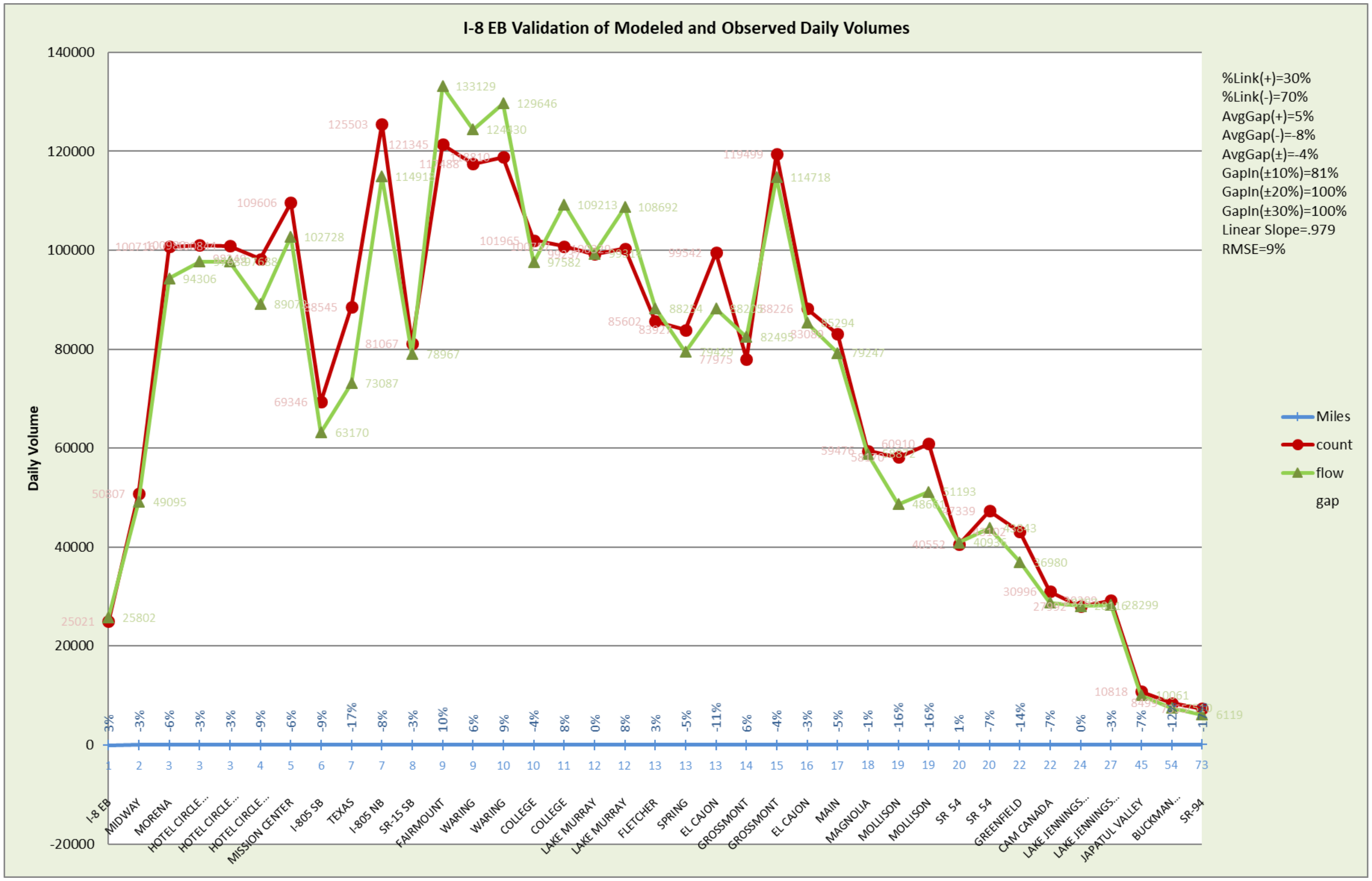


FIGURE 69: KEY CORRIDOR VALIDATION - I-8 EB

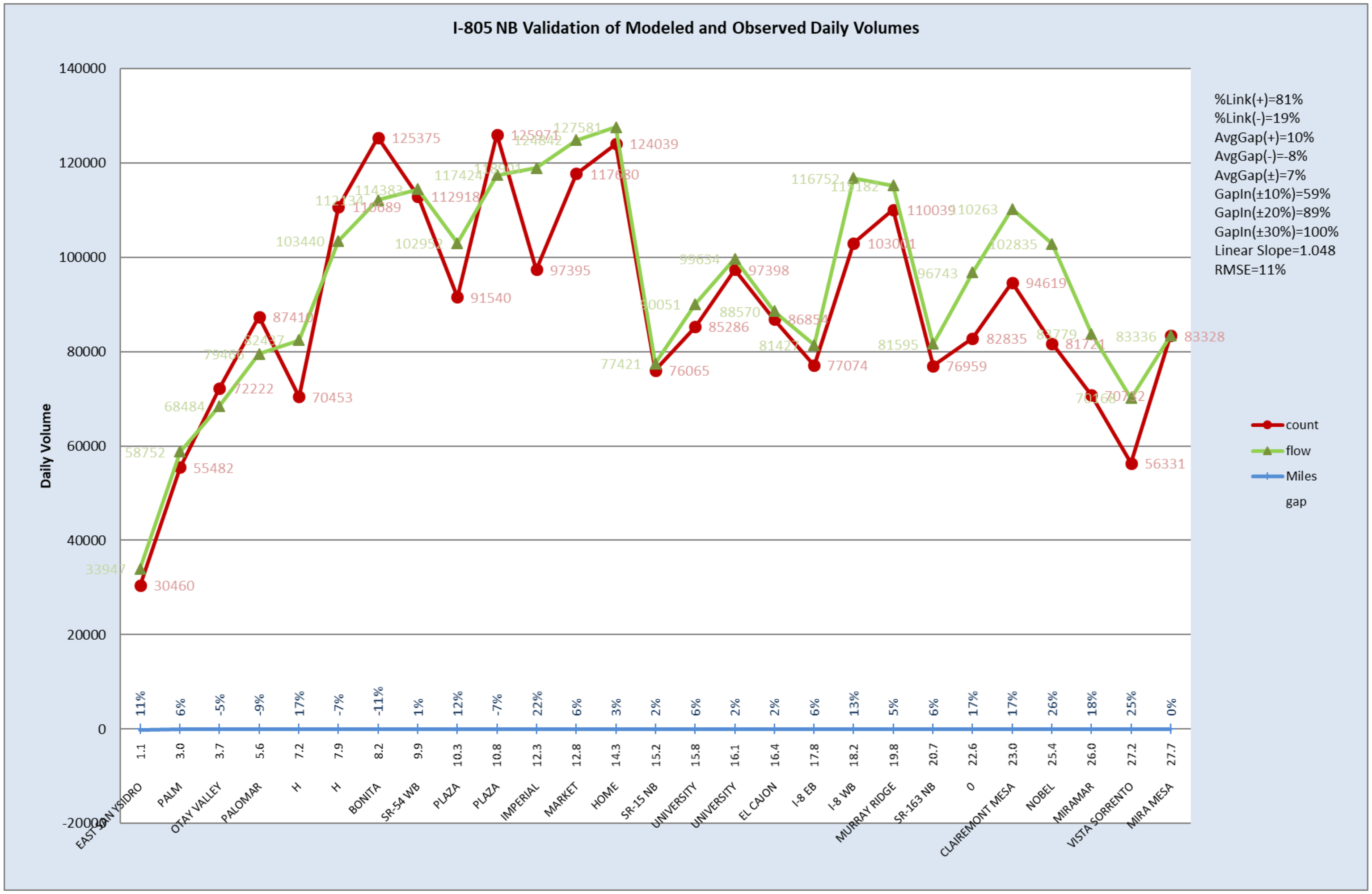


FIGURE 70: KEY CORRIDOR VALIDATION - I-805 NB

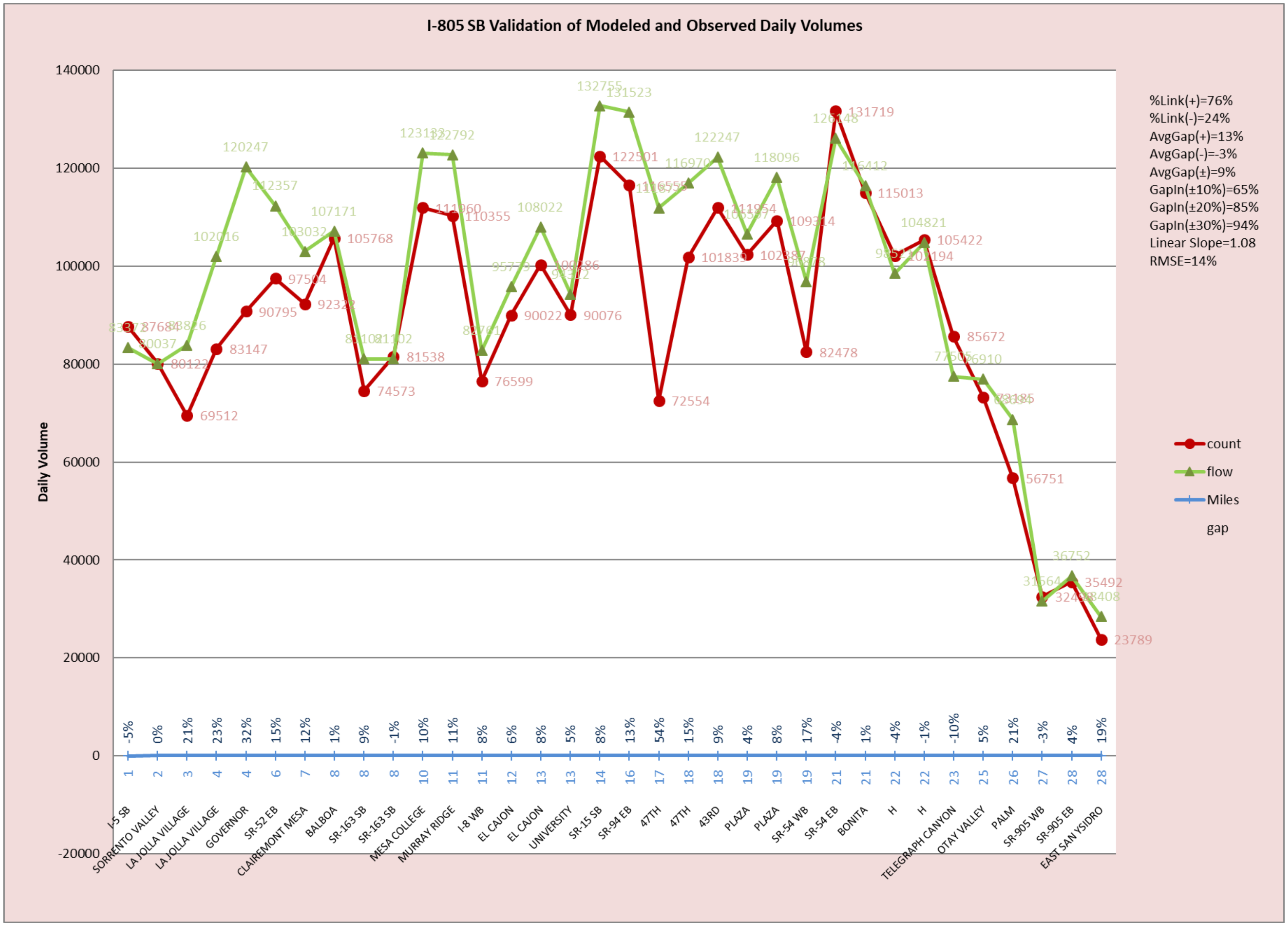


FIGURE 71: KEY CORRIDOR VALIDATION - I-805 SB

PRMSE Comparison

The FHWA report provides example guidelines on PRMSE by volume range using data sources[23] from various States Ohio, Florida, and Oregon. Figure 72 compares the RMSE from the SANDAG ABM with these guidelines. The comparison is by link volume.

For higher volume (>50K) roads, the SANDAG ABM outperforms most guidelines. For lower volume roads (<50K), the ABM generally show higher RMSE values, though very close to the guidelines. As discussed in validations by volume group, this points to the quality of traffic counts on arterials and collectors.

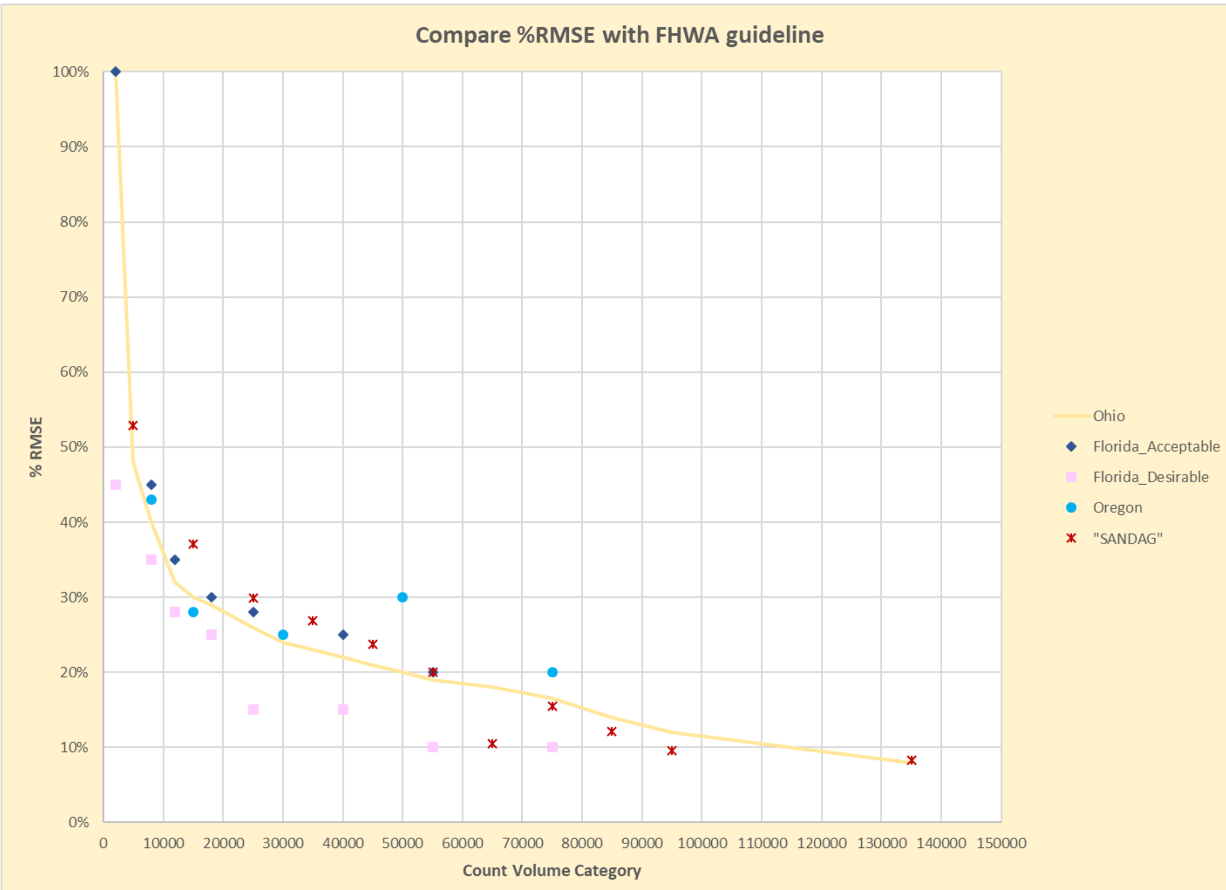


FIGURE 72: MODEL RMSE WITH FHWA GUIDELINES

[23] Figure 9.8 Example %RMSE Guidelines on page 9-20, Travel Model Validation and Reasonableness Checking Manual, 2nd Edition, TIMP

5.2 TRANSIT

Transit ridership produced by the model is compared against the observed ridership obtained from the Passenger Count Program. The ridership (boarding) is compared by transit line-haul mode as well by transit line.

The FHWA provides guidelines to check reasonableness of the transit assignment results from a model. The recommended guidelines are presented in Table 31.

TABLE 31: THE FHWA'S TRANSIT VALIDATION GUIDELINES

METRIC	THRESHOLD
Difference between actual counts and model results for a given year by route group (e.g. local bus, express bus, etc.)	+/- 20%
Difference between actual counts and model results for a given year by Transit Mode (e.g. light rail, bus, etc.)	+/- 10%

*Source: The Travel Model Validation and Reasonableness Checking Manual, II Second Edition, September 2010.

The subsequent sections discuss the transit validation by:

- Region
- Transit Line-Haul Mode
- Transit line

Region

Regionally, Table 32, the ABM generates 4% more transit boardings than the observed data and well within the Caltrans threshold of 10% (Table 31). However, the corresponding transit trips in the ABM are underestimated (-10%), thus indicating a higher regional boarding rate[24] in the model (1.43) compared to the survey (1.23). Note that the transit boardings and the transit trips in the observed data are from two different sources; the transit boardings are from the transit on-board survey, whereas the transit trips are from the transit on-board survey. Also, in general, the observed boarding rate appear low compared to other regions in the nation. The boarding rate in the current version of the ABM is a big improvement over the previous version. As discussed in Chapter 2.0 Model Enhancements, this project completely revamped the transit component of the model with several improvements to represent transit travel behavior more realistically as well as efficiently. The improvements also included several measures to improve

[24] Boarding rate is a measure of number of times transit service is boarded for every transit trip. The regional boarding rate is calculated as the total number of transit boardings divided by the total number of transit trips

(reduce) transit boarding rate estimated by the model (see Transit Best Path Calculator under 4.2 Resident Model (CT-RAMP)).

TABLE 32: TRANSIT SUMMARIES - REGIONAL

MEASURE	OBSERVED	SDABM16	DIFF	% DIFF
boarding	327,516	340,585	13,535	4%
trips	266,337	238,467	(27,870)	-10%
boarding rate	1.23	1.43	0.20	16%

Transit Line-Haul Mode

Based on their speed and operation (rail or bus), the transit services in the region are categorized into five line-haul modes: local bus, rapid bus, express bus, light rail (LRT), and commuter rail (CR). In 2016, a total of 113 local bus routes serve the region. The rapid and the express bus transit services operate 9 and 8 bus routes respectively. The light rail mode includes four rail services: blue line, orange line, green line, and sprinter. The commuter rail is a single route rail service that runs along the coast north to south through the San Diego county, serving eights stations between Oceanside and downtown San Diego.

The distribution of the observed ridership in the five line-haul modes, Table 33, indicate that the local bus and the light rail carry most of the burden of transit travel in the region. This is expected as the two transit services serve the most population in the region. The commuter line is a single transit line and serve limited population, thus transport the least riders within the region.

Transit line-haul mode preference of rides in the ABM show good match with the observed data. Apart from the express bus which is overestimated by 19%, other line-haul modes are well within the 10% of the observed data, satisfying the FHWA's recommendation of within 10% (see Table 31). Note that the express bus carry only a 5% of the total transit riders in the region. The two heavily used transit line-haul modes in the region, local bus and light-rail, are doing well.

The ridership on the Commuter rail too match well with the observed data. It is noteworthy to mention here that even though the commuter rail is a single line service, its unique nature[25] of the service made it difficult for the model to produce ridership that reasonably match the observed data. Substantial effort and time went into updating the model to replicate the observed commuter rail travel in the region.

[25] Several shuttle buses connect the population far from the service directly to coaster stations. The schedule of the buses is generally organized around the arrival and departure of the coaster rail. It competes with a parallel high-speed roadway facility, I-5. Its primary purpose is serving commuters, however, the observed data indicated only 50% of the commuter rail trips as work-related.

TABLE 33: TRANSIT BOPARDINGS – LINE HAUL MODE

TRANSIT MODE	OBSERVED	SDABM16	DIFF	DIFF (%)
Local	160,555	170,265	9,710	6%
Rapid	25,874	26,363	488	2%
Express	15,974	19,048	3,075	19%
LRT	120,099	118,138	(1,961)	-2%
Commuter Rail	5,015	5,276	261	5%
TOTAL	**327,516**	**339,090**	**11,574**	**4%**

Transit Line

A comparison of ridership by transit line examines the model's ability of producing transit ridership by transit line. A scatter plot in Figure 74 shows the relationship between the transit boardings from the ABM and the observed boarding by transit line. The X-axis in the plot represent the observed boardings and the estimated boardings from the model are presented on the Y-axis.

A high R-squared value of 0.96 indicates that the linear regression line is a very good fit for all data points or in other words the model matches route level boardings very well. Further, the regression line has a slope of 0.98, suggesting a good balance of underestimated and overestimated transit lines in the region.

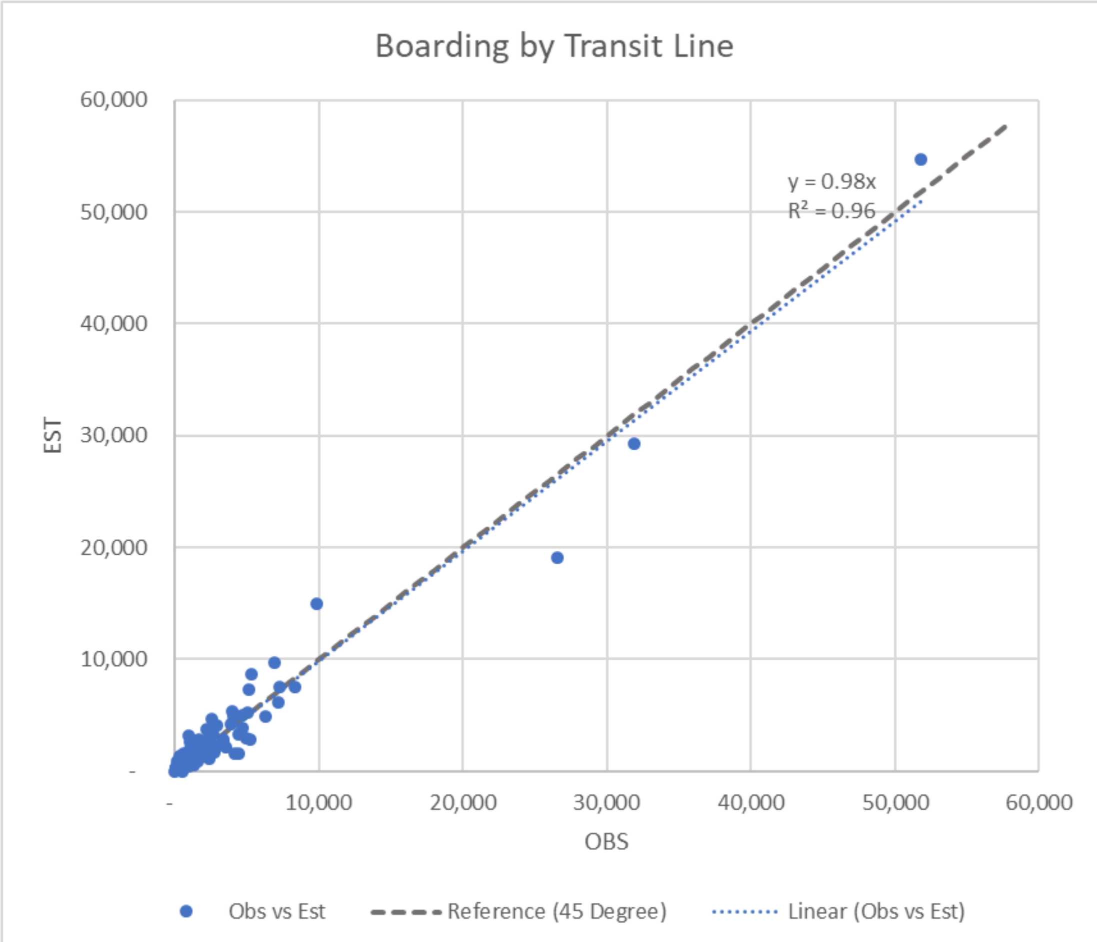


FIGURE 73: OBSERVED AND ESTIMATED TRANSIT BOARDINGS

A comparison of number of boardings by individual transit lines is presented in Figure 74. The X-axis is transit line id and the Y-axis is number of boardings. The transit lines are sorted from high observed boarding to low observed boarding. Note that the higher boarding lines in the map are LRT lines. The plot shows a reasonable match across all transit lines.

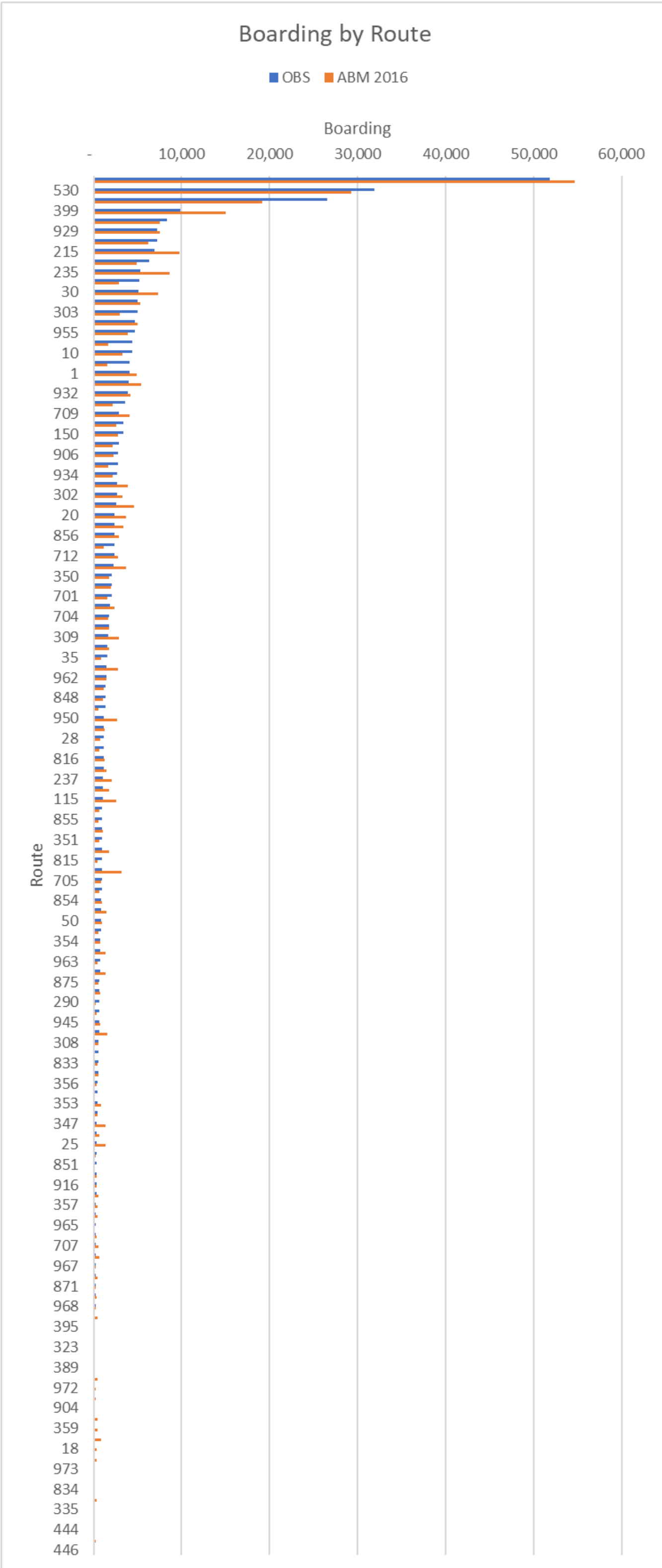


FIGURE 74: ESTIMATED AND OBSERVED BOARDINGS BY TRANSIT LINE

5.3 SUMMARY

The present model validation uses a traffic count database from various sources that vary in terms of their accuracy for representing real traffic on the count location. Specifically, the traffic counts on freeways and ramps are from Caltrans and are more reliable, whereas the other traffic counts (arterials and collectors) are obtained from local jurisdictions and are more error prone due to their sample size and high degree of seasonal variance on those road facilities. The model is also expected to exhibit greater error for lower-volume facilities, due to the size of TAZs and uncertainty in forecasts for smaller groups of decision-makers. The model results show an excellent match for count locations on freeways.

The highway validation uses the FHWA's various measures of reasonableness checks including, volume-to-count (gap), R-squared, RMSE, and percent links with volume-to-count within Caltrans deviation allowance. The following are a few key takeaways:

- Regionwide, the total traffic flow and the VMT produced by the ABM are close to the observed values for the same. The estimated traffic flow and the estimated VMT are within 2% and -1% of the observed values respectively.
- The estimated traffic flows from the model compare well with the observed traffic counts. The linear regression line for the relationship between the estimated traffic flow and the real traffic counts has a slope of 1.02 and a R-squared value of 0.96.
- Across all measures, the freeway facilities outperform the FHWA's recommendations.
- The arterials and the collectors slightly underperform, raising questions about accuracy of the traffic counts from local jurisdictions. The two road classes are generally underestimated.
- The AM and PM peak periods are overestimated.

The transit validation compares transit ridership by line-haul mode as well as by transit line. The two set of comparisons show a good representation of the observed transit behavior in the ABM. The following are a few takeaways:

- Regionwide, the ABM overestimate transit boardings by 4%
- The boarding rate in the latest ABM is a significant improvement from the previous version of the ABM, although, the boarding rate in the ABM (1.4) is still higher than the observed boarding rate (1.2).
- The estimated boardings by transit line-haul modes generally meet the FHWA's recommended guideline (+/- 10%). The only exception being the express bus service which carry only 5% of the transit travel in the region.
- The estimated boardings compare well by transit line as well. The linear regression line for the relationship between the observed and estimated boardings has a slope of 0.98 and a R-squared value of 0.96.

6.0 SENSITIVITY TESTS

The SANDAG modeling staff conducted a series of sensitivity tests to demonstrate the effects of various inputs on vehicle miles traveled (VMT) and transit boardings in ABM2. The sensitivity tests, described in Table 34, include a baseline 2016 scenario and scenarios by varying transit fare, transit service frequency (headways), auto operating cost (AOC), and freeway capacity. The 2016 model used for sensitivity tests is slightly different from the final 2016 model, which was adjusted with minor improvements after sensitivity tests.

TABLE 34: SENSITIVITY TEST SCENARIOS

SCENARIO ID	TEST VARIABLE	DESCRIPTION
1		2016 baseline
2	transit fare	Reduce by 100% (free transit)
3		Reduce by 50%
4		Increase by 50%
5		Increase by 100%
6	transit service frequency	Increase by 50%
7		Increase by 25%
8		Reduce by 25%
9		Reduce by 50%
10	auto operating cost (AOC)	Increase by 50%
11		Increase by 25%
12		Reduce by 25%
13		Reduce by 50%
14	roadway capacity	Increase by 50%
15		Reduce by 50%

6.1 ELASTICITIES

For transit fare and service frequency (headways) tests, the elasticity was derived as a change in boardings compared to the change in relevant variable. For auto operating cost and freeway capacity tests, the elasticity was derived as the change in VMT compared to the change in the relevant variable.

Results from all the tests were compared to the elasticities identified in the CARB Senate Bill 375, Research on Impacts of Transportation and Land Use-Related Policies[1]. Researchers, cited in the CARB policy white papers, are careful to stress that "no single transit elasticity value applies in all situations" (Litman, 2004, pg. 52)[2]. Currie & Loader (2009)[3], for example, found higher elasticity for increases in transit service in the evenings and on weekends, while Hickey (2005)[4] found a much lower elasticity for fare increases in New York City (-0.10) than reported in other studies.

Tables 2 and 3 describe SANDAG ABM2 sensitivity test results with comparison to elasticities identified in the CARB white papers. The derived elasticities vary, sometimes significantly, between test scenarios within the same test category. For example, the increase freeway capacity by 50% scenario has a derived elasticity of 0.2, while the decrease freeway capacity by 50% scenario has a derived elasticity of 0.81. An average elasticity is given for each test category in Table 35 and Table 36.

TABLE 35: SUMMARY OF BOARDING AND ELASICITY TO TRANSIT FARE AND SERVICE FREQUENCY (HEADWAYS)

ID	TEST VARIABLE	DESCRIPTION	BOARDINGS	% OF BOARDINGS DIFF	ELASTICITY (BOARDINGS)	ELASTICITY IN CARB WHITE PAPER
1		2016 baseline	379,364			
2	transit fare	Reduce by 100% (free transit)	602,890	59%	-0.59	
3		Reduce by 50%	475,570	25%	-0.51	
4		Increase by 50%	307,170	-19%	-0.38	
5		Increase by 100%	252,465	-33%	-0.33	
		Average			-0.45	-0.3 to -1.0 for bus -0.17 to -0.6 for Rail/Metro
6	transit frequency	Increase by 50%	461,095	22%	0.43	
7		Increase by 25%	416,516	10%	0.39	

ID	TEST VARIABLE	DESCRIPTION	BOARDINGS	% OF BOARDINGS DIFF	ELASTICITY (BOARDINGS)	ELASTICITY IN CARB WHITE PAPER
8		Reduce by 25%	350,319	-8%	0.31	
9		Reduce by 50%	325,185	-14%	0.29	
		Average			0.35	0.3 to 1.0

TABLE 36: SUMMARY OF VMT AND ELASTICITY TO AUTO OPERATING COST AND FREEWAY CAPACITY CHANGE

ID	TEST VARIABLE	DESCRIPTION	VMT	% OF VMT DIFFERENCE	ELASTICITY	ELASTICITY IN CARB WHITE PAPER
1		2016 baseline	82,601,294			
10	auto operating cost (AOC)	Increase by 50%	79,076,868	-4.3%	-0.09	
11		Increase by 25%	80,762,508	-2.2%	-0.09	
12		Reduce by 25%	84,874,715	2.8%	-0.11	
13		Reduce by 50%	87,411,935	5.8%	-0.12	
		Average			-0.10	-0.03 to -0.10
14	freeway capacity	Increase by 50%	83,763,899	1.4%	0.20	
15		Reduce by 50%	77,951,544	-5.6%	0.81	
		Average			0.51	0.3 to 1.0

6.2 OTHER TEST RESULTS

In addition to transit boarding and VMT analysis, staff compared the mode shares from ABM2 simulated modules: resident individual, resident joint, visitor, internal to external, Mexican resident cross border, and the airport trips. Trips from aggregate modules such as external to internal, external to external, commercial travel, and heavy truck trips are not included. Table

37 and Table 38 summarize mode shares and mode share differences between 2016 tests and baseline scenarios.

TABLE 37: MODE SHARE COMPARISONS

TEST ID	TEST VARIABLE	SCENARIO	DRIVE ALONE	CARPOOL	TRANSIT	WALK & BIKE	OTHER
1		2016 baseline	40.62%	44.25%	1.89%	11.70%	1.54%
2	transit fare	Reduce by 100% (free transit)	39.97%	43.94%	2.97%	11.59%	1.53%
3		Reduce by 50%	40.33%	44.11%	2.35%	11.67%	1.54%
4		Increase by 50%	40.83%	44.35%	1.54%	11.73%	1.55%
5		Increase by 100%	41.02%	44.44%	1.27%	11.72%	1.55%
6	transit frequency	Increase by 50%	40.40%	44.13%	2.19%	11.73%	1.55%
7		Increase by 25%	40.52%	44.18%	2.03%	11.72%	1.55%
8		Reduce by 25%	40.70%	44.30%	1.78%	11.69%	1.54%
9		Reduce by 50%	40.77%	44.35%	1.67%	11.68%	1.54%
10	auto operating cost (AOC)	Increase by 50%	40.08%	44.00%	2.16%	12.07%	1.69%
11		Increase by 25%	40.34%	44.13%	2.02%	11.89%	1.62%
12		Reduce by 25%	40.91%	44.34%	1.77%	11.51%	1.47%
13		Reduce by 50%	41.15%	44.50%	1.65%	11.31%	1.39%
14	freeway capacity	Increase by 50%	40.64%	44.23%	1.88%	11.71%	1.55%
15		Reduce by 50%	40.27%	44.44%	1.97%	11.74%	1.58%

TABLE 38: DIFFERENCE IN MODE SHARE

TEST ID	TEST VARIABLE	SCENARIO	DRIVE ALONE	CARPOOL	TRANSIT	WALK & BIKE	OTHER
1		2016 baseline	0.00%	0.00%	0.00%	0.00%	0.00%
2	transit fare	Reduce by 100% (free transit)	-0.65%	-0.31%	1.08%	-0.11%	-0.01%
3		Reduce by 50%	-0.29%	-0.14%	0.47%	-0.03%	-0.01%
4		Increase by 50%	0.21%	0.10%	-0.35%	0.04%	0.01%
5		Increase by 100%	0.40%	0.19%	-0.62%	0.03%	0.00%
6	transit frequency	Increase by 50%	-0.22%	-0.12%	0.30%	0.03%	0.01%
7		Increase by 25%	-0.10%	-0.07%	0.14%	0.02%	0.01%
8		Reduce by 25%	0.08%	0.05%	-0.11%	-0.01%	0.00%
9		Reduce by 50%	0.15%	0.10%	-0.22%	-0.02%	-0.01%
10	auto operating cost (AOC)	Increase by 50%	-0.54%	-0.25%	0.27%	0.37%	0.15%
11		Increase by 25%	-0.28%	-0.12%	0.13%	0.19%	0.08%
12		Reduce by 25%	0.29%	0.09%	-0.12%	-0.19%	-0.08%
13		Reduce by 50%	0.53%	0.25%	-0.24%	-0.39%	-0.15%
14	freeway capacity	Increase by 50%	0.02%	-0.02%	-0.01%	0.01%	0.00%

TEST ID	TEST VARIABLE	SCENARIO	DRIVE ALONE	CARPOOL	TRANSIT	WALK & BIKE	OTHER
15		Reduce by 50%	-0.35%	0.19%	0.08%	0.04%	0.04%

Finally, staff compared daily vehicle delays (VHD, in hours). Daily vehicle delay is the sum of roadway total link level vehicle volume by time of day multiplied by difference of congested minus free flow travel time by time of day. Table 39 and Table 40 summarize VHD and VHD differences between 2016 tests and baseline scenarios.

TABLE 39: DAILY VEHICLE HOURS DELAY

TEST ID	TEST VARIABLE	SCENARIO	VHD
1		2016 baseline	534,195
2	transit fare	Reduce by 100% (free transit)	521,476
3		Reduce by 50%	529,170
4		Increase by 50%	540,048
5		Increase by 100%	544,628
6	transit frequency	Increase by 50%	532,018
7		Increase by 25%	533,451
8		Reduce by 25%	536,232
9		Reduce by 50%	536,461
10	auto operating cost (AOC)	Increase by 50%	496,320
11		Increase by 25%	513,884
12		Reduce by 25%	560,076
13		Reduce by 50%	590,810
14	freeway capacity	Increase by 50%	477,748
15		Reduce by 50%	827,564

TABLE 40: DIFFERENCE IN DAILY VEHICLE HOURS DELAY

TEST ID	TEST VARIABLE	SCENARIO	VHD DIFF.	% OF VHD DIFF.
1		2016 baseline	0	0.0%
2	transit fare	Reduce by 100% (free transit)	-12,718	-2.4%
3		Reduce by 50%	-5,025	-0.9%
4		Increase by 50%	5,853	1.1%
5		Increase by 100%	10,433	2.0%
6	transit frequency	Increase by 50%	-2,177	-0.4%
7		Increase by 25%	-744	-0.1%
8		Reduce by 25%	2,037	0.4%
9		Reduce by 50%	2,266	0.4%
10	auto operating cost (AOC)	Increase by 50%	-37,875	-7.1%
11		Increase by 25%	-20,310	-3.8%
12		Reduce by 25%	25,881	4.8%
13		Reduce by 50%	56,615	10.6%
14	freeway capacity	Increase freeway capacity by 50%	-56,447	-10.6%
15		Reduce freeway capacity by 50%	293,370	54.9%

7.0 SUMMARY & CONCLUSIONS

This project updated the SANDAG Activity-based model to reflect travel behavior patterns from 2016/2017 household travel survey data and 2015 transit on-board survey data. The project also updated the model base year to 2016 and made several changes and enhancements to the model system, including;

- Conversion of the commercial transportation modeling package from TransCAD to EMME
- Implementation of a new model that explicitly models 'partially joint' travel episodes; specifically, the drop-off and pickup of children at school by parents
- Incorporation of recently-completed work to implement Strategic Highway Research Program recommendations regarding improving the sensitivity of travel models to pricing and reliability
- Update of the algorithm used to find transit paths
- Update of volume-delay function parameters based upon an analysis of INRIX travel time data
- Replacement of an asserted, aggregate commercial vehicle model with a disaggregate commercial vehicle model developed several years ago but not previously integrated with the San Diego travel model system
- Update of the heavy truck model, which models internal-external truck flows, to incorporate the latest Freight Analysis Framework (FAF4) data and projections
- Implementation of an airport ground access model for the Cross-Border Express (CBX) facility, serving Tijuana International Airport
- Update of models to better match 'big data' for special travel destinations including beaches, parks, hospitals, and shopping malls
- Incorporation of a new population synthesizer developed by SANDAG
- Update of the SQL model reporting database to incorporate the revisions noted above and streamline the database reporting process

The calibration of the AB model system involved adjustment to the resident model (CT-RAMP) as well as special market models (cross-border mode, visitor model, airport model, and external model). The resident model calibration utilized a web-based calibration tool, HTML visualizer, and relied mostly on the 2016/2017 household travel survey and 2015 transit on-board survey. Adjustment to special market models utilized several observed data sources: SANDAG border crossing/entry database for the cross-border model, on-board survey trips for the San Diego airport model, on-board survey trips for the visitor model, and external model.

The ABM generates slightly higher travel rates than the HTS. This is due to the changes made by the project team to calibration targets to reflect more travel to school and higher rates of travel for full-time workers and non-working adults; both changes were made due to suspected HTS under-estimates of these rates compared to other household travel surveys.

The work from home share was matched to SANDAG target of 7.1% regionwide. The share is relatively uniform across 8 SANDAG districts and could be improved by incorporating worker occupation as an explanatory variable.

Overall, the frequency distribution of non-mandatory tours by distance and purpose in the ABM matches well with the HTS. The sample size for joint tours in the HTS is smaller than that of individual tours; therefore, the joint tour length frequency distributions are somewhat lumpy and are not matched with the same accuracy as individual tours.

The HTS data observe that on average, non-mandatory tours are about 4.9 miles in distance. As expected, at-work tours are shorter than home-based tours, as a significant proportion of these tours are made for lunch trips that tend to be close to the place of work. Average tour lengths compare well with the HTS data, both total and by purpose.

The ABM generates somewhat more tours arriving in the AM and MD period than the HTS, possibly because of the increased number of school tours generated and the school escort model predicting higher numbers of drop-offs of children at school than is shown in the observed data.

In addition to adjusting alternative-specific constants by mode, the tour mode choice calibration adjusted several distance-based and destination-based coefficients to better match transit trips to parking constrained areas (initially there were too few transit trips to downtown San Diego compared to the transit on-board survey) and the distribution of transit tours by access mode and distance.

The ABM in its present form allow a maximum of three intermediate stops in each direction (outbound or inbound) of a tour but the HTS contain significant tours with intermediate stops higher than three. To account for these missing stops in the ABM, the HTS targets are adjusted in such a way that equivalent number of stops from the tour frequencies sum up to the total number of stops regionwide.

Overall, the ABM distribution of out of distance for intermediate stops matches the HTS distribution well, but results in intermediate stops that are somewhat longer than the HTS. Regionally, the ABM generate stops that results in an average out of distance of 4.3 miles compared to 3.1 miles in the HTS. We did not calibrate this model to match the observed distribution perfectly because assignment results indicated an under-estimate of traffic. Decreasing intermediate stop trip length further would decrease goodness-of-fit of assignment results.

The ABM is updated with new stop departure time distributions created from the HTS. As the ABM determine stop departures based on distribution from the survey data itself, the stop departure profile from the ABM output is likely to follow the survey stop departure profile. However, the ABM profile appear to differ, showing more stops in the morning (AM) period and fewer stops during the mid-day (MD) period. This is because the HTS profile does not reflect increased travel rates of full-time workers thus giving an impression of differences in diurnal distribution of stops.

The ABM was calibrated to match HTS trip mode shares. The datasets indicate that on an average weekday, 47% trips in the region are drive alone and 42% are shared-ride (SR2 and SR3), approximately 1.6% of San Diego County resident trips are made by transit, and 8% are made by a non-motorized mode (walk or bike).

The cross-border model was calibrated to match border crossings by points of entry, mode, and purpose with the observed targets created using 2016 crossing from the SANDAG database and proportions by purpose from the previous version of the model (ABM).

The travel model was validated using 2016 traffic counts joined to the model network, 2016 ridership by transit route, and 2016 vehicle miles travelled (VMT) from HPMS database. The model flows and transit boardings are validated against observed data using FHWA and Caltrans model reasonableness guidelines.

Regionwide, the total estimated VMT is within 1% of the HPMS value. The model flows match well with the observed traffic counts. The linear regressed line between the flows and the counts shows a slope of 1.02 and R-squared value of 0.96. Across all measures, the freeway facilities outperform recommended guidelines. The arterials and the collectors slightly underperform, raising questions about accuracy of the traffic counts from local jurisdictions. The estimated transit boardings by transit line haul mode generally meet the FHWA's recommended guideline, except the express bus service which carries only 5% of the total transit travel in the region. The estimated boardings by route compare well too as the linear regression line of the observed and estimated boardings has a slope of 0.98 and a R-squared value of 0.96.

The updated model showed reasonable sensitivities to changes in transit fare, transit headways, auto operating cost, and roadway capacity. Average elasticities of change in boardings and vehicle miles travelled (VMT) were in the range identified in the CARB Senate Bill 375, Research on Impacts of Transportation and Land Use-Related Policies.

APPENDIX A. SANDAG HTS AND TRANSIT ON-BOARD SURVEY DATA CLEANING AND PROCESSING

This section describes coding the SANDAG household travel survey and transit on-board survey datasets in more detail. Note that the statistics in this appendix are from the HTS dataset before it was processed to create model calibration targets. Therefore, these statistics are slightly different than the statistics from the calibration data.

Household Travel Survey (HTS)

The San Diego Regional Transportation Study began in 2016 and ended in 2017. The study leveraged smartphone-based travel diaries as the primary means of travel data collection; households with smartphones participated using the smartphone-based GPS travel diary and survey app, rMove, for up to one week (on average, households using rMove participated for 3.5 days). The study obtained complete surveys from 6,199 households. These households completed 22,598 days with travel details of all household members. The dataset collected more than 282,000 trips, with more than 193,000 trips collected on days with complete data for the household.

The study collected travel diary data using rMove and an online travel diary tool, rSurvey. Online or telephone survey collected a single travel day (Tuesday, Wednesday, or Thursday), whereas rMove allowed respondents to record travel up-to seven days. Only the weekday travel days were included in the travel-day weighting. Two-thirds (67%) of households used rMove to collect data in some way. There were 4,080 “online” travel days and 28,605 rMove complete HH day person days.

Data and Weighting

6,139 households provided complete data for at least one weekday and were included in the weighting. Some households (60) completed travel days only on the weekend, therefore were excluded from the weighting analysis.

The survey team completed weighting analysis in three steps:

- First, calculated initial expansion weights to represent the study area population.
- Second, adjusted initial weights to meet marginal distributions of key household and person-level socio-demographic measures (used PUMS).
- Last, calculated trip (and travel day) adjustment factors to account for known reporting biases associated with certain data collection methods (age group, and data/reporting type).

The final weighted dataset indicates an overall trip rate of 4.30 trips per day for the average person. This equates to 11.3 trips per day for the average household in the San Diego region.

Processing

The weighted HTS data are processed and transformed into formats needed to generate calibration targets. First, the data are input to an R script that creates a place file and a few other supporting files (household, person, and route). Next, a python-based process, Survey Processing Application (SPA), takes these outputs as inputs and codes daily activity patterns, activity types, tours, linked trips, and other summary files that are consistent with CT-RAMP formats.

The R-script is a pre-processing script to the SPA. It prepares the survey data in the format expected in the SPA. The R-script performs four major tasks; first, converts the HTS trips file into a place file; second, computes aggregate mode (the raw data has multiple mode fields for each trip); third, recodes trip purpose consistent with SPA trip purpose formats; and last, produces input files (place, households, persons, and route) in the necessary format for each survey day required for the SPA.

The input files produced by the R-script are fed into the SPA. The SPA first derives and appends the between-places distances from the route file to the place file and computes person type among other relevant attributes. It also checks for and resolves any inconsistencies between the reported purpose and location for work and work-related activities. Then the process loops through place records to identify tours and linked trips. It creates a tour for each sequence of place records starting and ending with “Home” being the activity purpose. Within each tour, a trip is created for each sub-sequence of place records that correspond to a linked person trip. A trip is tagged as a join trip if any of its constituting legs involves the person travelling with other household member(s). Once all place records are processed and corresponding trips and tours are created, the SPA checks for tours that start before or end after the designated survey period (3am to 3am). Such tours are tagged as partial tours because some of their attributes either cannot be determined or need to be computed in a manner different from non-partial tours. Additional attributes are then derived from their constituting trips. Also, new tours are created for work-to-work subtours.

Next, the SPA identifies joint travel episodes across household members. Due to the inconsistency often found in the data reported by different travel participants of a joint travel, rule-based intelligence is implemented in the SPA to identify and remove errors. The SPA further derives escort-related attributes (e.g. who is the chauffeur and whether the escorted individuals are being dropped off or picked up) for each travel group and tags the information to the associated trips.

Lastly, tours of different household members that contain identical series of joint travel are tagged as fully joint tours. Tours that contain both joint and non-joint trips are referred to as partially joint tours. As the last computational step of the SPA, escort related attributed at the trip level are aggregated to the tour level for partially joint tours.

The SPA produces six data tables and three log files for error investigation purposes, Table 41. The data tables are in the format similar to CT-RAMP and are therefore, used to generate calibration targets.

Calculate and append trip distances to the Place file
For each observed household
    Create a HOUSEHOLD object
    For each observed person
        Create a PERSON object for the HOUSEHOLD
        Compute person type (section **Error! Reference source not found.**)
        Check work purpose against location (section **Error! Reference source not found.**)
        For each series of observed place records that start and end at home
            Create a TOUR object for the PERSON
            For each series of observed place records that make up a linked trip within the tour
                Create and attribute a TRIP object (section **Error! Reference source not found.**)
                For each leg of the trip involving joint travel
                    Create a JOINT_ULTRIP object for the HOUSEHOLD
        Identify partial tours
        Populate tour attributes (section **Error! Reference source not found.**)
    Match JOINT_ULTRIP objects into joint travel episodes (section**Error! Reference source not found.**)
    Compute escort related attributes for TRIPs
    Create and attribute a JOINT_TOUR object for each fully joint tour (section**Error! Reference source not found.**)
    Compute escort related attributes for partially joint tours

FIGURE 75: OVERVIEW OF THE COMPUTATIONAL PROCEDURE UNDERLYING THE SURVEY PROCESSING APPLICATION (SPA)

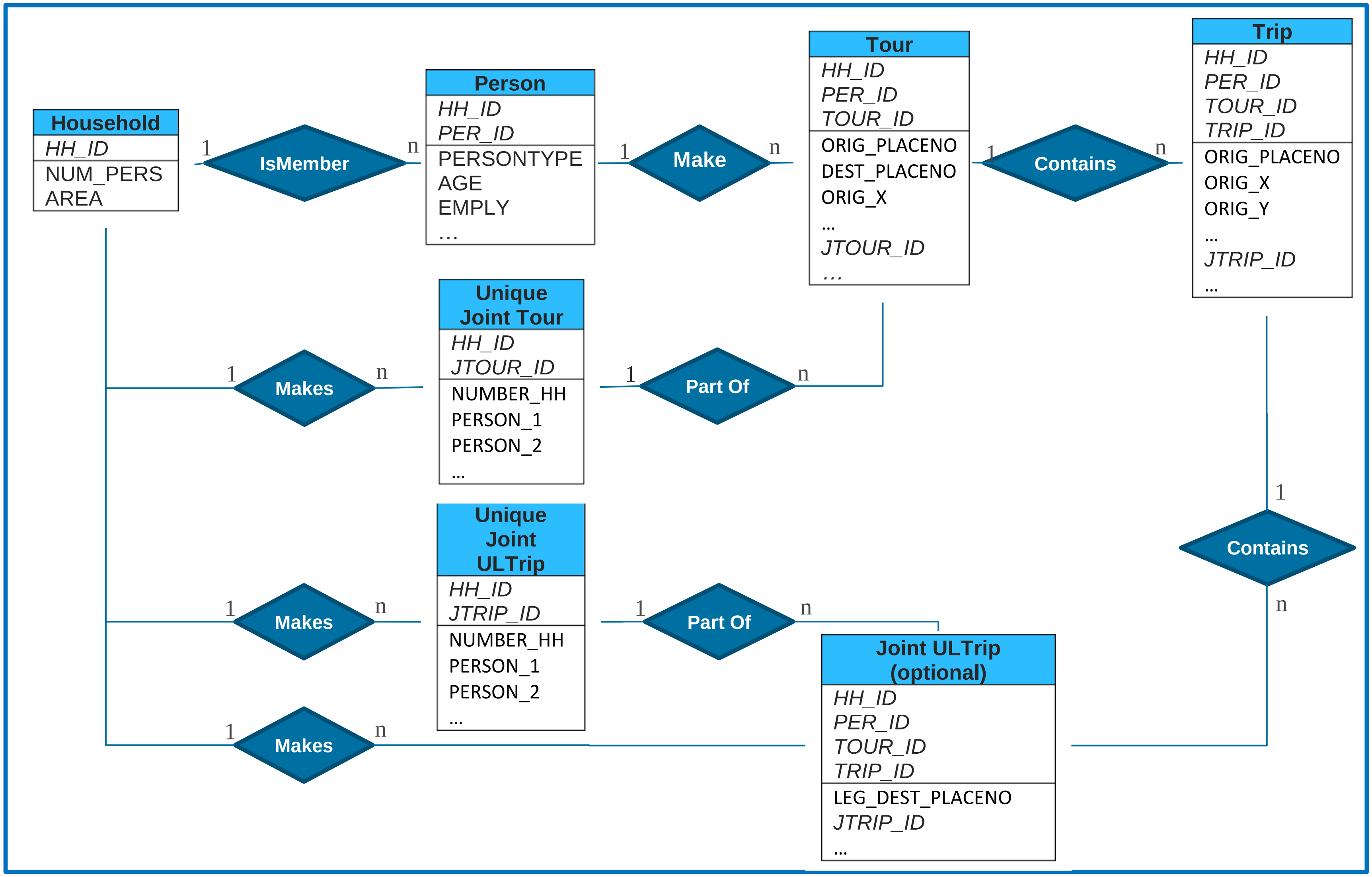


FIGURE 76: ENTITY-RELATIONSHIP DIAGRAM ILLUSTRATING THE RELATIONSHIPS BETWEEN DATA TABLES PRODUCED BY THE SPA (FIELDS LABELED IN *ITALIC* ARE PART OF THE PRIMARY KEY OF THE ASSOCIATED DATA ENTITY)

TABLE 41: SPA OUTPUTS

FILE NAME	DESCRIPTION
Households.csv	Each row contains selected attributes of an observed household. See Table 42 for the definition of table fields.
Persons.csv	Each row contains selected attributes of an observed person. See Table 43 for the definition of table fields.
Tours.csv	Each row contains attributes derived for an observed person tour. See Table 44 for the definition of table fields.
Trips.csv	Each row contains attributes derived for an observed person trip. See Table 45 for the definition of table fields.
Unique_joint_tours.csv	Each row contains attributes describing a fully joint tour made by multiple household members. See Table 46 for the definition of table fields.
Unique_joint_trips.csv	Each row contains attributes describing a joint trip (unlinked) made by multiple household members. See Table 47 for the definition of table fields.
Joint_ultrips.csv	Optional output used for analyzing data errors relating to joint travel episodes. Each row contains selected attributes of an unlinked person trip that is part of a joint trip. See Table 48 for the definition of table fields.

Error_log.txt	Text file containing error and warning messages about unresolved data anomalies.
Recode_log.txt	Text file describing assumptions and recoding made to resolve known data anomalies and inconsistencies.

TABLE 42: DEFINITION OF VARIABLES IN "HOUSEHOLDS.CSV"

NAME	DESCRIPTION	TYPE	VALUE RANGE
HH_ID	Household ID	Integer	
NUM_PERS	Number of person records found for the household in the Person file	Integer	

TABLE 43: DEFINITION OF VARIABLES IN "PERSONS.CSV"

NAME	DESCRIPTION	TYPE	VALUE RANGE
HH_ID	Household ID	Integer	
PER_ID	Person ID	Integer	
PERSONTYPE	Person Type	Integer	1=Full-time worker 2=Part-time worker 3=University student 4=Non-working adult 5=Non-working senior 6=Driving age student 7=Non-driving student 8=Pre-school
AGE	Age	Integer	
EMPLY	Employed?	Integer	1=Yes 2=No 8=DK 9=RF
HOURS	Hours work per week	Integer	RANGE: 1-150 998=DK 999=RF
EMP_CAT	Employment category	Integer	1=Employed full-time 2=Employed Part-time 3=Age 16 and over and not employed 4=Not in labor force
STUDE	Student?	Integer	1=YES - Full Time 2=YES - Part Time 3=NO

			8=DK 9=RF
SCHOL	School grade level attends	Integer	1=DAYCARE 2=NURSERY SCHOOL, PRE-SCHOOL 3=KINDERGARTEN TO GRADE 8 4=GRADE 9 TO 12 5=TECHNICAL/VOCATIONAL SCHOOL 6=2-YEAR COLLEGE (COMMUNITY COLLEGE) 7=4-YEAR COLLEGE OR UNIVERSITY 8=GRADUATE SCHOOL/PROFESSIONAL 97=OTHER, SPECIFY 98=DK 99=RF
STU_CAT	Student category	Integer	1 Student in high school and lower 2 Student in trade school, college or higher 3 Not attending school
PERSONTYPE0	Person Type prior to automated edit, if applicable	Integer	1=Full-time worker 2=Part-time worker 3=University student 4=Non-working adult 5=Non-working senior 6=Driving age student 7=Non-driving student 8=Pre-school

EMP_CAT0	Employment category prior to automated edit, if applicable	Integer	1=Employed full-time 2=Employed Part-time 3=Age 16 and over and not employed 4=Not in labor force
STU_CAT0	Student category prior to automated edit, if applicable	Integer	1 Student in high school and lower 2 Student in trade school, college or higher 3 Not attending school
ERROR	Description of error, if applicable	String	

TABLE 44: DEFINITION OF VARIABLES IN “TOURS.CSV”

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
HH_ID	Household ID		Integer	
PER_ID	Person ID	Unique within household	Integer	
TOUR_ID	Tour ID (tour number)	Unique within person, including subtours and joint tours	Integer	
ORIG_PLACENO	Origin place number	Not known if partial tour at start of day	Integer	=nan if PARTIAL_TOUR==1 >0 otherwise
DEST_PLACENO	Primary Destination place number	Not known if partial at end of day	Integer	=nan if PARTIAL_TOUR==2 >0 otherwise
ORIG_X	Origin X Coordinate (long)	Not known if partial tour at start of day	Real	=nan if PARTIAL_TOUR==1 >0 otherwise
ORIG_Y	Origin Y Coordinate (lat)	Not known if partial tour at start of day	Real	=nan if PARTIAL_TOUR==1 >0 otherwise
ORIG_TAZ	Origin TAZ	Not yet available; Not known if partial tour at start of day	Integer	=nan if PARTIAL_TOUR==1 >0 otherwise
ORIG_MAZ	Origin MAZ	Not yet available; Not known if partial tour at start of day	Integer	=nan if PARTIAL_TOUR==1 >0 otherwise
DEST_X	Destination X Coordinate	Not known if partial at end of day	Real	=nan if PARTIAL_TOUR==2 >0 otherwise
DEST_Y	Destination Y Coordinate	Not known if partial at end of day	Real	=nan if PARTIAL_TOUR==2 >0 otherwise
DEST_TAZ	Destination TAZ	Not yet available; Not known if partial tour at start of day	Integer	=nan if PARTIAL_TOUR==2 >0 otherwise
DEST_MAZ	Destination MAZ	Not yet available; Not known if partial tour at start of day	Integer	=nan if PARTIAL_TOUR==2 >0 otherwise

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
DEST_MODE	Mode to primary destination	Not known if partial at end of day	Integer	nan=Partial at end of day (PARTIAL_TOUR==2) 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ORIG_MODE	Mode to origin	Not known if partial tour at start of day	Integer	nan=Partial at start of day (PARTIAL_TOUR==1) 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
TOURPURP	Tour Purpose	Determined using score-based method for non-partial tours; Assigned to first or last place of the day if partial at start or end of day	Integer	1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
TOURMODE	Tour Mode		Integer	1=Auto SOV 2=Auto 2 Person (Free) 3=Auto 3+ Person (Free) 4=Walk 5=Bike/Moped 6=Walk-Transit 7=PNR-Transit 8=KNR-Transit 9=School Bus 10=Taxi\Shuttle 11=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
DRIVER	if person was an auto driver for any trip on tour?		Integer	1=driver of auto mode 0=otherwise
ANCHOR_DEPART_HOUR	Tour departure hour	Hour leaving tour origin	Integer	0-23
ANCHOR_DEPART_MIN	Tour departure minute	Minute leaving tour origin	Integer	0-59
ANCHOR_DEPART_BIN	Tour departure in time window bin number		Integer	1-48
PRIMDEST_ARRIVE_HOUR	Primary Destination arrival hour	Hour arriving at Primary Destination	Integer	0-23
PRIMDEST_ARRIVE_MIN	Primary Destination arrival minute	Minute arriving at Primary Destination	Integer	0-59
PRIMDEST_ARRIVE_BIN	Primary Destination arrival in time window bin number		Integer	1-48
PRIMDEST_DEPART_HOUR	Primary Destination departure hour	Hour leaving Primary Destination	Integer	0-23
PRIMDEST_DEPART_MIN	Primary Destination departure minute	Minute leaving Primary Destination	Integer	0-59
PRIMDEST_DEPART_BIN	Primary Destination departure in time window bin number		Integer	1-48
ANCHOR_ARRIVE_HOUR	Tour arrival hour	Hour arriving back at tour origin	Integer	0-23
ANCHOR_ARRIVE_MIN	Tour arrival minute	Minute arriving back at tour origin	Integer	0-59

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ANCHOR_ARRIVE_BIN	Tour arrival in time window bin number		Integer	1-48
TOUR_DUR_HR	Tour duration hours	Hours difference between anchor departure and anchor arrival	Integer	0-23
TOUR_DUR_MIN	Tour duration minutes	Residual minutes (over hours) between anchor departure and anchor arrival	Integer	0-59
TOUR_DUR_BIN	Tour duration in number of time window bins		Integer	0-47
MAJOR_UNIV_DEST	1 if destination is major university, else 0	Not yet available	Integer	
SPEC_EVENT_DEST	1 if destination is special event, else 0	Not yet available	Integer	
IS_SUBTOUR	Is tour an at-work subtour?		Integer	0/1
PARENT_TOUR_ID	If IS_SUBTOUR==1, the ID of the parent At-Work Subtour, else 0		Integer	>=0

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
PARENT_TOUR_MODE	if IS_SUBTOUR==1, the TOURMODE of the parent work tour, else 0		Integer	nan=Partial at end of day (PARTIAL_TOUR==2) 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
NUM_SUBTOURS	number of At-work subtours if the tour is a work tour, else 0		Integer	>=0
CHILD_TOUR_ID_1	The ID of the 1st child At-Work Subtour (0 if HAS_SUBTOUR==0)		Integer	>=0
CHILD_TOUR_ID_2	The ID of the 2nd child At-Work Subtour (0 if HAS_SUBTOUR==0)		Integer	>=0
CHILD_TOUR_ID_3	The ID of the 3rd child At-Work Subtour (0 if HAS_SUBTOUR==0)		Integer	>=0
ESCORTED_TOUR	1 if the tour includes a pickup or drop-off by another household member		Integer	determined based on all constituting trips with JOINT=2
CHAUFFUER_ID	The Person ID of the chauffeur if the driver is a household member		Integer	
ESCORTING_TOUR	1 if the tour includes a pickup or drop-off of another HH member		Integer	
NUM_PERSONS_ESCORTED	The number of persons being picked-up or dropped-off on the tour		Integer	

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ESCORT_PERS_1	The Person ID of the first person being escorted (order not important)		Integer	
ESCORT_PERS_2	The Person ID of the second person being escorted (order not important)		Integer	
ESCORT_PERS_3	The Person ID of the third person being escorted (order not important)		Integer	
ESCORT_PERS_4	The Person ID of the fourth person being escorted (order not important)		Integer	
ESCORT_PERS_5	The Person ID of the fifth person being escorted (order not important)		Integer	
OUTBOUND_STOPS	Number of outbound stops		Integer	>=0
INBOUND_STOPS	Number of inbound stops		Integer	>=0
OSTOP_1_PLACENO	Outbound stop 1 place number		Integer	>0 if OUTBOUND_STOPS>=1
OSTOP_1_X	Outbound stop 1 X Coordinate		Real	
OSTOP_1_Y	Outbound stop 1 Y Coordinate		Real	
OSTOP_1_TAZ	Outbound stop 1 TAZ	Not yet available	Integer	
OSTOP_1_MAZ	Outbound stop 1 MAZ	Not yet available	Integer	

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_1_ARR_HR	Outbound stop 1 arrival hour		Integer	0-23 if OUTBOUND_STOPS>=1
OSTOP_1_ARR_MIN	Outbound stop 1 arrival minute		Integer	0-59 if OUTBOUND_STOPS>=1
OSTOP_1_ARR_BIN			Integer	1-48 if OUTBOUND_STOPS>=1
OSTOP_1_DEP_HR	Outbound stop 1 departure hour		Integer	0-23 if OUTBOUND_STOPS>=1
OSTOP_1_DEP_MIN	Outbound stop 1 departure minute		Integer	0-59 if OUTBOUND_STOPS>=1
OSTOP_1_DEP_BIN			Integer	1-48 if OUTBOUND_STOPS>=1
OSTOP_1_DUR_HR	Outbound stop 1 duration hours		Integer	0-23 if OUTBOUND_STOPS>=1
OSTOP_1_DUR_MIN	Outbound stop 1 duration minutes		Integer	0-59 if OUTBOUND_STOPS>=1
OSTOP_1_DUR_BIN			Integer	0-47 if OUTBOUND_STOPS>=1
OSTOP_1_PURP	Purpose for outbound stop 1		Integer	>0 if OUTBOUND_STOPS>=1

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_1_MODE	Mode to outbound stop 1		Integer	If OUTBOUND_STOPS>=1: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_1_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
OSTOP_1_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
OSTOP_1_MAJUNIV	1 if major university, else 0	Not yet available	Integer	
OSTOP_1_SPECEVENT	1 if special event, else 0	Not yet available	Integer	
OSTOP_2_PLACENO	Outbound stop 2 place number		Integer	>0 if OUTBOUND_STOPS>=2
OSTOP_2_X	Outbound stop 2 X Coordinate		Real	
OSTOP_2_Y	Outbound stop 2 Y Coordinate		Real	
OSTOP_2_TAZ	Outbound stop 2 TAZ	Not yet available	Integer	
OSTOP_2_MAZ	Outbound stop 2 MAZ	Not yet available	Integer	
OSTOP_2_ARR_HR	Outbound stop 2 arrival hour		Integer	0-23 if OUTBOUND_STOPS>=2
OSTOP_2_ARR_MIN	Outbound stop 2 arrival minute		Integer	0-59 if OUTBOUND_STOPS>=2
OSTOP_2_ARR_BIN			Integer	1-48 if OUTBOUND_STOPS>=2
OSTOP_2_DEP_HR	Outbound stop 2 departure hour		Integer	0-23 if OUTBOUND_STOPS>=2
OSTOP_2_DEP_MIN	Outbound stop 2 departure minute		Integer	0-59 if OUTBOUND_STOPS>=2
OSTOP_2_DEP_BIN			Integer	1-48 if OUTBOUND_STOPS>=2

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_2_DUR_HR	Outbound stop 2 duration hours		Integer	0-23 if OUTBOUND_STOPS>=2
OSTOP_2_DUR_MIN	Outbound stop 2 duration minutes		Integer	0-59 if OUTBOUND_STOPS>=2
OSTOP_2_DUR_BIN			Integer	0-47 if OUTBOUND_STOPS>=2
OSTOP_2_PURP	Purpose for outbound stop 2		Integer	>0 if OUTBOUND_STOPS>=2
OSTOP_2_MODE	Mode to outbound stop 2		Integer	If OUTBOUND_STOPS>=2: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other
OSTOP_2_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
OSTOP_2_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
OSTOP_2_MAJUNIV	1 if major university, else 0		Integer	
OSTOP_2_SPECEVENT	1 if special event, else 0		Integer	

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_3_PLACENO	Outbound stop 3 place number		Integer	>0 if OUTBOUND_STOPS>=3
OSTOP_3_X	Outbound stop 3 X Coordinate		Real	
OSTOP_3_Y	Outbound stop 3 Y Coordinate		Real	
OSTOP_3_TAZ	Outbound stop 3 TAZ	Not yet available	Integer	
OSTOP_3_MAZ	Outbound stop 3 MAZ	Not yet available	Integer	
OSTOP_3_ARR_HR	Outbound stop 3 arrival hour		Integer	0-23 if OUTBOUND_STOPS>=3
OSTOP_3_ARR_MIN	Outbound stop 3 arrival minute		Integer	0-59 if OUTBOUND_STOPS>=3
OSTOP_3_ARR_BIN			Integer	1-48 if OUTBOUND_STOPS>=3
OSTOP_3_DEP_HR	Outbound stop 3 departure hour		Integer	0-23 if OUTBOUND_STOPS>=3
OSTOP_3_DEP_MIN	Outbound stop 3 departure minute		Integer	0-59 if OUTBOUND_STOPS>=3
OSTOP_3_DEP_BIN			Integer	1-48 if OUTBOUND_STOPS>=3
OSTOP_3_DUR_HR	Outbound stop 3 duration hours		Integer	0-23 if OUTBOUND_STOPS>=3
OSTOP_3_DUR_MIN	Outbound stop 3 duration minutes		Integer	0-59 if OUTBOUND_STOPS>=3
OSTOP_3_DUR_BIN			Integer	0-47 if OUTBOUND_STOPS>=3
OSTOP_3_PURP	Purpose for outbound stop 3		Integer	>0 if OUTBOUND_STOPS>=3

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_3_MODE	Mode to outbound stop 3		Integer	If OUTBOUND_STOPS>=3: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_3_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
OSTOP_3_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
OSTOP_3_MAJUNIV	1 if major university, else 0		Integer	
OSTOP_3_SPECEVENT	1 if special event, else 0		Integer	
OSTOP_4_PLACENO	Outbound stop 4 place number		Integer	>0 if OUTBOUND_STOPS>=4
OSTOP_4_X	Outbound stop 4 X Coordinate		Real	
OSTOP_4_Y	Outbound stop 4 Y Coordinate		Real	
OSTOP_4_TAZ	Outbound stop 4 TAZ	Not yet available	Integer	
OSTOP_4_MAZ	Outbound stop 4 MAZ	Not yet available	Integer	
OSTOP_4_ARR_HR	Outbound stop 4 arrival hour		Integer	0-23 if OUTBOUND_STOPS>=4
OSTOP_4_ARR_MIN	Outbound stop 4 arrival minute		Integer	0-59 if OUTBOUND_STOPS>=4
OSTOP_4_ARR_BIN			Integer	1-48 if OUTBOUND_STOPS>=4
OSTOP_4_DEP_HR	Outbound stop 4 departure hour		Integer	0-23 if OUTBOUND_STOPS>=4
OSTOP_4_DEP_MIN	Outbound stop 4 departure minute		Integer	0-59 if OUTBOUND_STOPS>=4
OSTOP_4_DEP_BIN			Integer	1-48 if OUTBOUND_STOPS>=4

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OSTOP_4_DUR_HR	Outbound stop 4 duration hours		Integer	0-23 if OUTBOUND_STOPS>=4
OSTOP_4_DUR_MIN	Outbound stop 4 duration minutes		Integer	0-59 if OUTBOUND_STOPS>=4
OSTOP_4_DUR_BIN			Integer	0-47 if OUTBOUND_STOPS>=4
OSTOP_4_PURP	Purpose for outbound stop 4		Integer	>0 if OUTBOUND_STOPS>=4
OSTOP_4_MODE	Mode to outbound stop 4		Integer	If OUTBOUND_STOPS>=4: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other
OSTOP_4_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
OSTOP_4_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
OSTOP_4_MAJUNIV	1 if major university, else 0		Integer	
OSTOP_4_SPECEVENT	1 if special event, else 0		Integer	

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_1_PLACENO	Inbound stop 1 place number		Integer	>0 if INBOUND_STOPS>=1
ISTOP_1_X	Inbound stop 1 X Coordinate		Real	
ISTOP_1_Y	Inbound stop 1 Y Coordinate		Real	
ISTOP_1_TAZ	Outbound stop 1 TAZ	Not yet available	Integer	
ISTOP_1_MAZ	Outbound stop 1 MAZ	Not yet available	Integer	
ISTOP_1_ARR_HR	Inbound stop 1 arrival hour		Integer	0-23 if INBOUND_STOPS>=1
ISTOP_1_ARR_MIN	Inbound stop 1 arrival minute		Integer	0-59 if INBOUND_STOPS>=1
ISTOP_1_ARR_BIN			Integer	1-48 if INBOUND_STOPS>=1
ISTOP_1_DEP_HR	Inbound stop 1 departure hour		Integer	0-23 if INBOUND_STOPS>=1
ISTOP_1_DEP_MIN	Inbound stop 1 departure minute		Integer	0-59 if INBOUND_STOPS>=1
ISTOP_1_DEP_BIN			Integer	1-48 if INBOUND_STOPS>=1
ISTOP_1_DUR_HR	Inbound stop 1 duration hours		Integer	0-23 if INBOUND_STOPS>=1
ISTOP_1_DUR_MIN	Inbound stop 1 duration minutes		Integer	0-59 if INBOUND_STOPS>=1
ISTOP_1_DUR_BIN			Integer	0-47 if INBOUND_STOPS>=1
ISTOP_1_PURP	Purpose for Inbound stop 1		Integer	>0 if INBOUND_STOPS>=1

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_1_MODE	Mode to inbound stop 1		Integer	If INBOUND_STOPS>=1: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_1_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
ISTOP_1_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
ISTOP_1_MAJUNIV	1 if major university, else 0		Integer	
ISTOP_1_SPECEVENT	1 if special event, else 0		Integer	
ISTOP_2_PLACENO	Inbound stop 2 place number		Integer	>0 if INBOUND_STOPS>=2
ISTOP_2_X	Inbound stop 2 X Coordinate		Real	
ISTOP_2_Y	Inbound stop 2 Y Coordinate		Real	
ISTOP_2_TAZ	Inbound stop 2 TAZ	Not yet available	Integer	
ISTOP_2_MAZ	Inbound stop 2 MAZ	Not yet available	Integer	
ISTOP_2_ARR_HR	Inbound stop 2 arrival hour		Integer	0-23 if INBOUND_STOPS>=2
ISTOP_2_ARR_MIN	Inbound stop 2 arrival minute		Integer	0-59 if INBOUND_STOPS>=2
ISTOP_2_ARR_BIN			Integer	1-48 if INBOUND_STOPS>=2
ISTOP_2_DEP_HR	Inbound stop 2 departure hour		Integer	0-23 if INBOUND_STOPS>=2
ISTOP_2_DEP_MIN	Inbound stop 2 departure minute		Integer	0-59 if INBOUND_STOPS>=2
ISTOP_2_DEP_BIN			Integer	1-48 if INBOUND_STOPS>=2
ISTOP_2_DUR_HR	Inbound stop 2 duration hours		Integer	0-23 if INBOUND_STOPS>=2
ISTOP_2_DUR_MIN	Inbound stop 2 duration minutes		Integer	0-59 if INBOUND_STOPS>=2
ISTOP_2_DUR_BIN			Integer	0-47 if INBOUND_STOPS>=2

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_2_PURP	Purpose for Inbound stop 2		Integer	>0 if INBOUND_STOPS>=2
ISTOP_2_MODE	Mode to inbound stop 2		Integer	If INBOUND_STOPS>=2: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_2_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
ISTOP_2_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
ISTOP_2_MAJUNIV	1 if major university, else 0		Integer	
ISTOP_2_SPECEVENT	1 if special event, else 0		Integer	
ISTOP_3_PLACENO	Inbound stop 3 place number		Integer	>0 if INBOUND_STOPS>=3
ISTOP_3_X	Inbound stop 3 X Coordinate		Real	
ISTOP_3_Y	Inbound stop 3 Y Coordinate		Real	
ISTOP_3_TAZ	Inbound stop 3 TAZ	Not yet available	Integer	
ISTOP_3_MAZ	Inbound stop 3 MAZ	Not yet available	Integer	
ISTOP_3_ARR_HR	Inbound stop 3 arrival hour		Integer	0-23 if INBOUND_STOPS>=3
ISTOP_3_ARR_MIN	Inbound stop 3 arrival minute		Integer	0-59 if INBOUND_STOPS>=3
ISTOP_3_ARR_BIN			Integer	1-48 if INBOUND_STOPS>=3
ISTOP_3_DEP_HR	Inbound stop 3 departure hour		Integer	0-23 if INBOUND_STOPS>=3
ISTOP_3_DEP_MIN	Inbound stop 3 departure minute		Integer	0-59 if INBOUND_STOPS>=3
ISTOP_3_DEP_BIN			Integer	1-48 if INBOUND_STOPS>=3
ISTOP_3_DUR_HR	Inbound stop 3 duration hours		Integer	0-23 if INBOUND_STOPS>=3
ISTOP_3_DUR_MIN	Inbound stop 3 duration minutes		Integer	0-59 if INBOUND_STOPS>=3
ISTOP_3_DUR_BIN			Integer	0-47 if INBOUND_STOPS>=3

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_3_PURP	Purpose for Inbound stop 3		Integer	>0 if INBOUND_STOPS>=3
ISTOP_3_MODE	Mode to inbound stop 3		Integer	If INBOUND_STOPS>=3: 1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_3_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
ISTOP_3_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
ISTOP_3_MAJUNIV	1 if major university, else 0		Integer	
ISTOP_3_SPECEVENT	1 if special event, else 0		Integer	
ISTOP_4_PLACENO	Inbound stop 4 place number		Integer	>0 if INBOUND_STOPS>=4
ISTOP_4_X	Inbound stop 4 X Coordinate		Real	
ISTOP_4_Y	Inbound stop 4 Y Coordinate		Real	
ISTOP_4_TAZ	Inbound stop 1 TAZ	Not yet available	Integer	
ISTOP_4_MAZ	Inbound stop 1 MAZ	Not yet available	Integer	
ISTOP_4_ARR_HR	Inbound stop 4 arrival hour		Integer	0-23 if INBOUND_STOPS>=4
ISTOP_4_ARR_MIN	Inbound stop 4 arrival minute		Integer	0-59 if INBOUND_STOPS>=4
ISTOP_4_ARR_BIN			Integer	1-48 if INBOUND_STOPS>=4
ISTOP_4_DEP_HR	Inbound stop 4 departure hour		Integer	0-23 if INBOUND_STOPS>=4
ISTOP_4_DEP_MIN	Inbound stop 4 departure minute		Integer	0-59 if INBOUND_STOPS>=4
ISTOP_4_DEP_BIN			Integer	1-48 if INBOUND_STOPS>=4
ISTOP_4_DUR_HR	Inbound stop 4 duration hours		Integer	0-23 if INBOUND_STOPS>=4
ISTOP_4_DUR_MIN	Inbound stop 4 duration minutes		Integer	0-59 if INBOUND_STOPS>=4
ISTOP_4_DUR_BIN			Integer	0-47 if INBOUND_STOPS>=4

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_4_PURP	Purpose for Inbound stop 4		Integer	>0 if INBOUND_STOPS>=4
ISTOP_4_MODE	Mode to inbound stop 4		Integer	1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ISTOP_4_ESCORT_ID	The ID of the person being picked-up or dropped-off if PU/DO		Integer	
ISTOP_4_PUDO	1 if picked-up, 2 if dropped-off, 0 if neither		Integer	
ISTOP_4_MAJUNIV	1 if major university, else 0		Integer	
ISTOP_4_SPECEVENT	1 if special event, else 0		Integer	
PEREXPFACT	Person Level Expansion factor	Not yet available		
HHEXPFACT	Household Level Expansion factor	Not yet available		
PERSONTYPE	Person Type (1-8)		Integer	1=Full-time worker 2=Part-time worker 3=University student 4=Non-working adult 5=Non-working senior 6=Driving age student 7=Non-driving student 8=Pre-school
FULLY_JOINT	1 for fully joint tour; 0 otherwise		Integer	0=No 1=FULLY JOINT
PARTIAL_TOUR	0 if not partial, 1 if starts not at home, and 2 if ends not at home		Integer	0=NOT_PARTIAL 1=PARTIAL_START 2=PARTIAL_END

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
JTOUR_ID	Joint Tour ID if part of a fully joint tour (FULLY_JOINT==1)		Integer	
ERROR	Description of error, if applicable		String	
JOINT_STATUS	4-way classification of a tour		Integer	1=independent tour 2=partially joint tour 3=fully joint tour 4=problematic, fully or partially joint tour
JOINT_TOUR_PURP	Purpose of the joint tour	all person tours that are part of this joint tour have the same value	Integer	1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
DIST	Total tour distance in feet		Float	>=0

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
OUT_ESCORT_TYPE	Outbound escort type		Integer	1=Ride share 2=Pure escort 3=No escort
OUT_CHAUFFUER_ID	Outbound escorting chauffer id		Integer	
OUT_CHAUFFUER_PURP	Outbound escorting tour purpose		Integer	1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
OUT_CHAUFFUER_PTYPE	Outbound escorting chauffer person type		Integer	1=Full-time worker 2=Part-time worker 3=University student 4=Non-working adult 5=Non-working senior 6=Driving age student

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				7=Non-driving student 8=Pre-school
INB_ESCORT_TYPE	Inbound escort type		Integer	1=Ride share 2=Pure escort 3=No escort
INB_CHAUFFUER_ID	Inbound escorting chauffer id		Integer	
INB_CHAUFFUER_PURP	Inbound escorting tour purpose		Integer	1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
INB_CHAUFFUER_PTYPE	Inbound escorting chauffer person type		Integer	1=Full-time worker 2=Part-time worker 3=University student 4=Non-working adult 5=Non-working senior

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				6=Driving age student 7=Non-driving student 8=Pre-school
OUT_ESCORTING_TYPE	Outbound escorting type		Integer	1=Ride share 2=Pure escort 3=No escort
INB_ESCORTING_TYPE	Inbound escorting type		Integer	1=Ride share 2=Pure escort 3=No escort
OUT_ESCORTEE_TOUR_PURP	Outbound escortee tour purpose		Integer	1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
INB_ESCORTEE_TOUR_PURP	Inbound escortee tour purpose		Integer	1=Work 2=University

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
OUT_ESCORTING_EPISODES	Number of outbound escorting episodes		Integer	>=0
INB_ESCORTING_EPISODES	Number of inbound escorting episodes		Integer	>=0

TABLE 45: DEFINITION OF VARIABLES IN "TRIPS.CSV"

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
HH_ID	Household ID		Integer	>0
PER_ID	Person ID		Integer	>0
TOUR_ID	Tour ID (tour number)		Integer	>0
TRIP_ID	Trip ID (trip number)	Unique within tours	Integer	>0
ORIG_PLACENO	Origin Place no.		Integer	>0
ORIG_X	Origin X Coordinate (long)		Real	
ORIG_Y	Origin Y Coordinate (lat)		Real	
ORIG_TAZ	Origin TAZ	not yet available	Integer	
ORIG_MAZ	Origin MAZ	not yet available	Integer	
DEST_PLACENO	Destination Place no.		Integer	>0
DEST_X	Destination X Coordinate		Real	
DEST_Y	Destination Y Coordinate		Real	
DEST_TAZ	Destination TAZ	not yet available	Integer	
DEST_MAZ	Destination MAZ	not yet available	Integer	

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ORIG_PURP	Origin purpose		Integer	0=Home 1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
DEST_PURP	Destination purpose		Integer	0=Home 1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
ORIG_ARR_HR	Origin arrival hour	3:00AM is the default ORIG_ARR value for the 1st trip of the day.	Integer	0-23
ORIG_ARR_MIN	Origin arrival minutes		Integer	0-59
ORIG_ARR_BIN	Origin arrival time in time window bin number		Integer	1-48
ORIG_DEP_HR	Origin departure hour		Integer	0-23
ORIG_DEP_MIN	Origin departure minutes		Integer	0-59
ORIG_DEP_BIN	Origin departure time in time window bin number		Integer	1-48
DEST_ARR_HR	Destination arrival hour		Integer	0-23
DEST_ARR_MIN	Destination arrival minutes		Integer	0-59

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
DEST_ARR_BIN	Destination departure time in time window bin number		Integer	1-48
DEST_DEP_HR	Destination departure hour	2:59AM is the default DEST_DEP value for the last trip of the day.	Integer	0-23
DEST_DEP_MIN	Destination departure minutes		Integer	0-59
DEST_DEP_BIN	Destination departure time in time window bin number		Integer	1-48
TRIP_DUR_HR	Trip duration hours (based on origin departure and destination arrival)		Integer	0-23
TRIP_DUR_MIN	Trip duration minutes (based on origin departure and destination arrival)		Integer	0-59
TRIP_DUR_BIN	Trip duration in time window bin number			0-47

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
TRIPMODE	Mode of trip		Integer	1=Auto SOV (Free) 2=Auto SOV (Pay) 3=Auto 2 Person (Free) 4=Auto 2 Person (Pay) 5=Auto 3+ Person (Free) 6=Auto 3+ Person (Pay) 7=Walk 8=Bike/Moped 9=Walk-Bus 10=Walk-Exp Bus 11=Walk-LRT 12=Walk-Commuter Rail 13=PNR-Bus 14=PNR-Exp Bus 15=PNR-LRT 16=PNR-Commuter Rail 17=KNR-Bus 18=KNR-Exp Bus 19=KNR-LRT 20=KNR-Commuter Rail 21=School Bus 22=Taxi\Shuttle 23=Other
ISDRIVER	1 if person was auto driver, else 0		Integer	1=driver of auto mode 0=passenger of auto mode or non-auto mode

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
CHAUFFUER_ID	Person number of chauffuer if driver is household member	applicable only if person is escorted on the trip	Integer	>0 if ESCORTED>0 =nan if ESCORTED=0
AUTO_OCC	Automobile occupancy for auto trips, else 0		Integer	>0 if TRIPMODE=1~6 =0 if TRIPMODE>6 (non-auto)
TOURMODE	Mode of tour		Integer	1=Auto SOV 2=Auto 2 Person (Free) 3=Auto 3+ Person (Free) 4=Walk 5=Bike/Moped 6=Walk-Transit 7=PNR-Transit 8=KNR-Transit 9=School Bus 10=Taxi\Shuttle 11=Other

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
TOURPURP	Purpose of tour		Integer	0=Home 1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
BOARDING_PLACENO	Transit boarding place number	Applicable only to transit Assume same as origin if no linking	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
BOARDING_PNAME	Transit boarding place name	Applicable only to transit Assume same as origin if no linking	Text	nan: if TRIPMODE<9 or TRIPMODE>20
BOARDING_X	Transit boarding X coordinate	Applicable only to transit Assume same as origin if no linking	Real	nan: if TRIPMODE<9 or TRIPMODE>20

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
BOARDING_Y	Transit boarding Y coordinate	Applicable only to transit Assume same as origin if no linking	Real	nan: if TRIPMODE<9 or TRIPMODE>20
BOARDING_TAP	Transit boarding transit access point	Applicable only to transit Assume same as origin if no linking	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
ALIGHTING_PLACENO	Transit alighting place number	Applicable only to transit Assume same as destination if no linking	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
ALIGHTING_PNAME	Transit alighting place name	Applicable only to transit Assume same as destination if no linking	Text	nan: if TRIPMODE<9 or TRIPMODE>20
ALIGHTING_X	Transit alighting X coordinate	Applicable only to transit Assume same as destination if no linking	Real	nan: if TRIPMODE<9 or TRIPMODE>20
ALIGHTING_Y	Transit alighting Y coordinate	Applicable only to transit Assume same as destination if no linking	Real	nan: if TRIPMODE<9 or TRIPMODE>20
ALIGHTING_TAP	Transit alighting transit access point	Applicable only to transit Assume same as destination if no linking	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
TRANSIT_NUM_XFERS	Transit number of transfers	Applicable only to transit	Integer	

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
TRANSIT_ROUTE_1	First transit route from boarding to alighting	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
TRANSIT_MODE_1	First transit mode from boarding to alighting	Applicable only to transit	Integer	1=LOCAL BUS (Metro – Tri-Met Bus) 2=LIGHT RAIL (Metro – MAX of WES Rail) 3=BUS RAPID TRANSIT (LCOG-EMX, Metro–Streetcar) 4=OTHER BUS (C-Tran, SMART, SAM, CAT, RTC–Limited Bus) 5=EXPRESS BUS (LCOG, RTC) OSHU AERIAL TRAM (Metro) 6=CHERRIOTS (Salem-Keizer) 7=PARK & RIDE SHUTTLE 8=CARTS (Chemeketa Area Regional Transport System) 9=SMART (South Metro Area Regional Transit) 97=OTHER, SPECIFY 99=DON'T KNOW / REFUSED nan=if TRIPMODE<9 or TRIPMODE>20
XFER_1_PLACENO	First transfer place number	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes)

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				=nan if TRIPMODE<9 or TRIPMODE>20
XFER_1_PNAME	First transfer place name	Applicable only to transit	Text	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_1_X	First transfer X coordinate	Applicable only to transit	Real	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_1_Y	First transfer Y coordinate	Applicable only to transit	Real	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_1_TAP	First transfer transit access point	Applicable only to transit	Integer	>0 if TRIPMODE=9-20(transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
TRANSIT_ROUTE_2	Second transit route from boarding to alighting	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
TRANSIT_MODE_2	Second transit mode from boarding to alighting	Applicable only to transit	Integer	1=LOCAL BUS (Metro – Tri-Met Bus) 2=LIGHT RAIL (Metro – MAX of WES Rail) 3=BUS RAPID TRANSIT (LCOG-EMX, Metro–Streetcar) 4=OTHER BUS (C-Tran, SMART, SAM, CAT, RTC–Limited Bus) 5=EXPRESS BUS (LCOG, RTC) OSHU AERIAL TRAM (Metro) 6=CHERRIOTS (Salem-Keizer) 7=PARK & RIDE SHUTTLE 8=CARTS (Chemeketa Area Regional Transport System) 9=SMART (South Metro Area Regional Transit) 97=OTHER, SPECIFY 99=DON'T KNOW / REFUSED nan=if TRIPMODE<9 or TRIPMODE>20
XFER_2_PLACENO	Second transfer place number	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
XFER_2_PNAME	Second transfer place name	Applicable only to transit	Text	nan: if TRIPMODE<9 or TRIPMODE>20

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
XFER_2_X	Second transfer X coordinate	Applicable only to transit	Real	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_2_Y	Second transfer Y coordinate	Applicable only to transit	Real	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_2_TAP	Second transfer transit access point	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
TRANSIT_ROUTE_3	Third transit route from boarding to alighting	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
TRANSIT_MODE_3	Third transit mode from boarding to alighting	Applicable only to transit	Integer	1=LOCAL BUS (Metro – Tri-Met Bus) 2=LIGHT RAIL (Metro – MAX of WES Rail) 3=BUS RAPID TRANSIT (LCOG-EMX, Metro–Streetcar) 4=OTHER BUS (C-Tran, SMART, SAM, CAT, RTC–Limited Bus) 5=EXPRESS BUS (LCOG, RTC) OSHU AERIAL TRAM (Metro) 6=CHERRIOTS (Salem-Keizer) 7=PARK & RIDE SHUTTLE 8=CARTS (Chemeketa Area

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				Regional Transport System) 9=SMART (South Metro Area Regional Transit) 97=OTHER, SPECIFY 99=DON'T KNOW / REFUSED nan=if TRIPMODE<9 or TRIPMODE>20
XFER_3_PLACENO	Third transfer place number	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes) =nan if TRIPMODE<9 or TRIPMODE>20
XFER_3_PNAME	Third transfer place name	Applicable only to transit	Text	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_3_X	Third transfer X coordinate	Applicable only to transit	Real	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_3_Y	Third transfer Y coordinate	Applicable only to transit	Real	nan: if TRIPMODE<9 or TRIPMODE>20
XFER_3_TAP	Third transfer transit access point	Applicable only to transit	Integer	>0 if TRIPMODE=9-20 (transit modes)

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
				=nan if TRIPMODE<9 or TRIPMODE>20
PARKING_PLACENO	Parking place number	Applicable only if parking location not same as destination for auto trips	Integer	>0 if TRIPMODE<9 and parking location not same as destination =nan otherwise
PARKING_PNAME	Parking place name	Applicable only if parking location not same as destination for auto trips	Text	>0 if TRIPMODE<9 and parking location not same as destination =nan otherwise
PARKING_X	Parking location X coordinate	Applicable only if parking location not same as destination for auto trips	Real	>0 if TRIPMODE<9 and parking location not same as destination =nan otherwise
PARKING_Y	Parking location Y coordinate	Applicable only if parking location not same as destination for auto trips	Real	>0 if TRIPMODE<9 and parking location not same as destination =nan otherwise
SUBTOUR	1 if trip is on an At-Work Subtour, else 0		Integer	1=At-work subtour 0=Home-based tour
IS_INBOUND	1 if trip is in inbound direction, else 0		Integer	1=Inbound direction 0=Outbound direction
TRIPS_ON_JOURNEY	Number of trips on journey to or from primary destination	If IS_INBOUND==1, tour.INBOUND_STOPS + 1, else tour.OUTBOUND_STOPS + 1	Integer	>=1
TRIPS_ON_TOUR	Total trips on tour	= 2 + outboundStops + inboundStops	Integer	>=1
ORIG_IS_TOUR_ORIG	1 if trip origin is tour anchor/origin, else 0		Integer	1=Trip origin is tour anchor/origin 0=Otherwise

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ORIG_IS_TOUR_DEST	1 if trip origin is tour primary destination, else 0		Integer	1=Trip origin is tour anchor/origin 0=Otherwise
DEST_IS_TOUR_DEST	1 if trip destination is tour primary destination, else 0		Integer	1=Trip origin is tour anchor/origin 0=Otherwise
DEST_IS_TOUR_ORIG	1 if trip destination is tour anchor/origin, else 0		Integer	1=Trip origin is tour anchor/origin 0=Otherwise
PEREXPFACT	Person Level Expansion factor	not yet available	Integer	
HHEXPFACT	Household Level Expansion factor	not yet available	Integer	
PERSONTYPE	Person Type		Integer	1=Full-time worker 2=Part-time worker 3=University student 4=Non-working adult 5=Non-working senior 6=Driving age student 7=Non-driving student 8=Pre-school
FULLY_JOINT	Parent tour value		Integer	1=Parent tour is fully joint 0=Otherwise
PARTIAL_TOUR	Parent tour value		Integer	1=Parent tour is partially recorded 0=Otherwise
JTRIP_ID	ID(s) of any Joint Unlinked Trip that is part of this linked trip. Ths ID is used to look up the joint episode in the	unique at household level; an unlinked trip can be identified as joint only if it is made with at least one other household member and	List of comma-separated integers	list of positive integers if trip is made jointly and lined up with trips from the rest of the travel group =nan otherwise

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
	Unique_Joint_Trips file. There are as many IDs as NUM_UL_JTRIPS	if the travel times and reported travel party could be lined up across multiple household members		
ESCORTED	Whether joint travel was due to person being picked up or dropped-off	Applicable only to joint trips	Integer	1=Picked-up by a hh member at ORIG 2=Dropped-off by a hh member at DEST 0=Neither nan=Not a joint trip
ESCORTING	Whether joint travel was due to person picking-up or dropping-off one or more household member	Applicable only to joint trips	Integer	1=Picking hh member up at ORIG 2=Dropped hh member off at DEST 0=Neither nan=Not a joint trip
NUM_PERSONS_ESCORTED	The total number of persons being picked-up at ORIG or dropped-off at DEST	Applicable only if person is the driver on a joint trip	Integer	>0 if joint trip with picking up or dropping off =0 if joint trip with no picking up or dropping off =nan if not a joint trip
ESCORT_PERS_1	The Person ID of the first person being escorted (order not important)	Applicable only if NUM_PERSONS_ESCORTED>0	Integer	>0 if NUM_PERSONS_ESCORTED>0 =nan otherwise

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
ESCORT_PERS_2	The Person ID of the second person being escorted (order not important)	Applicable only if NUM_PERSONS_ESCORTED>1	Integer	>0 if NUM_PERSONS_ESCORTED>1 =nan otherwise
ESCORT_PERS_3	The Person ID of the third person being escorted (order not important)	Applicable only if NUM_PERSONS_ESCORTED>2	Integer	>0 if NUM_PERSONS_ESCORTED>2 =nan otherwise
ESCORT_PERS_4	The Person ID of the fourth person being escorted (order not important)	Applicable only if NUM_PERSONS_ESCORTED>3	Integer	>0 if NUM_PERSONS_ESCORTED>3 =nan otherwise
ESCORT_PERS_5	The Person ID of the fifth person being escorted (order not important)	Applicable only if NUM_PERSONS_ESCORTED>4	Integer	>0 if NUM_PERSONS_ESCORTED>4 =nan otherwise
DEST_ESCORTING	Pick up or drop off activity at trip end		Integer	1=Picking-up by a hh member at DEST 2=Dropping-off by a hh member at DEST 3=Picking-up a non-hh member at DEST (MTC only) 4=Dropping-off a non-hh member at DEST (MTC only) 0=Neither'

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
JOINT	Indicator of whether this is a joint trip (i.e. NUM_UL_JTRIPS>0)		Integer	1=JOINT (more than 1 household member traveled together) 2=JOINT-GROUP (joint trip that has been successfully lined up with trip records from the rest of the groups; assigned a valid JTRIP_ID) 0=NOT-JOINT
NUM_UL_JTRIPS	Number of constituting unlinked trips that were made jointly with one or more household member	This is the number of IDs found in JTRIP_ID	Integer	
DIST	Total trip distance in feet		Float	>=0
ERROR	Description of error, if applicable		String	

TABLE 46: DEFINITION OF VARIABLES IN "UNIQUE_JOINT_TOURS.CSV"

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
HH_ID	Household ID		Integer	>0
JTOUR_ID	Joint tour ID	Unique within household	Integer	>0
NUMBER_HH	Number of household members making the tour together		Integer	>1
PERSON_1	ID of person 1		Integer	>0
PERSON_2	ID of person 2		Integer	>0
PERSON_3	ID of person 3		Integer	nan, >0
PERSON_4	ID of person 4		Integer	nan, >0
PERSON_5	ID of person 5		Integer	nan, >0
PERSON_6	ID of person 6		Integer	nan, >0
PERSON_7	ID of person 7		Integer	nan, >0
PERSON_8	ID of person 8		Integer	nan, >0
PERSON_9	ID of person 9		Integer	nan, >0
COMPOSITION	Composition of tour (1 = all adults, 2 = all children, 3 = mixed)	Adults = person types ('FW', 'PW', 'US', 'NW', 'RE')	Integer	1/2/3

JOINT_PURP	Joint tour purpose	In the case of differing purposes reported by participants, this is determined based on purpose hierarchy	Integer	1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other

TABLE 47: DEFINITION OF VARIABLES IN “UNIQUE_JOINT_ULTRIPS.CSV”

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
HH_ID	Household ID		Integer	>0
JTRIP_ID	Joint Unlinked Trip ID	Unique within household	Integer	>0
NUMBER_HH	Number of household members making the trip together		Integer	>1
PERSON_1	ID of person 1		Integer	>0
PERSON_2	ID of person 2		Integer	>0
PERSON_3	ID of person 3		Integer	nan, >0
PERSON_4	ID of person 4		Integer	nan, >0
PERSON_5	ID of person 5		Integer	nan, >0
PERSON_6	ID of person 6		Integer	nan, >0
PERSON_7	ID of person 7		Integer	nan, >0
PERSON_8	ID of person 8		Integer	nan, >0
PERSON_9	ID of person 9		Integer	nan, >0
COMPOSITION	Composition of tour (1=all adults, 2=all children, 3=mixed)	Adults = person types ('FW','PW','US','NW','RE')	Integer	1/2/3

TABLE 48: DEFINITION OF VARIABLES IN "JOINT_ULTRIPS.CSV"

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
HH_ID	Household ID		Integer	>0
PER_ID	Person ID		Integer	>0
TOUR_ID	ID of the person tour that this unlinked trip is part of	Unique within person	Integer	>0
TRIP_ID	ID of the person (linked) trip that this unlinked trip is part of	Unique within tour	Integer	>0
LEG_DEST_PLACENO	Destination Place no. of this (unlinked) trip	Unique within person	Integer	>0
JTRIP_ID	Joint (unlinked) trip ID	Unique within household	Integer	>0
NUMBER_HH	Reported number of household members making the trip together (HHMEM+1)		Integer	>1
CHAUFFUER_ID	The Person ID of the chauffeur if the driver is a household member		Integer	nan, >=1
ORIG_DEP_HR	Origin departure hour		Integer	1-24
ORIG_DEP_MIN	Origin departure minutes		Integer	0-59
DEST_ARR_HR	Destination arrival hour		Integer	1-24
DEST_ARR_MIN	Destination arrival minutes		Integer	0-59

NAME	DESCRIPTION	NOTES	TYPE	VALUE RANGE
DEST_PURP	Destination purpose		Integer	0=Home 1=Work 2=University 3=School 4=Escorting 5=Shopping 6=Maintenance 7=Eat Out 8=Social/Visit 9=Discretionary 10=Work-Related 11=Loop 12=Change Mode (applicable only to partial tours) 13=Other
PARTY	PIDs of household memebers reported to be travling together	PIDs are concatenated by '_' to form a string	String	
ERROR	Description of error, if applicable		String	

Transit On-Board Survey

The transit on-board survey was coded using a Stata script. The script first codes a purpose for each origin and destination that is consistent with the purposes used in the model. Resident status was used to identify overnight visitor transit trips and Mexican resident transit trips. If the airport was provided as an origin or destination, the trip was identified as a San Diego airport trip (the data was collected prior to the CBX terminal opening). Once trip purpose was identified, tour purpose was coded consistent with trip purpose, except for the following:

- The tour purpose for non-home-based trips was coded according to a hierarchy (work>school>maintenance>discretionary) in which the highest purpose for either the origin or the destination controls the purpose of the tour.
- Work-based trips were identified based on the answers to questions whether the respondent has been at work and are going somewhere other than home but are planning to return to work.
- Any trip with one end at the airport was coded as an airport trip
- Anyone staying in a hotel or non-San Diego County residents & non-Mexican residents were coded as overnight visitor tours
- Mexican resident status was used to identify Mexican resident tours
- External-internal trips were identified if made by non-residents & non-Mexican residents between home and some other location
- Any trip with an origin or destination at a special event was coded as a special event trip & tour, regardless of residence status

Next, access/egress mode (walk, PNR, or KNR) was coded at a trip level. Park-and-ride trips were coded based on any trip reporting driving and parking, driving and riding with others, or carshare. Kiss-and-ride was coded based on any trip reporting being dropped off, taking uber\lyft\etc, taking a free shuttle, and also included bicycle access\egress mode since the current version of CT-RAMP does not explicitly model bicycle access\egress separately. All other trips were coded as walk (including wheelchair, skateboard\scooter, and other). Once both access and egress ends were coded as walk, PNR, or KNR, the tour access mode was coded based on an access mode hierarchy (PNR>KNR>Walk).

The reported route sequence is analyzed next, to determine whether the record is a local-only, premium-only, or local+premium with a transfer type of transit trip. This is used to validate the best transit path utility calculation. The total number of transfers for each trip is also calculated.

Next, the processing script runs a series of imputations for non-collected or non-reported data. The first imputation is for auto sufficiency; the on-board survey collected the number of vehicles owned by the household but did not collect the number of licensed drivers in the household. Since the CT-RAMP tour mode choice models are calibrated by tour purpose and auto sufficiency (number of autos compared to number of adults), it was necessary to impute auto sufficiency. There are three categories of auto sufficiency used in market segmentation in CT-RAMP – 0 autos, autos less than adults, and autos greater than or equal to adults. A multinomial logit model was estimated using household travel survey data to predict auto sufficiency for transit trips based on household auto ownership, household size, household income, and a binary variable indicating drive-access to transit. The estimation was limited to households where:

- autos are greater than zero (zero auto households are automatically in the 0 auto sufficiency bin).
- Household size is greater than one (households with size equal to one are assumed to be an adult)
- The number of autos is less than household size (any household where cars is equal to or greater than household size is automatically in the autos equal to or greater than adults category).

Estimation results of this model are below in Table 49.

TABLE 49: AUTO SUFFICIENCY IMPUTATION MODEL FOR TRANSIT ON-BOARD SURVEY

```
Iteration 0:   log likelihood = -1297.2299
Iteration 1:   log likelihood = -801.80723
Iteration 2:   log likelihood = -675.08062
Iteration 3:   log likelihood = -649.81153
Iteration 4:   log likelihood = -647.57372
Iteration 5:   log likelihood = -647.47983
Iteration 6:   log likelihood = -647.47958
Iteration 7:   log likelihood = -647.47958

Multinomial logistic regression
Number of obs   =       2770
LR chi2(19)     =    1299.50
Prob > chi2     =     0.0000
Log likelihood = -647.47958
Pseudo R2       =     0.5009

--------------------------------------------------------------------------------
       autoSuff |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+---------------------------------------------------------------
veh_lt_adts     |  (base outcome)
----------------+---------------------------------------------------------------
veh_ge_adts     |
vehLTNonWorkers |  -.1310408   .3241781    -0.40   0.686    -.7664183    .5043366
                |
  vehicle_count |
    2 vehicles  |    4.01252   .3468213    11.57   0.000     3.332763    4.692277
    3 vehicles  |   3.842545   .4738946     8.11   0.000     2.913729    4.771362
    4 vehicles  |   4.235954   2.613241     1.62   0.105    -.8859037    9.357812
                |
       wrkrColl |
             1  |    3.08137   .8028955     3.84   0.000     1.507724    4.655017
             2  |   2.920107   .8400671     3.48   0.001     1.273606    4.566608
             3  |  -2.789711   1.355914    -2.06   0.040    -5.447254   -.1321682
                |
     hhsizeColl |
             3  |   1.163638   .3413197     3.41   0.001     .4946635    1.832612
             4  |   2.108441   .4299955     4.90   0.000     1.265665    2.951217
             5  |   2.151518   .5995605     3.59   0.000     .9764013    3.326635
                |
     incomeColl |
```

```
     $15k-$30k  |   6.011981   1.065939     5.64   0.000     3.922779    8.101183
      $30k-45k  |     3.2341   1.058795     3.05   0.002     1.158899      5.3093
      $45k-60k  |   5.570954   1.065903     5.23   0.000     3.481823    7.660086
      $60k-75k  |     3.0419   1.086399     2.80   0.005     .9125977    5.171202
     $75k-100k  |   3.336825   1.056767     3.16   0.002     1.265599     5.40805
     $100k-150  |   3.503697   1.045139     3.35   0.001     1.455262    5.552132
        $150k+  |   4.582533   1.065067     4.30   0.000      2.49504    6.670026
       Unknown  |   2.412534   1.049756     2.30   0.022     .3550494    4.470018
                |
    driveAccess |   2.785309   .8488915     3.28   0.001     1.121512    4.449106
          _cons |  -14.31472   1.565364    -9.14   0.000    -17.38278   -11.24667
--------------------------------------------------------------------------------
```

The model parameters were applied to the transit on-board survey records with number of autos greater than 0, household size greater than 1 and persons per household less than autos to generate the probability of being in the autos less than adults or autos greater than or equal to adults category, and Monte Carlo selection from the probability distribution was used to code auto sufficiency for these records.

The on-board survey also has 2,413 synthetic records which were used for light-rail transit and commuter rail station-pairs in which there were observed station to station trips but no actual survey records. These synthetic records accounted for approximately 23k rail trips. For these records, key variables such as auto sufficiency, access mode, number of transfers, and tour purpose were not available and had to be imputed. The process of imputing each variable was similar to the imputation of auto sufficiency described above. For each variable, a model was estimated from on-board survey data. A probability distribution was estimated for each synthetic rail record by applying the estimated model. A random number was drawn and a discrete choice was made from the probability distribution, and the variable was coded. The estimation results for each model are provided below in Table 50, Table 51, Table 52, and Table 53. Note that the only explanatory variables to use in each model are route number and time period. In subsequent models, the results of the previously applied model can also be used.

TABLE 50: AUTO SUFFICIENCY IMPUTATION MODEL FOR SYNTHETIC RAIL RECORDS

```
Iteration 0:   log likelihood = -78574.006
Iteration 1:   log likelihood = -75088.593
Iteration 2:   log likelihood = -74845.011
Iteration 3:   log likelihood = -74817.248
Iteration 4:   log likelihood = -74817.198
Iteration 5:   log likelihood = -74817.198

Multinomial logistic regression                   Number of obs   =      13307
                                                  LR chi2(22)     =    7513.62
                                                  Prob > chi2     =     0.0000
Log likelihood = -74817.198                       Pseudo R2       =     0.0478

------------------------------------------------------------------------------
     autoSuff |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
No_Veh        |
ROUTE_~E_CODE |
      M510SB  |    .161759   .0265542     6.09   0.000     .1097138    .2138043
      M520EB  |   .7032305   .0323381    21.75   0.000     .6398491     .766612
      M520WB  |   .6090914   .0321756    18.93   0.000     .5460284    .6721545
      M530EB  |   .5787961   .0314101    18.43   0.000     .5172335    .6403587
      M530WB  |   .5665728   .0310926    18.22   0.000     .5056324    .6275133
      N398NB  |  -1.316093   .1354859    -9.71   0.000    -1.581641   -1.050546
      N398SB  |  -1.209152   .1302861    -9.28   0.000    -1.464508   -.9537964
```

```
      N399EB  |  -.4200449   .0580678    -7.23   0.000    -.5338558    -.306234
      N399WB  |  -.2039437   .0565959    -3.60   0.000    -.3148695   -.0930178
              |
TIMEPERIOD_~E |
          MD  |   .3191768   .0247014    12.92   0.000     .2707629    .3675907
          PM  |   .3066007    .024937    12.30   0.000     .2577251    .3554763
              |
        _cons |  -1.115464   .0247284   -45.11   0.000     -1.16393   -1.066997
--------------+----------------------------------------------------------------
Veh_lt_Adults |  (base outcome)
--------------+----------------------------------------------------------------
Veh_ge_Adults |
ROUTE_~E_CODE |
      M510SB  |   .0856902   .0325874     2.63   0.009     .0218201    .1495602
      M520EB  |   .4943403   .0403656    12.25   0.000     .4152252    .5734553
      M520WB  |   .3710301   .0405529     9.15   0.000     .2915478    .4505123
      M530EB  |   1.040165     .03455    30.11   0.000     .9724482    1.107882
      M530WB  |     1.0045   .0343254    29.26   0.000     .9372237    1.071777
      N398NB  |   2.235875   .0567051    39.43   0.000     2.124735    2.347014
      N398SB  |   2.176557   .0545953    39.87   0.000     2.069552    2.283562
      N399EB  |   .2755324   .0565164     4.88   0.000     .1647623    .3863024
      N399WB  |   .7102849   .0523239    13.57   0.000     .6077319    .8128379
              |
TIMEPERIOD_~E |
          MD  |  -.1285268   .0267898    -4.80   0.000    -.1810339   -.0760197
          PM  |   .1361371   .0261035     5.22   0.000     .0849752    .1872991
              |
        _cons |  -1.410162    .027692   -50.92   0.000    -1.464438   -1.355887
-------------------------------------------------------------------------------
```

TABLE 51: ACCESS\EGRESS MODE IMPUTATION MODEL FOR SYNTHETIC RAIL RECORDS

```
Iteration 0:   log likelihood = -62283.396
Iteration 1:   log likelihood = -56790.854
Iteration 2:   log likelihood = -54486.596
Iteration 3:   log likelihood = -53855.578
Iteration 4:   log likelihood = -53295.303
Iteration 5:   log likelihood = -53289.476
Iteration 6:   log likelihood = -53289.472

Multinomial logistic regression                   Number of obs   =      13307
                                                  LR chi2(26)     =   17987.85
                                                  Prob > chi2     =     0.0000
Log likelihood = -53289.472                       Pseudo R2       =     0.1444

-------------------------------------------------------------------------------
 accessEgress |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
Walk          |  (base outcome)
--------------+----------------------------------------------------------------
PNR           |
ROUTE_~E_CODE |
      M510SB  |  -.0562352   .0567364    -0.99   0.322    -.1674364    .0549661
      M520EB  |   .2990662   .0618358     4.84   0.000     .1778703    .4202621
      M520WB  |  -.1005741   .0666845    -1.51   0.132    -.2312733    .0301251
      M530EB  |   .1281086   .0572264     2.24   0.025     .0159468    .2402703
      M530WB  |   .6141452   .0522668    11.75   0.000     .5117042    .7165862
      N398NB  |    3.27726   .0799513    40.99   0.000     3.120558    3.433961
      N398SB  |   3.267475   .0802637    40.71   0.000     3.110161    3.424789
      N399EB  |   .7394654     .07741     9.55   0.000     .5877445    .8911863
      N399WB  |   1.017558    .072752    13.99   0.000     .8749671     1.16015
              |
```

```
TIMEPERIOD_~E |
           MD  |  -.7895036   .0387806   -20.36   0.000    -.8655122    -.713495
           PM  |  -.5532224   .0370482   -14.93   0.000    -.6258356   -.4806091
               |
     autoSuff |
Veh.lt.Adu~s  |   1.991481    .073802    26.98   0.000     1.846832    2.136131
Veh.ge.Adu~s  |   3.282175   .0738003    44.47   0.000     3.137529    3.426821
               |
        _cons |  -4.192117   .0817356   -51.29   0.000    -4.352316   -4.031918
--------------+----------------------------------------------------------------
KNR           |
ROUTE_~E_CODE |
      M510SB  |  -.0545571   .0250599    -2.18   0.029    -.1036735   -.0054407
      M520EB  |  -1.284305   .0418532   -30.69   0.000    -1.366335   -1.202274
      M520WB  |  -1.205512   .0398707   -30.24   0.000    -1.283658   -1.127367
      M530EB  |  -1.001096   .0346834   -28.86   0.000    -1.069074    -.933118
      M530WB  |  -1.093604   .0357365   -30.60   0.000    -1.163646   -1.023562
      N398NB  |   1.026201   .0760904    13.49   0.000     .8770665    1.175335
      N398SB  |   .8288268   .0789885    10.49   0.000     .6740122    .9836414
      N399EB  |  -.4329652   .0522441    -8.29   0.000    -.5353617   -.3305688
      N399WB  |  -.2550671   .0508744    -5.01   0.000    -.3547791    -.155355
               |
TIMEPERIOD_~E |
           MD  |  -.5868894      .0249   -23.57   0.000    -.6356926   -.5380863
           PM  |  -.4003996   .0244378   -16.38   0.000    -.4482968   -.3525024
               |
     autoSuff |
Veh.lt.Adu~s  |   .4299972   .0227663    18.89   0.000     .3853761    .4746183
Veh.ge.Adu~s  |   .8071864   .0279759    28.85   0.000     .7523547    .8620181
               |
        _cons |   -.673723   .0282196   -23.87   0.000    -.7290324   -.6184136
-------------------------------------------------------------------------------
```

TABLE 52: NUMBER OF TRANSFERS IMPUTATION MODEL FOR SYNTHETIC RAIL RECORDS

```
Iteration 0:   log likelihood =  -69615.81
Iteration 1:   log likelihood = -67400.994
Iteration 2:   log likelihood = -67047.833
Iteration 3:   log likelihood = -66994.896
Iteration 4:   log likelihood = -66986.845
Iteration 5:   log likelihood = -66985.691
Iteration 6:   log likelihood = -66985.454
Iteration 7:   log likelihood = -66985.401
Iteration 8:   log likelihood = -66985.389
Iteration 9:   log likelihood = -66985.387
Iteration 10:  log likelihood = -66985.386
Iteration 11:  log likelihood = -66985.386
Iteration 12:  log likelihood = -66985.386

Multinomial logistic regression                   Number of obs   =      13307
                                                  LR chi2(75)     =    5260.85
                                                  Prob > chi2     =     0.0000
Log likelihood = -66985.386                       Pseudo R2       =     0.0378

-------------------------------------------------------------------------------
numberTrans~s |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
0             |  (base outcome)
--------------+----------------------------------------------------------------
1             |
ROUTE_~E_CODE |
      M510SB  |  -.3817114   .0263619   -14.48   0.000    -.4333799    -.330043
      M520EB  |   .1636231   .0321707     5.09   0.000     .1005697    .2266765
      M520WB  |   .0668209   .0320518     2.08   0.037     .0040005    .1296414
```

```
      M530EB |   .1056586   .0301153     3.51   0.000     .0466337    .1646835
      M530WB |   .0081378   .0300389     0.27   0.786    -.0507372    .0670129
      N398NB |  -.3033147   .0687333    -4.41   0.000    -.4380295   -.1685999
      N398SB |  -.5556055   .0689036    -8.06   0.000     -.690654    -.420557
      N399EB |  -.2761155   .0502606    -5.49   0.000    -.3746245   -.1776065
      N399WB |  -.2119854   .0505971    -4.19   0.000    -.3111538    -.112817
             |
TIMEPERIOD_~E |
          MD |  -.2256214   .0230582    -9.78   0.000    -.2708146   -.1804281
          PM |  -.4103415    .023247   -17.65   0.000    -.4559047   -.3647783
             |
    autoSuff |
Veh.lt.Adu~s |   .1089245   .0198747     5.48   0.000     .0699708    .1478781
Veh.ge.Adu~s |  -.1211273   .0257974    -4.70   0.000    -.1716893   -.0705652
             |
 accessEgress |
         PNR |  -.9779123    .037574   -26.03   0.000    -1.051556   -.9042686
         KNR |  -.5287062   .0216841   -24.38   0.000    -.5712063   -.4862062
             |
       _cons |  -.2889678   .0279103   -10.35   0.000    -.3436711   -.2342645
-------------+----------------------------------------------------------------
2            |
ROUTE_~E_CODE |
      M510SB |  -.4596365   .0437826   -10.50   0.000    -.5454488   -.3738243
      M520EB |    .150472   .0500135     3.01   0.003     .0524473    .2484966
      M520WB |   .0513946   .0499538     1.03   0.304    -.0465131    .1493022
      M530EB |   .2553053   .0459134     5.56   0.000     .1653168    .3452939
      M530WB |  -.0412051   .0484089    -0.85   0.395    -.1360848    .0536746
      N398NB |  -.2689311   .1385115    -1.94   0.052    -.5404087    .0025465
      N398SB |  -.6533054   .1491446    -4.38   0.000    -.9456235   -.3609874
      N399EB |  -.7281713   .0981242    -7.42   0.000    -.9204911   -.5358514
      N399WB |   -.303356   .0873188    -3.47   0.001    -.4744976   -.1322143
             |
TIMEPERIOD_~E |
          MD |   -.329106   .0368195    -8.94   0.000     -.401271   -.2569411
          PM |  -.4266259    .037112   -11.50   0.000     -.499364   -.3538878
             |
    autoSuff |
Veh.lt.Adu~s |    .142623   .0309962     4.60   0.000     .0818716    .2033744
Veh.ge.Adu~s |  -.3217951   .0441279    -7.29   0.000    -.4082842   -.2353059
             |
 accessEgress |
         PNR |  -1.729496   .0851449   -20.31   0.000    -1.896376   -1.562615
         KNR |  -1.229103   .0438115   -28.05   0.000    -1.314972   -1.143234
             |
       _cons |  -1.298899   .0436933   -29.73   0.000    -1.384537   -1.213262
-------------+----------------------------------------------------------------
3            |
ROUTE_~E_CODE |
      M510SB |  -.3584196   .1307156    -2.74   0.006    -.6146174   -.1022218
      M520EB |   .5866235   .1312905     4.47   0.000     .3292988    .8439482
      M520WB |    .533379   .1293661     4.12   0.000     .2798261    .7869319
      M530EB |   .6101369   .1245621     4.90   0.000     .3659997    .8542741
      M530WB |   .9508483   .1149543     8.27   0.000      .725542    1.176155
      N398NB |  -.1431025   .4849311    -0.30   0.768     -1.09355     .807345
      N398SB |     .45033   .3383434     1.33   0.183    -.2128109    1.113471
      N399EB |   -.410354   .2624866    -1.56   0.118    -.9248183    .1041104
      N399WB |   .7386457    .177433     4.16   0.000     .3908835    1.086408
             |
TIMEPERIOD_~E |
          MD |   -.352914   .0885892    -3.98   0.000    -.5265456   -.1792824
          PM |  -.5736706   .0920697    -6.23   0.000    -.7541239   -.3932174
             |
```

```
     autoSuff |
Veh.lt.Adu~s  |   .3620568   .0777625     4.66   0.000     .2096451    .5144685
Veh.ge.Adu~s  |  -.1580541   .1096219    -1.44   0.149     -.372909    .0568008
              |
 accessEgress |
          PNR |  -2.974961   .3405039    -8.74   0.000    -3.642336   -2.307586
          KNR |  -1.921946   .1521828   -12.63   0.000    -2.220219   -1.623673
              |
        _cons |  -3.672997   .1194755   -30.74   0.000    -3.907165   -3.438829
--------------+----------------------------------------------------------------
4             |
ROUTE_~E_CODE |
       M510SB |   .1821873    .438605     0.42   0.678    -.6774626    1.041837
       M520EB |   .7368736   .5018208     1.47   0.142     -.246677    1.720424
       M520WB |   .0859362   .5937241     0.14   0.885    -1.077742    1.249614
       M530EB |   .5842497    .494893     1.18   0.238    -.3857228    1.554222
       M530WB |  -.0708643   .5866991    -0.12   0.904    -1.220773    1.079045
       N398NB |   .9866394   .9898408     1.00   0.319     -.953413    2.926692
       N398SB |  -16.65282    6537.38    -0.00   0.998    -12829.68    12796.38
       N399EB |  -.0665419    .894202    -0.07   0.941    -1.819146    1.686062
       N399WB |   1.784788   .4861531     3.67   0.000     .8319458    2.737631
              |
TIMEPERIOD_~E |
           MD |   .5294434    .427499     1.24   0.216    -.3084393    1.367326
           PM |   .2922225    .436266     0.67   0.503    -.5628432    1.147288
              |
     autoSuff |
Veh.lt.Adu~s  |   .6624168   .3274102     2.02   0.043     .0207046    1.304129
Veh.ge.Adu~s  |   .0275279   .4541374     0.06   0.952     -.862565    .9176207
              |
 accessEgress |
          PNR |  -17.81319   2472.986    -0.01   0.994    -4864.777     4829.15
          KNR |  -.4373105   .3297312    -1.33   0.185    -1.083572    .2089507
              |
        _cons |  -7.518015   .5483683   -13.71   0.000    -8.592797   -6.443233
--------------+----------------------------------------------------------------
5             |
ROUTE_~E_CODE |
       M510SB |  -.7531966   10420.69    -0.00   1.000    -20424.92    20423.42
       M520EB |  -.2599123   13282.86    -0.00   1.000    -26034.19    26033.67
       M520WB |  -.2532159      13313    -0.00   1.000    -26093.26    26092.76
       M530EB |   18.92206   7319.344     0.00   0.998    -14326.73    14364.57
       M530WB |   17.06771   7319.344     0.00   0.998    -14328.58    14362.72
       N398NB |    1.72899   20213.56     0.00   1.000    -39616.12    39619.57
       N398SB |   2.325418   15749.92     0.00   1.000    -30866.95     30871.6
       N399EB |  -.2265656    19494.9    -0.00   1.000    -38209.53    38209.08
       N399WB |   .1423478   18980.76     0.00   1.000    -37201.47    37201.76
              |
TIMEPERIOD_~E |
           MD |  -.5054736   2143.862    -0.00   1.000    -4202.397    4201.386
           PM |   14.68591   1704.343     0.01   0.993    -3325.765    3355.137
              |
     autoSuff |
Veh.lt.Adu~s  |    1.63321   1.878141     0.87   0.385    -2.047878    5.314298
Veh.ge.Adu~s  |   -13.1096   1322.042    -0.01   0.992    -2604.264    2578.045
              |
 accessEgress |
          PNR |  -14.04705   1729.762    -0.01   0.994    -3404.318    3376.224
          KNR |  -13.82097   1245.567    -0.01   0.991    -2455.088    2427.446
              |
        _cons |  -41.15369   7515.157    -0.01   0.996    -14770.59    14688.28
```

TABLE 53: TOUR PURPOSE IMPUTATION MODEL FOR SYNTHETIC RAIL RECORDS

```
Iteration 0:   log likelihood = -155850.76
Iteration 1:   log likelihood = -146785.73
Iteration 2:   log likelihood = -135852.24
Iteration 3:   log likelihood = -134747.85
Iteration 4:   log likelihood = -133728.31
Iteration 5:   log likelihood = -133615.68
Iteration 6:   log likelihood = -133611.08
Iteration 7:   log likelihood = -133610.19
Iteration 8:   log likelihood = -133609.96
Iteration 9:   log likelihood = -133609.92
Iteration 10:  log likelihood = -133609.91
Iteration 11:  log likelihood = -133609.91
Iteration 12:  log likelihood = -133609.91
Iteration 13:  log likelihood = -133609.91
Iteration 14:  log likelihood = -133609.91

Multinomial logistic regression                   Number of obs   =      13142
                                                  LR chi2(240)    =   44481.70
                                                  Prob > chi2     =     0.0000
Log likelihood = -133609.91                       Pseudo R2       =     0.1427

------------------------------------------------------------------------------
  tourPurpose |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Work         |  (base outcome)
-------------+----------------------------------------------------------------
College_Uni~y |
ROUTE_~E_CODE |
      M510SB  | -.4346221    .040286   -10.79   0.000    -.5135813    -.355663
      M520EB  | -.3493648   .0473027    -7.39   0.000    -.4420764   -.2566533
      M520WB  | -.1719797   .0455413    -3.78   0.000    -.2612389   -.0827205
      M530EB  |  .2259226   .0409682     5.51   0.000     .1456265    .3062187
      M530WB  |  .2237491    .039879     5.61   0.000     .1455877    .3019106
      N398NB  | -2.424198   .1607968   -15.08   0.000    -2.739354   -2.109042
      N398SB  | -2.607903   .1709481   -15.26   0.000    -2.942955    -2.27285
      N399EB  |   .951867   .0574238    16.58   0.000     .8393185    1.064416
      N399WB  |  .6306885   .0562449    11.21   0.000     .5204505    .7409265
              |
TIMEPERIOD_~E |
          MD  |   .474737   .0299475    15.85   0.000     .4160409     .533433
          PM  | -.0665348   .0320873    -2.07   0.038    -.1294247   -.0036448
              |
     autoSuff |
Veh.lt.Adu~s  |  .4110372   .0292524    14.05   0.000     .3537035    .4683709
Veh.ge.Adu~s  |  .2962541   .0387695     7.64   0.000     .2202673    .3722409
              |
 accessEgress |
         PNR  |  -.207785   .0432586    -4.80   0.000    -.2925702   -.1229997
         KNR  | -.1576255    .032631    -4.83   0.000     -.221581    -.09367
              |
        _cons | -1.347113   .0405992   -33.18   0.000    -1.426686    -1.26754
-------------+----------------------------------------------------------------
K_12          |
ROUTE_~E_CODE |
      M510SB  |  .0371286   .0769523     0.48   0.629    -.1136951    .1879523
      M520EB  |  .8218657   .0755864    10.87   0.000     .6737191    .9700123
      M520WB  |  .5077419   .0794907     6.39   0.000     .3519429    .6635409
      M530EB  | -.2857957    .097356    -2.94   0.003    -.4766099   -.0949816
      M530WB  | -.4257113   .0998959    -4.26   0.000    -.6215037    -.229919
      N398NB  | -1.241638   .3008932    -4.13   0.000    -1.831378   -.6518983
      N398SB  |  -1.37305   .3031051    -4.53   0.000    -1.967125   -.7789749
      N399EB  |  1.551071   .0929778    16.68   0.000     1.368838    1.733305
```

```
      N399WB |    .516692   .1204345     4.29   0.000     .2806447    .7527392
             |
TIMEPERIOD_~E |
          MD |  -.3508935   .0553748    -6.34   0.000    -.4594262   -.2423609
          PM |  -.3650555   .0555143    -6.58   0.000    -.4738616   -.2562495
             |
    autoSuff |
Veh.lt.Adu~s |   .4030978   .0538484     7.49   0.000     .2975569    .5086388
Veh.ge.Adu~s |   .1189889   .0774486     1.54   0.124    -.0328075    .2707853
             |
 accessEgress |
         PNR |  -2.110147   .1765688   -11.95   0.000    -2.456215   -1.764078
         KNR |  -.3573676   .0638082    -5.60   0.000    -.4824294   -.2323058
             |
       _cons |  -2.573991   .0755814   -34.06   0.000    -2.722128   -2.425854
-------------+----------------------------------------------------------------
Ind_Shop     |
ROUTE_~E_CODE |
      M510SB |  -.1801033   .0437151    -4.12   0.000    -.2657833   -.0944234
      M520EB |  -.3742674   .0531858    -7.04   0.000    -.4785097   -.2700251
      M520WB |  -.0509126   .0510277    -1.00   0.318     -.150925    .0490999
      M530EB |   .0409651   .0489089     0.84   0.402    -.0548947    .1368248
      M530WB |  -.0780315     .04886    -1.60   0.110    -.1737953    .0177323
      N398NB |  -3.042327   .3393465    -8.97   0.000    -3.707434    -2.37722
      N398SB |  -1.610994   .2344043    -6.87   0.000    -2.070418    -1.15157
      N399EB |   -.603708   .1097385    -5.50   0.000    -.8187916   -.3886245
      N399WB |  -.7590837   .1037291    -7.32   0.000    -.9623889   -.5557784
             |
TIMEPERIOD_~E |
          MD |   1.826139   .0573112    31.86   0.000     1.713811    1.938467
          PM |   1.806134   .0573088    31.52   0.000     1.693811    1.918458
             |
    autoSuff |
Veh.lt.Adu~s |  -.5456537   .0298999   -18.25   0.000    -.6042565   -.4870509
Veh.ge.Adu~s |  -.5608004   .0457171   -12.27   0.000    -.6504042   -.4711965
             |
 accessEgress |
         PNR |  -1.749553    .105673   -16.56   0.000    -1.956668   -1.542438
         KNR |   -.512009   .0437189   -11.71   0.000    -.5976964   -.4263215
             |
       _cons |  -2.257739   .0625454   -36.10   0.000    -2.380326   -2.135153
-------------+----------------------------------------------------------------
Ind_Other_M~t |
ROUTE_~E_CODE |
      M510SB |    -.66838   .0810798    -8.24   0.000    -.8272935   -.5094666
      M520EB |  -.1066457   .0805452    -1.32   0.185    -.2645114      .05122
      M520WB |  -.1830482   .0840014    -2.18   0.029     -.347688   -.0184084
      M530EB |  -.1460104   .0808419    -1.81   0.071    -.3044576    .0124368
      M530WB |  -.3759273   .0831543    -4.52   0.000    -.5389066   -.2129479
      N398NB |  -2.125328   .3008314    -7.06   0.000    -2.714947    -1.53571
      N398SB |  -2.470983   .3644266    -6.78   0.000    -3.185246    -1.75672
      N399EB |   .0743252    .134753     0.55   0.581    -.1897858    .3384361
      N399WB |  -.2567836   .1342465    -1.91   0.056    -.5199019    .0063347
             |
TIMEPERIOD_~E |
          MD |   1.204486    .067477    17.85   0.000     1.072233    1.336738
          PM |   .0870865   .0777766     1.12   0.263    -.0653528    .2395257
             |
    autoSuff |
Veh.lt.Adu~s |  -.9514105    .053284   -17.86   0.000    -1.055845   -.8469758
Veh.ge.Adu~s |    -.36305   .0688689    -5.27   0.000    -.4980307   -.2280694
             |
 accessEgress |
         PNR |  -.1266752    .095513    -1.33   0.185    -.3138773    .0605268
```

```
          KNR |   -.063048   .0685651    -0.92   0.358    -.1974331    .0713371
              |
        _cons |  -2.437217   .0798703   -30.51   0.000     -2.59376   -2.280675
--------------+----------------------------------------------------------------
Ind_Eat_Out   |
ROUTE_~E_CODE |
       M510SB |  -.2603049   .0613642    -4.24   0.000    -.3805766   -.1400332
       M520EB |  -.3849577   .0748732    -5.14   0.000    -.5317064    -.238209
       M520WB |  -.3562477   .0770814    -4.62   0.000    -.5073244   -.2051709
       M530EB |  -.3824336   .0743886    -5.14   0.000    -.5282327   -.2366345
       M530WB |  -.4173102   .0731875    -5.70   0.000    -.5607552   -.2738653
       N398NB |  -1.926694   .2097096    -9.19   0.000    -2.337718   -1.515671
       N398SB |  -.5960091   .1764541    -3.38   0.001    -.9418527   -.2501654
       N399EB |   .0688723   .1173878     0.59   0.557    -.1612035    .2989481
       N399WB |   .2541063   .0974405     2.61   0.009     .0631263    .4450862
              |
TIMEPERIOD_~E |
           MD |   2.007161   .0939701    21.36   0.000     1.822983    2.191339
           PM |   2.181111   .0930612    23.44   0.000     1.998714    2.363508
              |
     autoSuff |
Veh.lt.Adu~s  |  -.6331282   .0451356   -14.03   0.000    -.7215923    -.544664
Veh.ge.Adu~s  |   .0010876    .056253     0.02   0.985    -.1091661    .1113414
              |
 accessEgress |
          PNR |  -1.040551    .104514    -9.96   0.000    -1.245395   -.8357075
          KNR |   .0860753   .0522123     1.65   0.099     -.016259    .1884096
              |
        _cons |  -3.461948   .1002785   -34.52   0.000     -3.65849   -3.265406
--------------+----------------------------------------------------------------
Ind_Other_D~c |
ROUTE_~E_CODE |
       M510SB |  -.4444957   .0397703   -11.18   0.000    -.5224441   -.3665473
       M520EB |  -.4386051   .0488692    -8.98   0.000     -.534387   -.3428231
       M520WB |  -.2442472    .047843    -5.11   0.000    -.3380177   -.1504766
       M530EB |  -.6323441    .050265   -12.58   0.000    -.7308617   -.5338265
       M530WB |  -.9291402   .0531642   -17.48   0.000     -1.03334   -.8249403
       N398NB |  -1.654065    .113906   -14.52   0.000    -1.877317   -1.430813
       N398SB |   -1.38728   .1335874   -10.38   0.000    -1.649107   -1.125454
       N399EB |  -.1978106   .0794575    -2.49   0.013    -.3535445   -.0420768
       N399WB |     -.6295   .0817021    -7.70   0.000    -.7896331   -.4693669
              |
TIMEPERIOD_~E |
           MD |   1.183205   .0450835    26.24   0.000     1.094843    1.271567
           PM |   1.409059   .0441705    31.90   0.000     1.322487    1.495632
              |
     autoSuff |
Veh.lt.Adu~s  |  -.3695039   .0301035   -12.27   0.000    -.4285057   -.3105021
Veh.ge.Adu~s  |  -.6474265   .0452284   -14.31   0.000    -.7360725   -.5587804
              |
 accessEgress |
          PNR |  -.5157574   .0675623    -7.63   0.000    -.6481771   -.3833376
          KNR |    .802482   .0315747    25.42   0.000     .7405966    .8643674
              |
        _cons |  -1.822449   .0499592   -36.48   0.000    -1.920367   -1.724531
--------------+----------------------------------------------------------------
Work_Based    |
ROUTE_~E_CODE |
       M510SB |   .7755443   .1503565     5.16   0.000     .4808511    1.070238
       M520EB |   .1890631   .1892834     1.00   0.318    -.1819256    .5600518
       M520WB |  -.2025133   .2203046    -0.92   0.358    -.6343025    .2292758
       M530EB |   .9170843   .1622649     5.65   0.000      .599051    1.235118
       M530WB |  -.5474439   .2231552    -2.45   0.014    -.9848201   -.1100677
```

```
       N398NB |  -.7398988   .2768558    -2.67   0.008    -1.282526   -.1972715
       N398SB |  -22.53504   20407.64    -0.00   0.999    -40020.78    39975.71
       N399EB |   .9036976   .2314596     3.90   0.000     .4500451     1.35735
       N399WB |  -19.41568   4078.651    -0.00   0.996    -8013.425    7974.594
              |
TIMEPERIOD_~E |
           MD |   2.215686   .2473639     8.96   0.000     1.730861     2.70051
           PM |   2.417703   .2450163     9.87   0.000     1.937479    2.897926
              |
     autoSuff |
Veh.lt.Adu~s  |   .1396652   .1059274     1.32   0.187    -.0679487    .3472792
Veh.ge.Adu~s  |   .0024431   .1389279     0.02   0.986    -.2698506    .2747369
              |
 accessEgress |
          PNR |   .8007848   .1350674     5.93   0.000     .5360577    1.065512
          KNR |   .7088844   .1005929     7.05   0.000      .511726    .9060428
              |
        _cons |  -6.577541   .2757243   -23.86   0.000    -7.117951   -6.037131
--------------+----------------------------------------------------------------
Visitor_Work  |
ROUTE_~E_CODE |
       M510SB |  -.3426556   .3592012    -0.95   0.340    -1.046677    .3613658
       M520EB |   .4167699   .3162163     1.32   0.188    -.2030026    1.036542
       M520WB |  -1.221418    .506864    -2.41   0.016    -2.214854   -.2279831
       M530EB |    .440088   .3065688     1.44   0.151    -.1607758    1.040952
       M530WB |  -.5179796   .3823846    -1.35   0.176     -1.26744    .2314805
       N398NB |  -20.13631      14888    -0.00   0.999    -29200.09    29159.82
       N398SB |   .8703966   .4640653     1.88   0.061    -.0391547    1.779948
       N399EB |  -19.04232   7929.308    -0.00   0.998     -15560.2    15522.12
       N399WB |  -19.22501   7323.177    -0.00   0.998    -14372.39    14333.94
              |
TIMEPERIOD_~E |
           MD |  -.2732824   .2149168    -1.27   0.204    -.6945116    .1479469
           PM |  -1.289305    .281126    -4.59   0.000    -1.840302   -.7383085
              |
     autoSuff |
Veh.lt.Adu~s  |   -3.99635   .7621893    -5.24   0.000    -5.490213   -2.502486
Veh.ge.Adu~s  |   .7926957   .1986101     3.99   0.000     .4034271    1.181964
              |
 accessEgress |
          PNR |  -3.263282   .6446186    -5.06   0.000    -4.526712   -1.999853
          KNR |  -1.920257   .4466433    -4.30   0.000    -2.795662   -1.044852
              |
        _cons |  -4.166522   .2729579   -15.26   0.000     -4.70151   -3.631534
--------------+----------------------------------------------------------------
Visitor_Rec   |
ROUTE_~E_CODE |
       M510SB |   .0883659   .1206052     0.73   0.464    -.1480159    .3247478
       M520EB |  -.6999027   .1577453    -4.44   0.000    -1.009078   -.3907275
       M520WB |  -.6604078   .1653445    -3.99   0.000    -.9844772   -.3363385
       M530EB |   1.399245   .1110364    12.60   0.000     1.181617    1.616872
       M530WB |   1.028844   .1138389     9.04   0.000     .8057236    1.251964
       N398NB |  -.0540251   .1692135    -0.32   0.750    -.3856773    .2776272
       N398SB |   .3117185   .1917849     1.63   0.104    -.0641731      .68761
       N399EB |   -.078209   .2390815    -0.33   0.744    -.5468002    .3903821
       N399WB |  -2.142243   .4420652    -4.85   0.000    -3.008675   -1.275811
              |
TIMEPERIOD_~E |
           MD |   1.716777   .1047938    16.38   0.000     1.511385     1.92217
           PM |   1.550077   .1049999    14.76   0.000     1.344281    1.755873
              |
     autoSuff |
Veh.lt.Adu~s  |  -.4693265   .1615027    -2.91   0.004     -.785866   -.1527871
Veh.ge.Adu~s  |   3.814155   .1181948    32.27   0.000     3.582497    4.045812
```

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             |
 accessEgress |
          PNR |  -2.812335   .1392423   -20.20   0.000    -3.085245   -2.539425
          KNR |  -.9583369    .082044   -11.68   0.000     -1.11914   -.7975335
              |
        _cons |  -6.350631   .1736555   -36.57   0.000     -6.69099   -6.010273
-------------+----------------------------------------------------------------
MR_Work      |
ROUTE_~E_CODE |
       M510SB |  -.0892908   .0419357    -2.13   0.033    -.1714834   -.0070983
       M520EB |  -3.540604   .1850992   -19.13   0.000    -3.903391   -3.177816
       M520WB |  -3.106689   .1555716   -19.97   0.000    -3.411603   -2.801774
       M530EB |  -2.811735   .1200211   -23.43   0.000    -3.046972   -2.576498
       M530WB |   -3.06341   .1306246   -23.45   0.000    -3.319429    -2.80739
       N398NB |  -6.079172   .7134457    -8.52   0.000      -7.4775   -4.680844
       N398SB |  -24.54043   6847.368    -0.00   0.997    -13445.14    13396.05
       N399EB |  -3.971934   .4072626    -9.75   0.000    -4.770154   -3.173714
       N399WB |  -3.028193   .2153622   -14.06   0.000    -3.450296   -2.606091
              |
TIMEPERIOD_~E |
           MD |  -.6413004   .0499088   -12.85   0.000      -.73912   -.5434809
           PM |  -.1562257   .0453109    -3.45   0.001    -.2450334    -.067418
              |
     autoSuff |
Veh.lt.Adu~s |  -.4341938   .0433365   -10.02   0.000    -.5191319   -.3492558
Veh.ge.Adu~s |  -.4273532   .0581997    -7.34   0.000    -.5414225   -.3132838
              |
 accessEgress |
          PNR |   .9338188   .0782082    11.94   0.000     .7805335    1.087104
          KNR |   2.014106    .039581    50.89   0.000     1.936528    2.091683
              |
        _cons |  -1.236087   .0505705   -24.44   0.000    -1.335204   -1.136971
-------------+----------------------------------------------------------------
MR_School    |
ROUTE_~E_CODE |
       M510SB |   .1504935   .0757882     1.99   0.047     .0019514    .2990356
       M520EB |  -2.714625   .2803497    -9.68   0.000      -3.2641    -2.16515
       M520WB |  -2.840917   .2951921    -9.62   0.000    -3.419483   -2.262352
       M530EB |  -20.04221   1411.987    -0.01   0.989    -2787.486    2747.401
       M530WB |  -3.064369   .2992175   -10.24   0.000    -3.650824   -2.477913
       N398NB |  -21.34296    4068.52    -0.01   0.996    -7995.495    7952.809
       N398SB |  -23.81061   11956.43    -0.00   0.998    -23457.97    23410.35
       N399EB |  -20.06766   2762.367    -0.01   0.994    -5434.207    5394.072
       N399WB |  -20.06382   2393.311    -0.01   0.993    -4710.868     4670.74
              |
TIMEPERIOD_~E |
           MD |  -.9583049   .0902736   -10.62   0.000    -1.135238   -.7813719
           PM |  -.7548245   .0834788    -9.04   0.000    -.9184399   -.5912091
              |
     autoSuff |
Veh.lt.Adu~s |  -.0468052   .0858354    -0.55   0.586    -.2150395     .121429
Veh.ge.Adu~s |   .0223372   .1105862     0.20   0.840    -.1944077    .2390822
              |
 accessEgress |
          PNR |  -1.771908   .4515963    -3.92   0.000    -2.657021   -.8867958
          KNR |   1.911607    .071357    26.79   0.000      1.77175    2.051464
              |
        _cons |  -2.686661   .0959905   -27.99   0.000    -2.874799   -2.498523
-------------+----------------------------------------------------------------
MR_Shop      |
ROUTE_~E_CODE |
       M510SB |  -.5899843   .0599057    -9.85   0.000    -.7073973   -.4725714
       M520EB |  -3.271832   .2186025   -14.97   0.000    -3.700285   -2.843379
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M520WB	-2.368045	.1508055	-15.70	0.000	-2.663618	-2.072472
M530EB	-3.41086	.2219235	-15.37	0.000	-3.845822	-2.975898
M530WB	-4.100656	.2890288	-14.19	0.000	-4.667142	-3.534169
N398NB	-22.84607	4562.45	-0.01	0.996	-8965.084	8919.392
N398SB	-24.6719	13242.16	-0.00	0.999	-25978.83	25929.49
N399EB	-20.67816	2489.6	-0.01	0.993	-4900.204	4858.848
N399WB	-20.88388	2347.629	-0.01	0.993	-4622.152	4580.384
TIMEPERIOD_~E						
MD	1.080502	.0772432	13.99	0.000	.9291081	1.231896
PM	.583453	.0823068	7.09	0.000	.4221346	.7447715
autoSuff						
Veh.lt.Adu~s	-.9264314	.0608099	-15.23	0.000	-1.045617	-.8072463
Veh.ge.Adu~s	-.9567257	.0890823	-10.74	0.000	-1.131324	-.7821275
accessEgress						
PNR	1.463686	.106972	13.68	0.000	1.254025	1.673347
KNR	1.75856	.0589741	29.82	0.000	1.642973	1.874147
_cons	-2.447547	.081889	-29.89	0.000	-2.608047	-2.287048
MR_Visit						
ROUTE_~E_CODE						
M510SB	-.6289896	.0665143	-9.46	0.000	-.7593552	-.4986239
M520EB	-2.286778	.1583653	-14.44	0.000	-2.597169	-1.976388
M520WB	-2.181119	.1612948	-13.52	0.000	-2.497251	-1.864987
M530EB	-3.576742	.269662	-13.26	0.000	-4.10527	-3.048214
M530WB	-3.609201	.2657908	-13.58	0.000	-4.130141	-3.08826
N398NB	-5.757587	.9294256	-6.19	0.000	-7.579228	-3.935946
N398SB	-24.05359	11542.71	-0.00	0.998	-22647.35	22599.24
N399EB	-20.54895	2668.462	-0.01	0.994	-5250.638	5209.54
N399WB	-20.71922	2436.095	-0.01	0.993	-4795.377	4753.939
TIMEPERIOD_~E						
MD	.6905854	.0914297	7.55	0.000	.5113864	.8697843
PM	1.110912	.087379	12.71	0.000	.939652	1.282171
autoSuff						
Veh.lt.Adu~s	-.7600324	.0662013	-11.48	0.000	-.8897846	-.6302802
Veh.ge.Adu~s	-1.28453	.1062269	-12.09	0.000	-1.492731	-1.076329
accessEgress						
PNR	1.609547	.118111	13.63	0.000	1.378053	1.84104
KNR	1.942661	.0649091	29.93	0.000	1.815441	2.069881
_cons	-2.897514	.093358	-31.04	0.000	-3.080492	-2.714536
ExtInt_Work						
ROUTE_~E_CODE						
M510SB	-17.97106	1509.326	-0.01	0.991	-2976.195	2940.253
M520EB	-.1931835	.3403265	-0.57	0.570	-.8602112	.4738442
M520WB	-.0033823	.3168568	-0.01	0.991	-.6244102	.6176457
M530EB	1.218702	.2440281	4.99	0.000	.740416	1.696989
M530WB	.7453307	.2545344	2.93	0.003	.2464523	1.244209
N398NB	.9601609	.2849216	3.37	0.001	.4017248	1.518597
N398SB	1.161773	.2719604	4.27	0.000	.6287402	1.694805
N399EB	-17.55446	3035.727	-0.01	0.995	-5967.471	5932.362
N399WB	-.2607743	.4938434	-0.53	0.597	-1.22869	.7071409
TIMEPERIOD_~E						
MD	-.7137988	.1820851	-3.92	0.000	-1.070679	-.3569184
PM	-.1596429	.1493661	-1.07	0.285	-.4523952	.1331093

autoSuff						
Veh.lt.Adu~s	.0618914	.2773237	0.22	0.823	-.4816531	.605436
Veh.ge.Adu~s	2.47573	.2429106	10.19	0.000	1.999634	2.951826
accessEgress						
PNR	-.6958355	.1684436	-4.13	0.000	-1.025979	-.365692
KNR	-.6755811	.1915868	-3.53	0.000	-1.051084	-.3000779
_cons	-5.802292	.3100223	-18.72	0.000	-6.409925	-5.194659
ExtInt_NonW~k						
ROUTE_~E_CODE						
M510SB	-.6818158	.1373365	-4.96	0.000	-.9509903	-.4126413
M520EB	-.6544938	.1565905	-4.18	0.000	-.9614055	-.3475822
M520WB	-1.461665	.2153811	-6.79	0.000	-1.883804	-1.039526
M530EB	.875519	.1147377	7.63	0.000	.6506372	1.100401
M530WB	.7452295	.1155892	6.45	0.000	.5186788	.9717802
N398NB	-1.597017	.2633107	-6.07	0.000	-2.113096	-1.080937
N398SB	-.899109	.2842563	-3.16	0.002	-1.456241	-.3419768
N399EB	-.0482603	.2388706	-0.20	0.840	-.5164381	.4199175
N399WB	-.1418098	.1952867	-0.73	0.468	-.5245646	.240945
TIMEPERIOD_~E						
MD	.9537001	.1123371	8.49	0.000	.7335233	1.173877
PM	1.389727	.1068444	13.01	0.000	1.180316	1.599139
autoSuff						
Veh.lt.Adu~s	-.5087482	.2201843	-2.31	0.021	-.9403014	-.0771949
Veh.ge.Adu~s	4.024997	.1580615	25.46	0.000	3.715202	4.334792
accessEgress						
PNR	-2.428046	.1508489	-16.10	0.000	-2.723704	-2.132387
KNR	-1.09866	.1039067	-10.57	0.000	-1.302313	-.8950063
_cons	-6.160435	.1995525	-30.87	0.000	-6.551551	-5.769319
Special_Event						
ROUTE_~E_CODE						
M510SB	-.269318	.1259763	-2.14	0.033	-.5162271	-.022409
M520EB	-.1221283	.1433623	-0.85	0.394	-.4031133	.1588567
M520WB	.2504191	.1407542	1.78	0.075	-.0254542	.5262923
M530EB	-.1782065	.1432772	-1.24	0.214	-.4590246	.1026116
M530WB	.8067026	.1188657	6.79	0.000	.5737301	1.039675
N398NB	-22.30586	4590.448	-0.00	0.996	-9019.418	8974.807
N398SB	.7914046	.156665	5.05	0.000	.4843467	1.098462
N399EB	-.2989633	.2557515	-1.17	0.242	-.800227	.2023005
N399WB	-.5539031	.2429426	-2.28	0.023	-1.030062	-.0777443
TIMEPERIOD_~E						
MD	2.305165	.1879572	12.26	0.000	1.936775	2.673554
PM	3.461561	.1791413	19.32	0.000	3.110451	3.812672
autoSuff						
Veh.lt.Adu~s	.2082394	.0979394	2.13	0.033	.0162818	.400197
Veh.ge.Adu~s	.9606779	.1044645	9.20	0.000	.7559312	1.165425
accessEgress						
PNR	1.161276	.0886735	13.10	0.000	.9874787	1.335072
KNR	.6125536	.088637	6.91	0.000	.4388283	.7862789
_cons	-6.89304	.2142743	-32.17	0.000	-7.31301	-6.47307

After the imputation of variables for rail records, the trip weights for synthetic rail records were re-calculated to account for imputed transfers, since it was previously assumed that the synthetic records did not transfer. This reduced the target number of linked trips that used LRT for some portion of their trip from 121k to 106k (target LRT boardings remain the same).

After imputing variables for synthetic rail records, origin-destination distance, as well as access and egress distance were coded to the on-board survey for use in calibration summaries.

APPENDIX B. STOP DEPARTURE AND ARRIVAL PROPORTIONS

This appendix describes the methodology used to assign a time period to each stop on a tour. The methodology uses a Monte Carlo procedure to assign each stop to a half-hour period. For outbound stops, the departure time of the last known activity location is used to determine the departure time of the stop. For outbound stops, the process works in sequential order from first stop to last stop on the half-tour. For inbound stops, the arrival time of the next known activity location is used to determine the arrival time of the stop. For inbound stops, the process works in reverse order from last stop on the half-tour to first stop on the half-tour. Constraints are imposed on the procedure to ensure that the final time-of-day distributions are reasonable, as follows:

1. No outbound stop departure time is chosen that is later than the arrival time of the tour.
2. No inbound stop arrival time is chosen that is earlier than the tour departure time.
3. No inbound stop arrival time is chosen that is earlier than the last outbound stop departure time.

If any of these conditions occur, the stop departure or arrival time is re-sampled from the distribution until all conditions are met. The distributions of stops by time period are segmented by tour purpose and number of stops. These tables were created from the 2016/2017 SANDAG Household Interview Survey. First, the survey data was processed to create distributions of stops purpose, direction, and half-hour period, and then the data was smoothed to account for unobserved stops by time period for certain purposes and/or directions, such that the resulting distributions are reasonable.

INITIAL SURVEY PROCESSING

The weighted household survey data was processed into one table that contains tour purpose, trip direction (outbound or inbound), departure time of the last trip (for outbound stops) or arrival time of the next stop (for inbound trips), and stop number (1 through 4) for each row. The columns contain the corresponding number of observed weighted stops by stop departure times (for outbound stops) or arrival times (for inbound stops) by half-hour period. Observations from 3 to 5 am were combined into 5 am. Due to lack of survey data, the percentage distribution was not smooth and had many gaps.

DATA SMOOTHING

The team reviewed the survey data to determine if there were patterns when stops were most likely to take place. Based on this analysis and expert judgment, the team determined a most likely stop distribution by time-of-day and number of stops. Based on the survey data, the first stop was 100% likely to take place in the first half hour period. For the purpose of data smoothing, the process will allow those trips to take place in the first two hours (four half hour periods). The second stop was 90% likely, the third stop was 92% likely and the fourth stop was 93% likely to take place in the first four hours (eight half hour periods).

Observations outside the most likely time-of-day distribution tended to be few and extreme outliers, and therefore were dropped. Then, missing values within the most likely distributions were interpolated by either taking an average of the observed trips in the periods immediately before and after the missing time-of-day period, or, in cases where there were larger gaps or missing values at either end of the most likely time-of-day distribution, by taking a percentage of the total for that particular tour purpose, direction, and stop number in the distribution.

There were rows with no valid observations, which could not be populated by the methodology above. In order to solve this problem, the model team created an average distribution by tour purpose and number of stops (collapsing the departure or arrival time of the last or next known stop). Due to lack of survey data for some purposes, this average was not done by direction. The averages are contained in Table 54.

TABLE 54: AVERAGE STOP DISTRIBUTIONS BY PURPOSE AND TRIP NUMBER

PURPOSE	TRIP	NUMBER OF HALF-HOUR PERIODS BEFORE (FOR OUTBOUND STOPS) OR AFTER (FOR INBOUND STOPS) LAST LOCATION								
		0	1	2	3	4	5	6	7	8
Work	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.3656	0.3165	0.1320	0.0790	0.0468	0.0295	0.0175	0.0132	0.3656
	3	0.3411	0.3441	0.1250	0.0635	0.0475	0.0354	0.0257	0.0178	0.3411
	4	0.2757	0.3232	0.1641	0.0727	0.0768	0.0356	0.0303	0.0216	0.2757
University	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.2441	0.3184	0.1682	0.0784	0.0705	0.0587	0.0406	0.0211	0.2441
	3	0.2019	0.2030	0.1494	0.0793	0.1218	0.1127	0.0807	0.0511	0.2019
	4	0.1675	0.2359	0.1618	0.1126	0.1405	0.0811	0.0697	0.0308	0.1675
School	1	0.9996	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9996
	2	0.4205	0.3459	0.0870	0.0469	0.0517	0.0193	0.0135	0.0152	0.4205
	3	0.2641	0.3245	0.1329	0.1009	0.0476	0.0587	0.0446	0.0267	0.2641
	4	0.4009	0.2994	0.1267	0.0755	0.0196	0.0470	0.0089	0.0220	0.4009
Escort	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.4269	0.3216	0.0794	0.0389	0.0541	0.0265	0.0187	0.0339	0.4269
	3	0.2428	0.3649	0.1521	0.0738	0.0400	0.0476	0.0683	0.0105	0.2428
	4	0.2929	0.3035	0.1792	0.1210	0.0482	0.0189	0.0319	0.0044	0.2929
Shop	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

PURPOSE	TRIP	NUMBER OF HALF-HOUR PERIODS BEFORE (FOR OUTBOUND STOPS) OR AFTER (FOR INBOUND STOPS) LAST LOCATION								
		0	1	2	3	4	5	6	7	8
	2	0.2275	0.3962	0.1325	0.0884	0.0451	0.0427	0.0438	0.0239	0.2275
	3	0.2694	0.3682	0.1303	0.0709	0.0407	0.0222	0.0389	0.0594	0.2694
	4	0.3520	0.3281	0.1478	0.0695	0.0402	0.0232	0.0108	0.0284	0.3520
Other Maintenance	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.2213	0.3573	0.1462	0.1038	0.0641	0.0365	0.0423	0.0284	0.2213
	3	0.2240	0.4480	0.1363	0.0675	0.0538	0.0326	0.0234	0.0143	0.2240
	4	0.2550	0.3913	0.1091	0.1248	0.0541	0.0295	0.0215	0.0146	0.2550
Eating Out	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.2421	0.3500	0.1356	0.0647	0.0603	0.0578	0.0445	0.0451	0.2421
	3	0.3057	0.2730	0.1353	0.1285	0.0486	0.0496	0.0257	0.0335	0.3057
	4	0.2336	0.2696	0.2168	0.0966	0.0452	0.0793	0.0377	0.0213	0.2336
Visiting	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.2397	0.3720	0.1532	0.0689	0.0602	0.0426	0.0369	0.0264	0.2397
	3	0.1896	0.4992	0.0807	0.0619	0.0426	0.0688	0.0546	0.0026	0.1896
	4	0.2327	0.2392	0.2434	0.0971	0.0731	0.0073	0.0021	0.1050	0.2327
Other Discretionary	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.3159	0.3058	0.1188	0.0765	0.0665	0.0508	0.0223	0.0435	0.3159
	3	0.2628	0.3159	0.1423	0.0931	0.0622	0.0486	0.0412	0.0338	0.2628
	4	0.2421	0.4146	0.1514	0.0865	0.0480	0.0249	0.0217	0.0109	0.2421
At-Work Sub-tour	1	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
	2	0.3229	0.3864	0.1160	0.0319	0.0777	0.0294	0.0097	0.0260	0.3229
	3	0.3047	0.3639	0.1421	0.1048	0.0402	0.0141	0.0251	0.0052	0.3047
	4	0.2227	0.4529	0.1934	0.0250	0.0596	0.0044	0.0057	0.0362	0.2227

Using the averages, the model team determined that it was ideal to maintain the survey distribution as much as possible. However, in addition to cases where there were no survey observations, there are cases where there were only a handful of raw survey observations within the ideal trip chain for each row in the distribution. While the expanded data may be a large number, the team has little confidence in records with only a few raw observations. These records are the most likely to have an abnormal distribution. In order to take that into account, the model team chose a minimum threshold of 20 raw observations. That means that if there were more than 20 raw survey observations, then the calculated survey distribution was used for that row. In cases where there were 0 raw survey observations, the entire row was populated by the calculated average. In cases where there were less than 20, then the final value was based on a percentage of the survey data and a percentage of the calculated average. For example, if there were 15 observations, then the final distribution is equal to 75%*Survey Distribution Value + 25%*Calculated Average.

Many different methodologies could have been used to smooth out this data and impute the missing values, but the model team chose this approach in order to maintain the survey data as much as possible, rather than using the generic averaged data for all records. Although there are still cases where the data does not have a normal distribution, there are no longer missing values. The team could decide to make some manual adjustments to the average data (which does have some cases where there is not a normal distribution), and also to increase the minimum raw observations threshold. That would result in a smoother data set. However, it would also move away from the survey.

APPENDIX C. SANDAG PMSA

TABLE 55: SANDAG PMSA

ID	DISTRICT
1	Downtown
2	Central
3	North City
4	South Suburban
5	East Suburban
6	North County West
7	North County East
8	East County

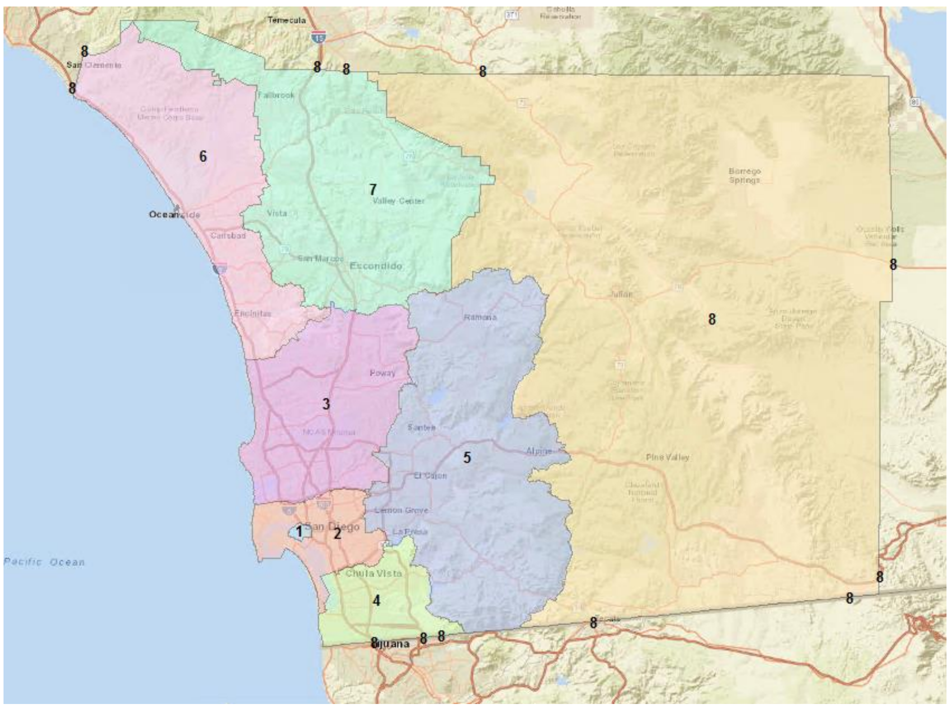

FIGURE 77: A MAP OF SANDAG PMSA

APPENDIX D. SYNTHETIC POPULATION

This appendix describes the process of generating a new synthetic population used in the new ABM. Synthetic population used in the SANDAG's version of the ABM is derived in a process that combines a microsimulation of personal and household demographic evolution with elements of probabilistic imputation of socioeconomic attributes. The process can be divided into several phases:

- Phase 1: Assembling micro data (synthetic persons and households) with only basic demographic attributes based on the 2010 Decennial Census data.
- Phase 2: Evolving synthetic persons and households (from phase 1) from 4/1/2010 (the Census day) first to 1/1/2011 and then in annual increments through 1/1/2017 (the latest effective date for the SANDAG land use inventory).
- Phase 3: Evolving synthetic persons and households (from phase 2) from 1/1/2017 through 1/1/2051 in annual increments.
- Phase 4: Imputing income for households.
- Phase 5: Imputing socioeconomic attributes for persons and households.

Following is a detail description of data methods used at each phase.

Phase 1: First, using a set of tables from the SF1 tabulation of the 2010 Census data, we create microdata for individuals (a roster of people). Each individual has the following attributes: location identifier (census tract), sex, single-year age, race (one of 7 categories), Hispanic origin (binary), role (household head, household member, Military Group Quarters (GQ), College GQ, Institutional GQ, Other GQ). Second, controlling for the household size distribution and using probabilities from the 2010 PUMS data (these probabilities describe the likely demographic attributes of household members, conditioned on the attributes of household head), we arrange individuals into households (match household members with household heads). Third, we assign household to housing units (microdata on housing units is developed from the SANDAG's land use inventory).

Phase 2: In the demographic microsimulation, events (aging, death, birth) occur to individuals. Death and birth counts are based on the vital statistics data. These events add and remove people and alter households. Migration is not explicitly represented in this version of the model; instead, we are using cohort-specific annual population targets from the latest population projections from California Department of Finance (DOF). After implementing the demographic events, the remaining population is compared with the cohort-specific targets. If the remaining cohort-specific population exceeds the target, the excess population is removed, thereby altering the households. Using the probability distributions derived from 2010 SF1 and ACS PUMS data, the target population is translated into a cohort-specific estimate of householders (heads of households) by household size. That estimate is compared with the count of remaining householders. If the remaining cohort- and size-specific count of householders exceeds the target, the excess households (and associated population) is removed, further altering the households. The final target for additional householders (cohort- and size-specific) is then developed; that target conforms to multiple constraints (e.g. number of households and household population by jurisdiction based on the DOF's published estimates). The remaining cohort-specific population is compared with the population target, the additional population is generated and added to a special pool (of individuals without households). In the next step, householders are matched up with the household members form the special pool. Finally, these new households are assigned to the currently unoccupied housing, the supply of which comes from new construction and housing units that became available due to the removal of households. Although this version of the model does not explicitly include migration (to or from the region) and relocation (within the region), the annual number of "new" households in the model is very close to the estimates produced by the ACS (tabulations that show how many households lived in the same house a year ago).

Phase 3: Conceptually, this phase is the same as Phase 2, except for minor details. There are no jurisdiction-level controls (there can't be actual data because this phase applies to the future years). Deaths and births come from the DOF's projections instead of the vital statistics. New housing units come from a separate model called UrbanSim, which creates a parcel-specific supply of future housing units based on local plans and historical trends.

Phase 4: For the observed period (2010-2017), the overall census tract-level income distributions are borrowed from the ACS and applied to the households. This means that if, according to the ACS, some percentage of household in some census tract has income in a certain category, the same percentage of synthetic household assigned to the same census tract will be assigned to the same income category. Further assignment to specific households uses probability distributions developed from the ACS PUMS data. These distributions show the probability that a household has a specific income, given the household size and sex and age of the householder. For the forecast period, the latest available (2016) ACS data is used. However, the income distribution of households is adjusted for every forecast year so that the region-wide distribution matches the expected distribution associated with the different levels of region-wide median income. Currently, we are using an assumption that region-wide median household income will grow at the rate 0.3% per year.

Phase 5: The rest of socioeconomic personal and household attributes is imputed using a set of attribute distributions from the ACS Summary data and a set of conditional probability tables derived from the ACS PUMS data. Below is a description of the sequential imputation steps.

School enrollment is imputed probabilistically as conditional on age.

Employment status is imputed probabilistically as conditional on joint sex/age/income distribution.

Weeks worked/hours worked/educational attainment/occupation status is imputed as conditional on joint sex/age/income/employment status distribution.

APPENDIX E. CT-RAMP CALIBRATION RESULTS

This appendix presents detailed CT-RAMP calibration results. A related discussion is available in Chapter 3.0 under Model Calibration.

LONG TERM CHOICES

Mandatory Tour Location Choice

TABLE 56: AVERAGE MANDATORY TOUR LENGTHS

	HTS			SDABM16		
Home District	Work	University	School	Work	University	School
Downtown	5.86	5.87	10.78	7.48	5.79	3.16
Central	10.30	8.57	4.89	9.32	7.91	4.30
North City	10.68	6.90	4.21	11.02	8.10	4.98
South Suburban	12.59	8.79	3.21	13.12	9.96	3.42
East Suburban	13.31	8.29	3.80	14.08	10.22	3.94
North County West	12.55	12.17	4.21	12.54	9.39	3.85
North County East	14.20	9.98	4.77	13.86	8.68	3.42
East County	83.90	-	-	26.91	17.95	10.05
Total	**11.80**	**8.55**	**4.26**	**11.99**	**8.82**	**4.10**

TABLE 57: DISTRICT-DISTRICT FLOW OF WORKERS (HTS)

	WORK DISTRICT								
Home District	Downtown	Central	North City	South Suburban	East Suburban	North County West	North County East	East County	Total
Downtown	8,172	3,636	4,902	825	449	145	21	-	18,150
Central	34,178	73,747	122,839	26,186	15,562	4,063	2,206	88	278,868
North City	25,510	40,968	258,238	7,412	15,465	11,032	9,350	-	367,975
South Suburban	22,362	34,514	37,190	58,865	5,683	78	-	-	158,693
East Suburban	17,195	30,276	68,374	6,451	77,488	5,675	2,833	-	208,292
North County West	4,959	3,495	42,507	667	370	110,481	30,361	-	192,840
North County East	2,581	1,045	50,245	1,891	2,964	44,711	77,912	-	181,350
East County	-	7,801	-	-	-	-	-	-	7,801
Total	114,958	195,482	84,295	102,296	117,981	176,185	22,684	88	1,413,969

TABLE 58: DISTRICT-DISTRICT FLOW OF WORKERS (SDABM16)

	WORK DISTRICT								
Home District	Downtown	Central	North City	South Suburban	East Suburban	North County West	North County East	East County	Total
Downtown	4,504	5,154	6,105	1,094	937	241	113	2	18,150
Central	27,054	98,088	02,149	22,376	23,794	3,411	1,964	32	278,868
North City	15,758	49,510	241,902	8,849	20,627	16,673	14,585	71	367,975
South Suburban	13,344	37,067	37,951	55,220	13,516	963	593	39	158,693
East Suburban	10,834	35,143	73,192	13,031	69,895	2,327	3,485	385	208,292
North County West	1,937	4,251	43,176	678	1,554	104,283	36,954	7	192,840
North County East	1,319	3,520	41,889	570	2,620	45,694	85,665	73	181,350
East County	79	330	784	237	2,228	83	468	3,592	7,801
Total	**74,829**	**233,063**	**547,148**	**102,055**	**135,171**	**173,675**	**43,827**	**4,201**	**1,413,969**

TABLE 59: DISTRICT-DISTRICT FLOW OF WORKERS (DIFF=SDABM16-HTS)

	WORK DISTRICT								
Home District	Downtown	Central	North City	South Suburban	East Suburban	North County West	North County East	East County	Total
Downtown	(3,668)	1,518	1,203	269	488	96	92	2	-
Central	(7,124)	24,341	20,690)	(3,810)	8,232	(652)	(242)	(56)	-
North City	(9,752)	8,542	16,336)	1,437	5,162	5,641	5,235	71	-
South Suburban	(9,018)	2,553	761	(3,645)	7,833	885	593	39	-
East Suburban	(6,361)	4,867	4,818	6,580	(7,593)	(3,348)	652	385	-
North County West	(3,022)	756	669	11	1,184	(6,198)	6,593	7	-
North County East	(1,262)	2,475	(8,356)	(1,321)	(344)	983	7,753	73	-
East County	79	(7,471)	784	237	2,228	83	468	3,592	-
Total	**(40,129)**	**37,581**	**(37,147)**	**(241)**	**17,190**	**(2,510)**	**21,143**	**4,113**	**-**

TABLE 60: DISTRICT-DISTRICT FLOW OF WORKERS (%DIFF)

	WORK DISTRICT								
Home District	Downtown	Central	North City	South Suburban	East Suburban	North County West	North County East	East County	Total
Downtown	-45%	42%	25%	33%	108%	66%	444%	-	
Central	-21%	33%	-17%	-15%	53%	-16%	-11%	-64%	
North City	-38%	21%	-6%	19%	33%	51%	56%	-	
South Suburban	-40%	7%	2%	-6%	138%	1130%	-	-	
East Suburban	-37%	16%	7%	102%	-10%	-59%	23%	-	
North County West	-61%	22%	2%	2%	320%	-6%	22%	-	
North County East	-49%	237%	-17%	-70%	-12%	2%	10%	-	
East County	-	-96%	-	-	-	-	-	-	
Total	**-35%**	**19%**	**-6%**	**0%**	**15%**	**-1%**	**17%**	**4691%**	

COORDINATED DAILY ACTIVITY PATTERN

TABLE 61: DAILY ACTIVITY PATTERN - FREQUENCY

	HTS			SDABM16		
Person Type	**M**	**N**	**H**	**M**	**N**	**H**
Full-time worker	918,201	182,828	117,814	868,399	127,079	88,061
Part-time worker	121,230	66,988	28,982	189,113	111,796	48,019
University student	197,922	55,687	51,730	116,390	38,133	30,831
Non-worker	-	253,345	134,960	-	358,075	126,573
Retired	-	193,210	127,090	-	227,084	146,275
Student of driving age	76,807	15,048	25,893	81,879	3,679	5,382
Student of non-driving age	279,263	71,242	65,646	447,638	25,994	8,376
Child too young for school	45,886	85,086	42,792	59,979	107,153	56,224
Total	**1,639,309**	**923,434**	**594,908**	**1,763,398**	**998,993**	**509,741**

TABLE 62: DAILY ACTIVITY PATTERN – SHARE (%)

	HTS			SDABM16		
Person Type	M	N	H	M	N	H
Full-time worker	75%	15%	10%	80%	12%	8%
Part-time worker	56%	31%	13%	54%	32%	14%
University student	65%	18%	17%	63%	21%	17%
Non-worker	0%	65%	35%	0%	74%	26%
Retired	0%	60%	40%	0%	61%	39%
Student of driving age	65%	13%	22%	90%	4%	6%
Student of non-driving age	67%	17%	16%	93%	5%	2%
Child too young for school	26%	49%	25%	27%	48%	25%
Total	**52%**	**29%**	**19%**	**54%**	**31%**	**16%**

MANDATORY TOUR FREQUENCY

TABLE 63: MANDATORY TOUR FREQUENCY (COUNT OF PERSONS)- HTS

PERSON TYPE	1 WORK	2 WORK	1 SCHOOL	2 SCHOOL	MIXED	TOTAL
Full-time worker	846,054	50,519	14,228	1,012	6,388	918,201
Part-time worker	110,079	11,150	-	-	-	121,230
University student	38,980	1,136	137,596	13,086	7,124	197,922
Student of driving age	2,869	22	69,466	3,058	1,391	76,807
Student of non-driving age	-	-	262,951	16,313	-	279,263
Child too young for school	-	-	45,427	459	-	45,886
Total	**997,983**	**62,828**	**529,668**	**33,928**	**14,903**	**1,639,309**

TABLE 64: MANDATORY TOUR FREQUENCY (COUNT OF PERSONS) – SDABM16

PERSON TYPE	1 WORK	2 WORK	1 SCHOOL	2 SCHOOL	MIXED	TOTAL
Full-time worker	824,311	44,088	-	-	-	868,399
Part-time worker	176,628	12,485	-	-	-	189,113
University student	13,878	-	85,209	5,566	11,737	116,390
Student of driving age	-	-	76,958	4,048	873	81,879
Student of non-driving age	-	-	442,031	5,607	-	447,638
Child too young for school	-	-	59,979	-	-	59,979
Total	**1,014,817**	**56,573**	**664,177**	**15,221**	**12,610**	**1,763,398**

TABLE 65: MANDATORY TOUR FREQUENCY (SHARE OF PERSONS)- HTS

PERSON TYPE	1 WORK	2 WORK	1 SCHOOL	2 SCHOOL	MIXED	TOTAL
Full-time worker	92%	6%	2%	0%	1%	100%
Part-time worker	91%	9%	0%	0%	0%	100%
University student	20%	1%	70%	7%	4%	100%
Student of driving age	4%	0%	90%	4%	2%	100%
Student of non-driving age	0%	0%	94%	6%	0%	100%
Child too young for school	0%	0%	99%	1%	0%	100%
Total	**61%**	**4%**	**32%**	**2%**	**1%**	**100%**

TABLE 66: MANDATORY TOUR FREQUENCY (SHARE OF PERSONS) – SDABM16

PERSON TYPE	1 WORK	2 WORK	1 SCHOOL	2 SCHOOL	MIXED	TOTAL
Full-time worker	95%	5%	0%	0%	0%	100%
Part-time worker	93%	7%	0%	0%	0%	100%
University student	12%	0%	73%	5%	10%	100%
Student of driving age	0%	0%	94%	5%	1%	100%
Student of non-driving age	0%	0%	99%	1%	0%	100%
Child too young for school	0%	0%	100%	0%	0%	100%
Total	**58%**	**3%**	**38%**	**1%**	**1%**	**100%**

INDIVIDUAL NON-MANDATORY TOUR FREQUENCY

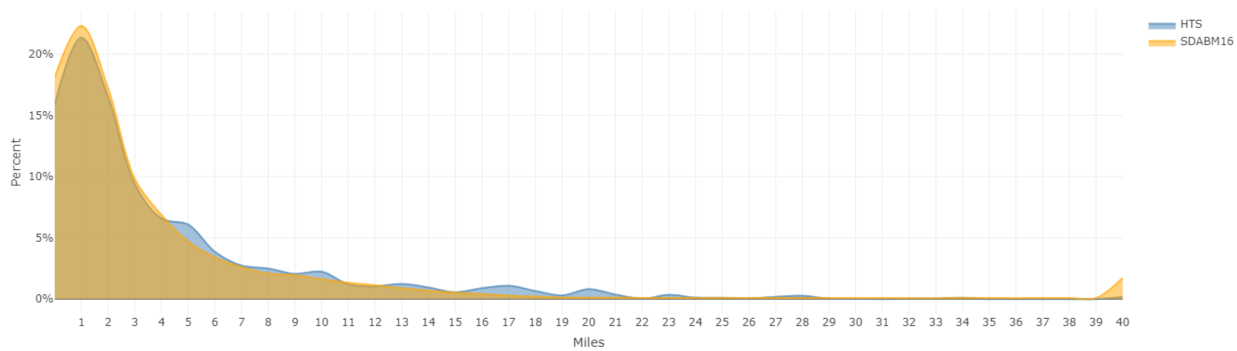

FIGURE 78: NM TOUR LENGTH FREQUENCY DISTRIBITION- INDIVIDUAL MAINTENANCE

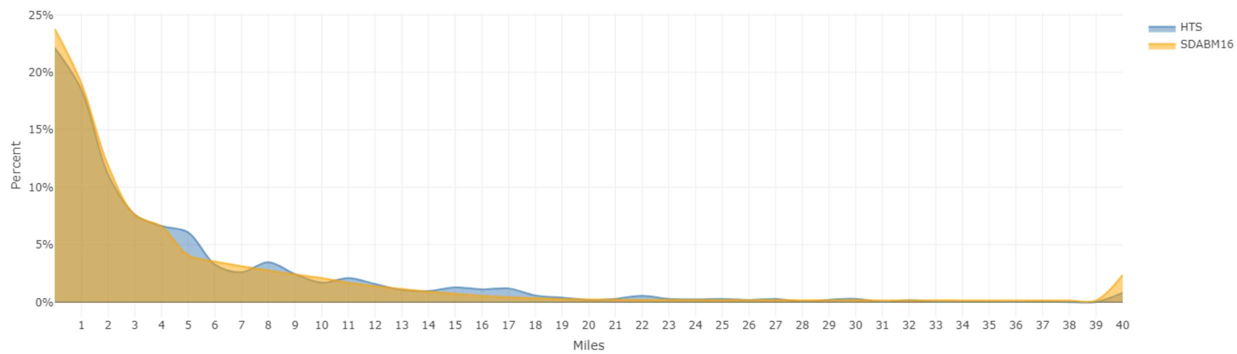

FIGURE 79: NM TOUR LENGTH FREQUENCY DISTRIBITION- INDIVIDUAL DISCRETIONARY

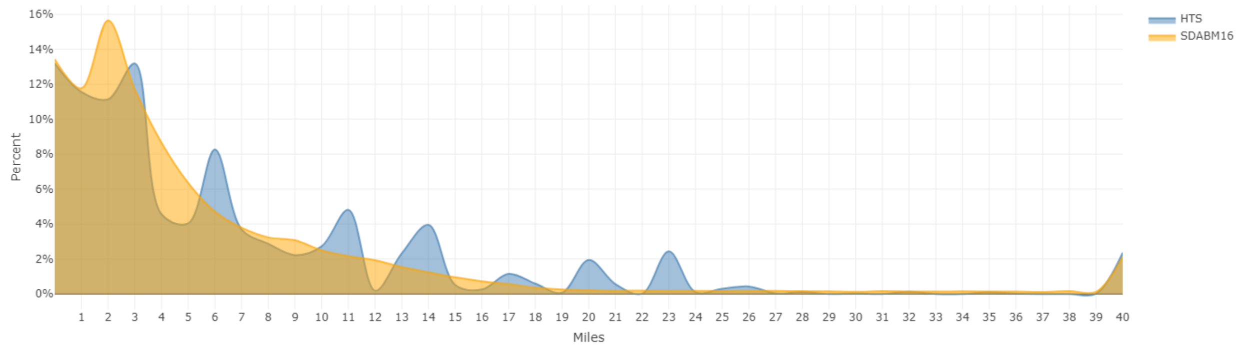

FIGURE 80: NM TOUR LENGTH FREQUENCY DISTRIBITION- JOINT MAINTENANCE

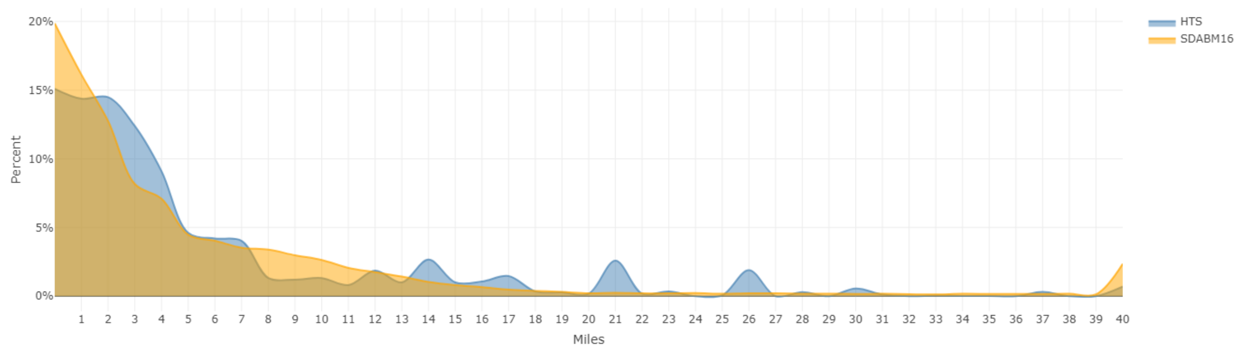

FIGURE 81: NM TOUR LENGTH FREQUENCY DISTRIBITION- JOINT DISCETIONARY

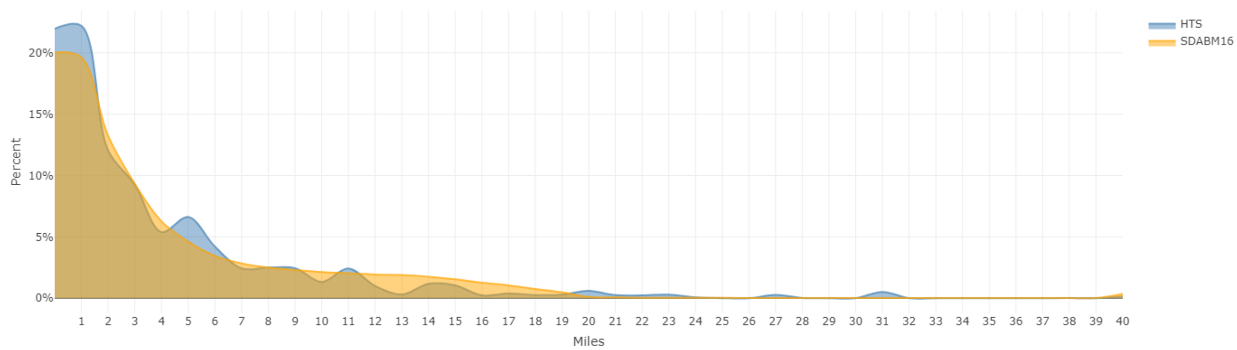

FIGURE 82: NM TOUR LENGTH FREQUENCY DISTRIBITION- ESCORTING

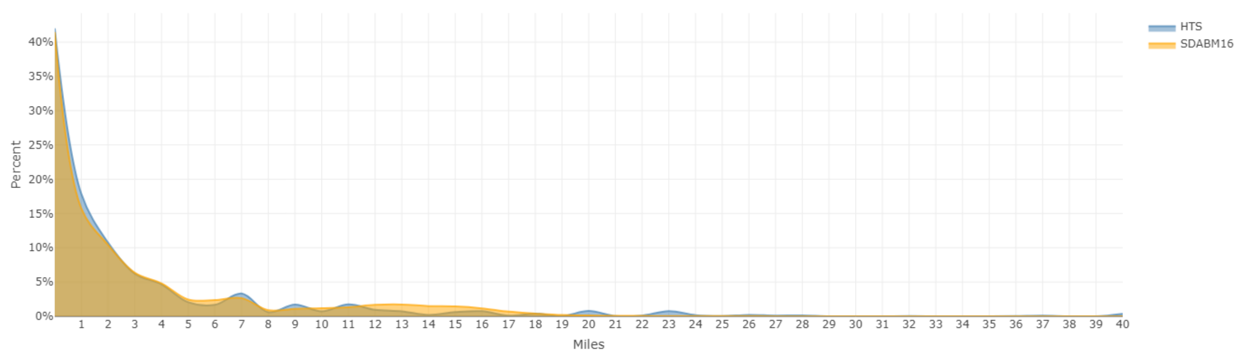

FIGURE 83: NM TOUR LENGTH FREQUENCY DISTRIBITION- AT WORK

TABLE 67: FREQUENCY OF PERSONS BY INDIVIDUAL NM TOURS - HTS

PERSON TYPE	0	1	2	3 PLUS	TOTAL
FT Worker	859,066	261,998	72,220	25,559	1,218,843
PT Worker	119,358	58,003	24,242	15,597	217,200
Univ Student	200,048	66,752	28,600	9,939	305,339
Non-Worker	174,547	126,264	52,607	34,887	388,305
Retiree	154,431	122,718	33,753	9,397	320,300
Driving-Age Student	90,689	25,314	1,609	137	117,748
Non-Driving Student	308,957	84,656	20,561	1,977	416,152
Pre-Schooler	109,638	44,686	13,291	6,149	173,765
Total	**2,016,734**	**790,391**	**246,883**	**103,642**	**3,157,651**

TABLE 68: FREQUENCY OF PERSONS BY INDIVIDUAL NM TOURS – SDABM16

PERSON TYPE	0	1	2	3 PLUS	TOTAL
FT Worker	758,014	222,544	64,419	38,562	1,083,539
PT Worker	176,568	88,982	44,997	38,381	348,928
Univ Student	110,133	43,674	20,609	10,938	185,354
Non-Worker	126,573	189,150	83,558	85,367	484,648
Retiree	146,275	160,781	49,101	17,202	373,359
Driving-Age Student	70,529	19,048	949	414	90,940
Non-Driving Student	381,249	83,670	15,514	1,575	482,008
Pre-Schooler	116,200	75,616	28,038	3,502	223,356
Total	**1,885,541**	**883,465**	**307,185**	**195,941**	**3,272,132**

TABLE 69: SHARE OF PERSONS BY INDIVIDUAL NM TOURS - HTS

PERSON TYPE	0	1	2	3 PLUS	TOTAL
FT Worker	70%	21%	6%	2%	100%
PT Worker	55%	27%	11%	7%	100%
Univ Student	66%	22%	9%	3%	100%
Non-Worker	45%	33%	14%	9%	100%
Retiree	48%	38%	11%	3%	100%
Driving-Age Student	77%	21%	1%	0%	100%
Non-Driving Student	74%	20%	5%	0%	100%
Pre-Schooler	63%	26%	8%	4%	100%
Total	**64%**	**25%**	**8%**	**3%**	**100%**

TABLE 70: SHARE OF PERSONS BY INDIVIDUAL NM TOURS – SDABM16

PERSON TYPE	0	1	2	3 PLUS	TOTAL
FT Worker	70%	21%	6%	4%	100%
PT Worker	51%	26%	13%	11%	100%
Univ Student	59%	24%	11%	6%	100%
Non-Worker	26%	39%	17%	18%	100%
Retiree	39%	43%	13%	5%	100%
Driving-Age Student	78%	21%	1%	0%	100%
Non-Driving Student	79%	17%	3%	0%	100%
Pre-Schooler	52%	34%	13%	2%	100%
Total	**58%**	**27%**	**9%**	**6%**	**100%**

SCHOOL ESCORT MODEL

TABLE 71: SHARE OF STUDENT SCHOOL HALF TOURS BY ESCORT TYPE - HTS

	OUTBOUND				INBOUND			
CHILD TYPE	RIDE SHARE	PURE ESCORT	NO ESCORT	TOTAL	RIDE SHARE	PURE ESCORT	NO ESCORT	TOTAL
Non-Driving Student	8.5%	25.0%	66.5%	100%	6.2%	27.1%	66.6%	100%
Pre-Schooler	36.9%	8.7%	54.4%	100%	27.1%	9.6%	63.3%	100%
Total	**11.7%**	**23.2%**	**65.1%**	**100%**	**8.6%**	**25.2%**	**66.3%**	**100%**

TABLE 72: SHARE OF STUDENT SCHOOL HALF TOURS BY ESCORT TYPE – SDABM16

	OUTBOUND				INBOUND			
CHILD TYPE	RIDE SHARE	PURE ESCORT	NO ESCORT	TOTAL	RIDE SHARE	PURE ESCORT	NO ESCORT	TOTAL
Non-Driving Student	8.5%	21.9%	69.6%	100%	6.2%	25.4%	68.5%	100%
Pre-Schooler	28.8%	10.0%	61.2%	100%	22.6%	11.2%	66.2%	100%
Total	**9.4%**	**17.6%**	**73.1%**	**100%**	**6.9%**	**20.4%**	**72.6%**	**100%**

TABLE 73: SHARE OF SCHOOL HALF-TOURS BY CHAUFFEUR AND ESCORT TYPE - HTS

	OUTBOUND			INBOUND		
CHAUFFEUR	RIDE SHARE	PURE ESCORT	TOTAL	RIDE SHARE	PURE ESCORT	TOTAL
FT Worker	56.0%	44.0%	100%	39.4%	60.6%	100%
PT Worker	51.6%	48.4%	100%	54.6%	45.4%	100%
Univ Stud	21.5%	78.5%	100%	32.6%	67.4%	100%
Non-Worker	0.0%	100.0%	100%	0.0%	100.0%	100%
Retiree	0.0%	100.0%	100%	0.0%	100.0%	100%
Total	**33.5%**	**66.5%**	**100%**	**25.4%**	**74.6%**	**100%**

TABLE 74: SHARE OF SCHOOL HALF-TOURS BY CHAUFFEUR AND ESCORT TYPE – SDABM16

	OUTBOUND			INBOUND		
CHAUFFEUR	RIDE SHARE	PURE ESCORT	TOTAL	RIDE SHARE	PURE ESCORT	TOTAL
FT Worker	71.5%	28.5%	100%	53.3%	46.7%	100%
PT Worker	34.1%	65.9%	100%	29.7%	70.3%	100%
Univ Stud	39.7%	60.3%	100%	36.0%	64.0%	100%
Non-Worker	0.0%	100.0%	100%	0.0%	100.0%	100%
Retiree	0.0%	100.0%	100%	0.0%	100.0%	100%
Total	**34.7%**	**65.3%**	**100%**	**25.4%**	**74.6%**	**100%**

JOINT TOURS

TABLE 75: HOUSEHOLDS BY JOINT TOUR FREQUENCY

JOINT TOUR COMBINATION	HTS	SDABM16	HTS	SDABM16
1 Shopping	26,128	26,897	20%	20%
1 Maintenance	28,672	29,567	22%	22%
1 Eating Out	25,822	14,578	20%	11%
1 Visiting	5,614	10,551	4%	8%
1 Other Discretionary	31,933	28,058	25%	20%
2 Shopping	667	1,936	1%	1%
1 Shopping / 1 Maintenance	377	1,369	0%	1%
1 Shopping / 1 Eating Out	400	233	0%	0%
1 Shopping / 1 Visiting	177	280	0%	0%
1 Shopping / 1 Other Discretionary	1,145	1,638	1%	1%
2 Maintenance	702	6,158	1%	4%
1 Maintenance / 1 Eating Out	1,127	1,045	1%	1%
1 Maintenance / 1 Visiting	54	1,717	0%	1%
1 Maintenance / 1 Other Discretionary	1,630	3,537	1%	3%
2 Eating Out	730	1,346	1%	1%
1 Eating Out / 1 Visiting	63	2,115	0%	2%
1 Eating Out / 1 Other Discretionary	538	3,565	0%	3%
2 Visiting	297	158	0%	0%
1 Visiting / 1 Other Discretionary	1,560	1,020	1%	1%
2 Other Discretionary	297	1,275	0%	1%
Total	**127,933**	**137,043**	**100%**	**100%**

TABLE 76: JOINT TOUR COMPOSITION

JOINT TOUR COMPOSITION	HTS	SDABM16	HTS	SDABM16
All Adult	84,023	89,073	57.6%	54.2%
All Children	31	4,969	0.0%	3.0%
Mixed	61,771	70,393	42.4%	42.8%
Total	**145,825**	**164,435**	**100.0%**	**100.0%**

TABLE 77: JOINT TOURS BY NUMBER OF PARTICIPANTS

JOINT PARTY SIZE	HTS	SDABM16	HTS	SDABM16
2	113,439	110,238	77.8%	67.0%
3	22,651	38,061	15.5%	23.1%
4	9,238	12,295	6.3%	7.5%
5	498	3,841	0.3%	2.3%
Total	**145,825**	**164,435**	**100.0%**	**100.0%**

TABLE 78: JOINT TOUR FREQUENCY BY HOUSEHOLD SIZE AND PARTY SIZE - HTS

	NUMBER OF JOINT TOURS			
HOUSEHOLD SIZE	0	1	2	TOTAL
2	313,276	43,893	3,812	**360,981**
3	160,346	23,566	1,759	**185,672**
4	133,001	25,403	2,761	**161,164**
5	105,721	25,308	1,431	**132,460**
Total	**712,344**	**118,170**	**9,763**	**840,277**

TABLE 79: JOINT TOUR FREQUENCY BY HOUSEHOLD SIZE AND PARTY SIZE – SDABM16

	NUMBER OF JOINT TOURS			
HOUSEHOLD SIZE	0	1	2	TOTAL
2	301,762	42,586	3,347	347,695
3	176,536	22,193	4,960	203,689
4	138,282	23,345	7,416	169,043
5	273,188	42,605	23,220	339,013
Total	**889,768**	**130,729**	**38,943**	**1,059,440**

TABLE 80: JOINT TOUR SHARE BY HOUSEHOLD SIZE AND PARTY SIZE - HTS

	NUMBER OF JOINT TOURS			
HOUSEHOLD SIZE	0	1	2	TOTAL
2	87%	12%	1%	**100%**
3	86%	13%	1%	**100%**
4	83%	16%	2%	**100%**
5	80%	19%	1%	**100%**
Total	**85%**	**14%**	**1%**	**100%**

TABLE 81: JOINT TOUR SHARE BY HOUSEHOLD SIZE AND PARTY SIZE – SDABM16

	NUMBER OF JOINT TOURS			
HOUSEHOLD SIZE	0	1	2	TOTAL
2	87%	12%	1%	**100%**
3	87%	11%	2%	**100%**
4	82%	14%	4%	**100%**
5	81%	13%	7%	**100%**
Total	84%	12%	4%	**100%**

STOP LOCATION CHOICE

TABLE 82: AVERAGE OUT OF DISTANCE (MILES)

TOUR PURPOSE	HTS	SDABM16
Work	3.67	3.72
University	2.41	4.11
School	3.00	8.34
Escorting	3.92	3.82
Individual Maintenance	2.79	3.80
Individual Discretionary	2.88	3.38
Joint Maintenance	2.23	4.20
Joint Discretionary	2.52	3.79
At-Work	1.03	5.85
Total	**3.08**	**4.30**

APPENDIX F. VALIDATION PLOTS FOR KEY FREEWAY CORRIDORS

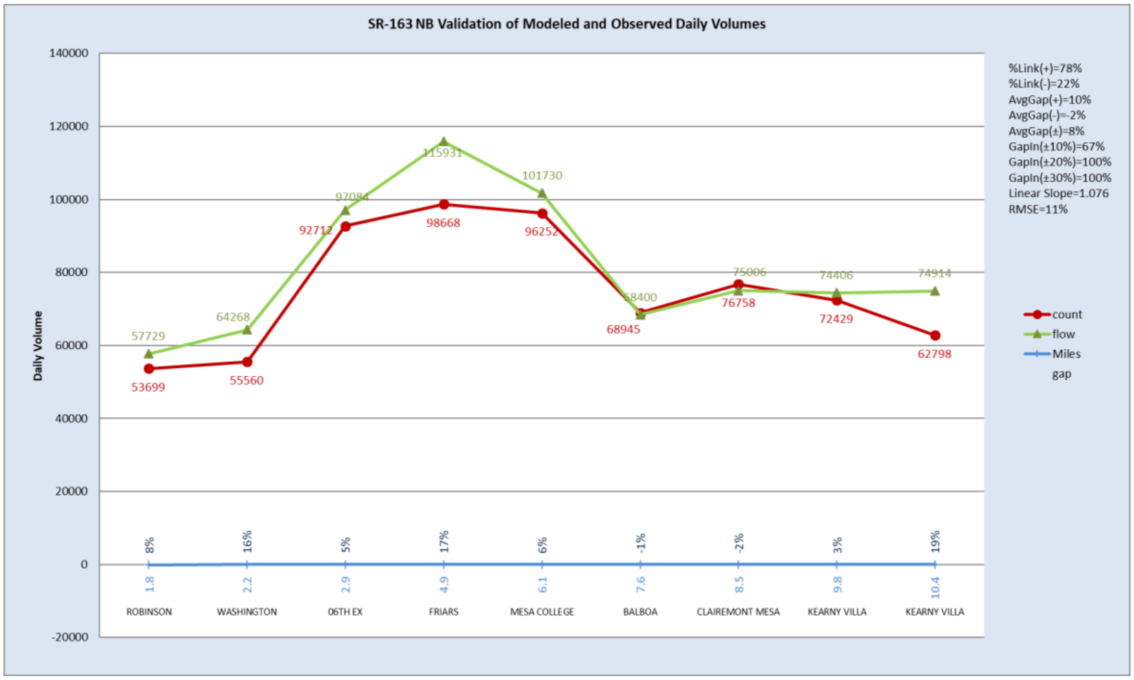

FIGURE 84: KEY CORRIDOR VALIDATION - SR-163 NB

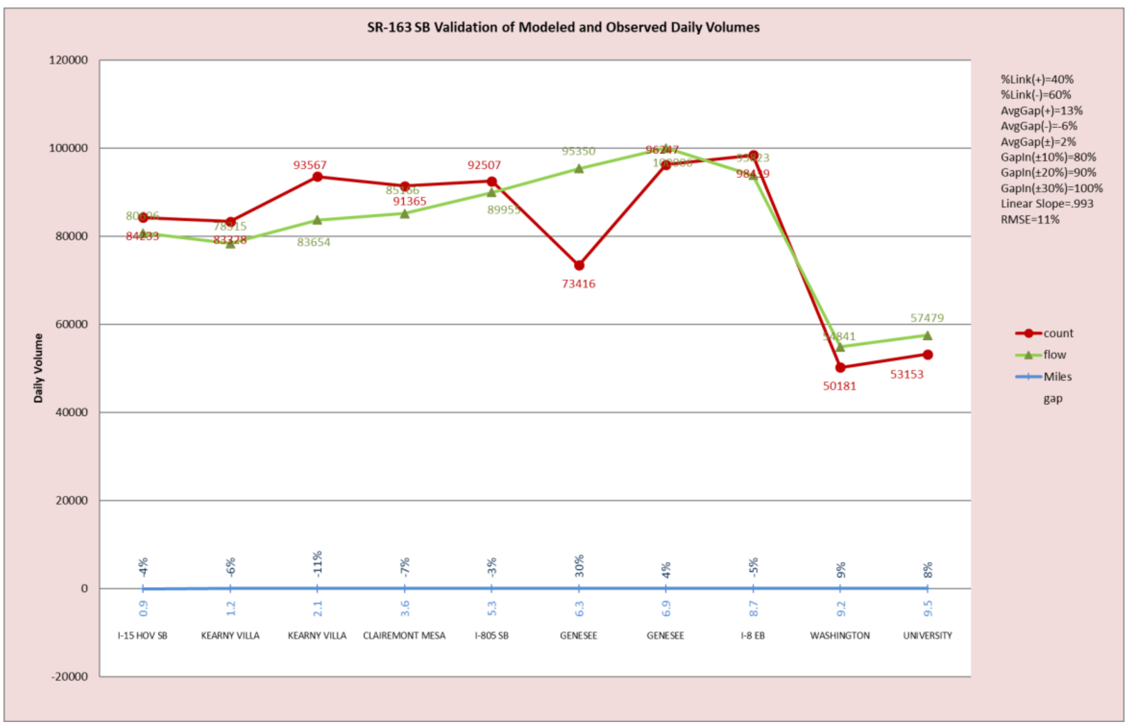

FIGURE 85: KEY CORRIDOR VALIDATION - SR-163 SB

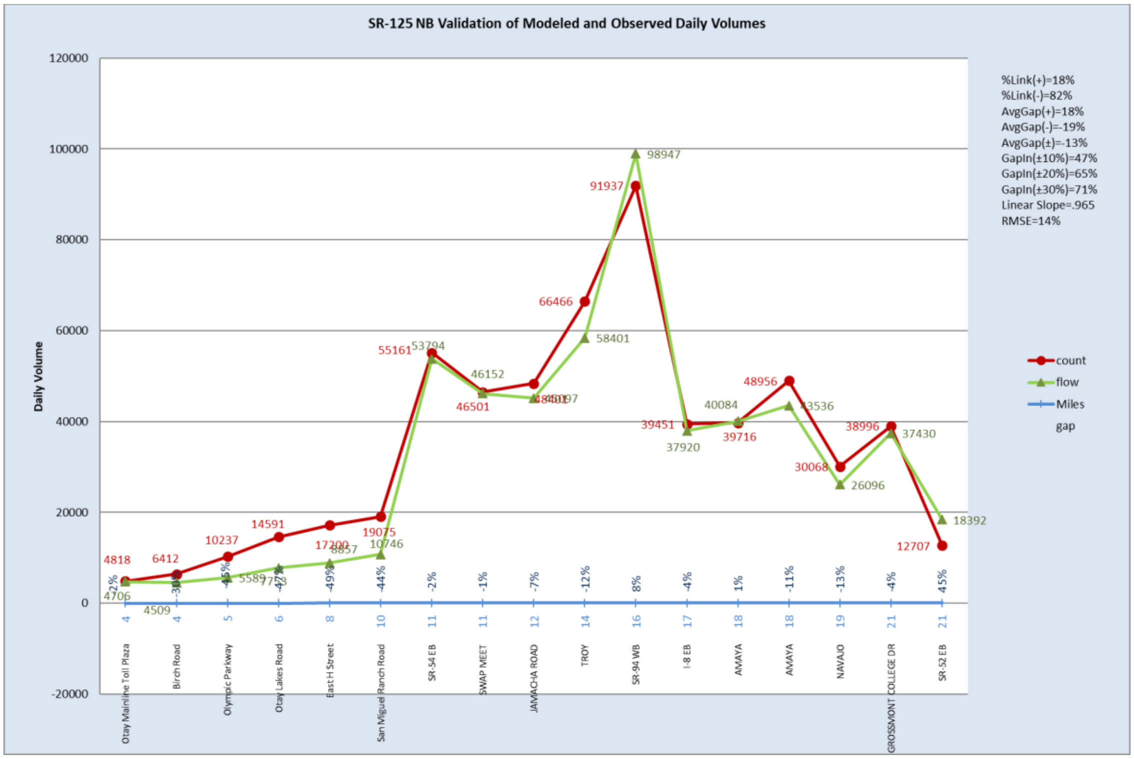

FIGURE 86: KEY CORRIDOR VALIDATION - SR-125 NB

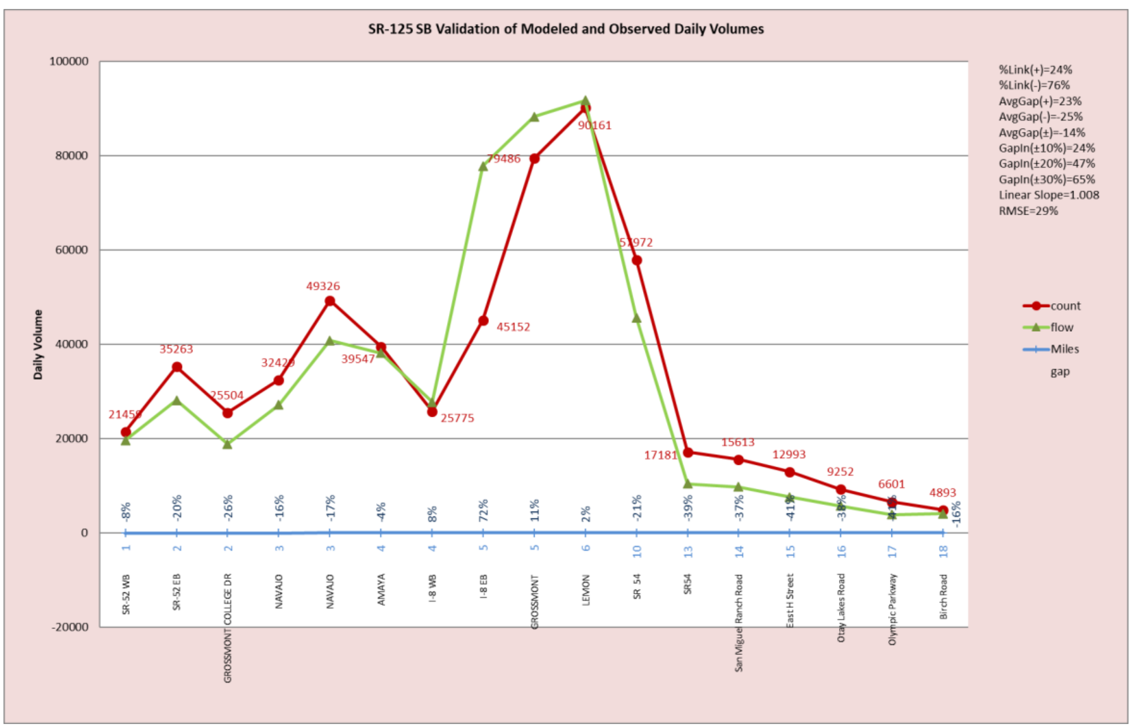

FIGURE 87: KEY CORRIDOR VALIDATION - SR-125 SB

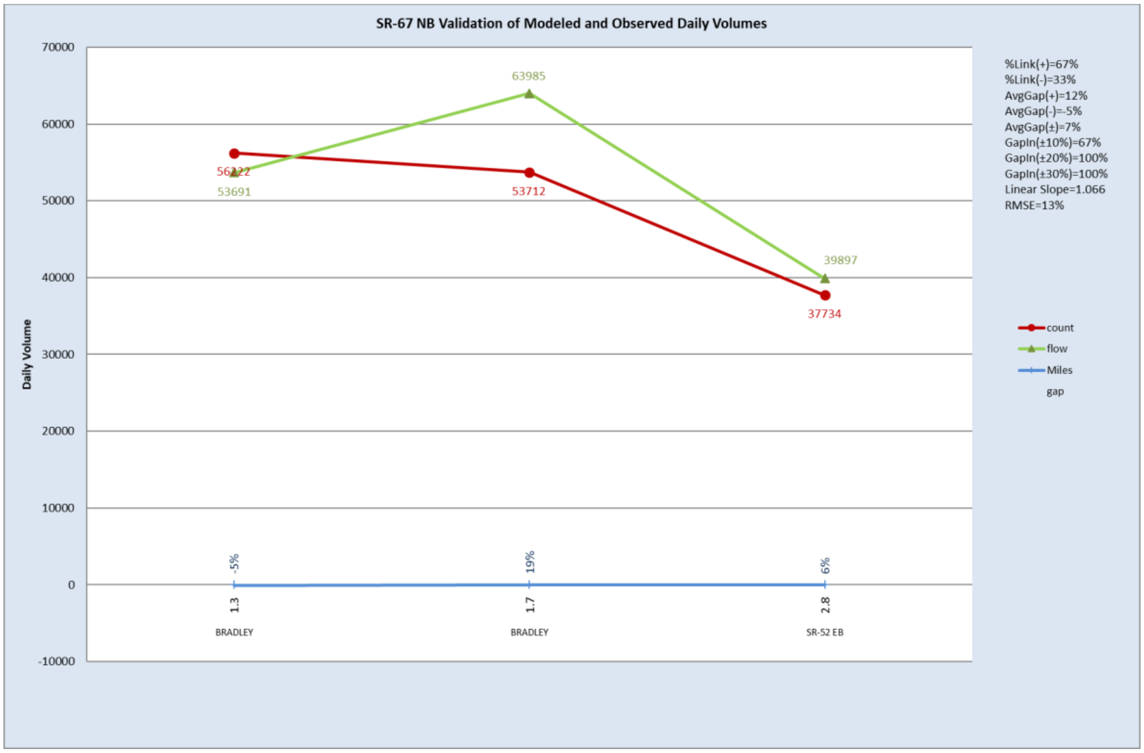

FIGURE 88: KEY CORRIDOR VALIDATION - SR-67 NB

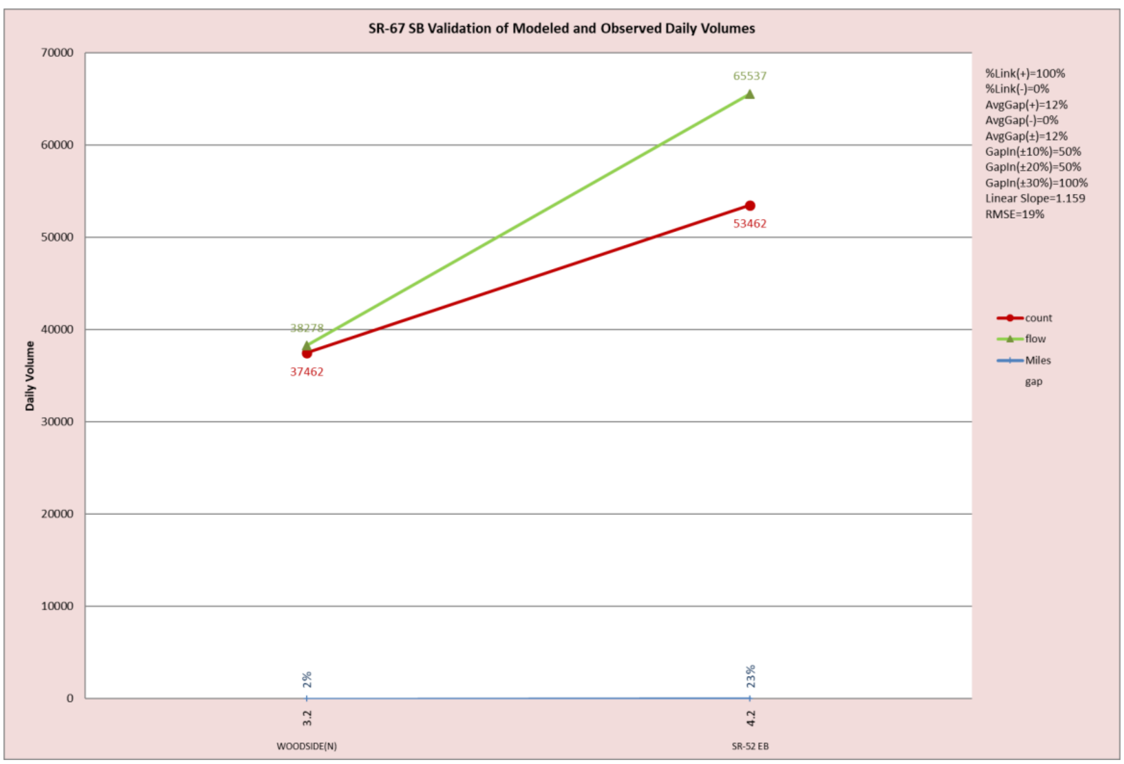

FIGURE 89: KEY CORRIDOR VALIDATION - SR-67 SB

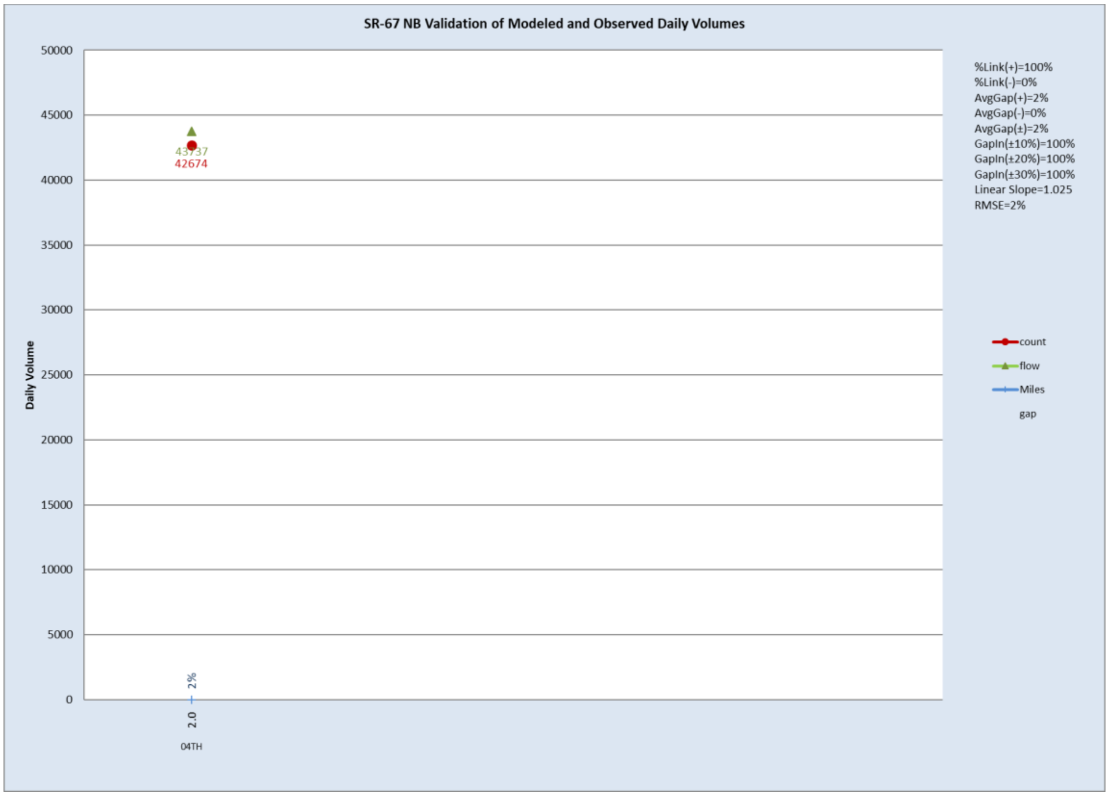

FIGURE 90: KEY CORRIDOR VALIDATION - SR-75 NB

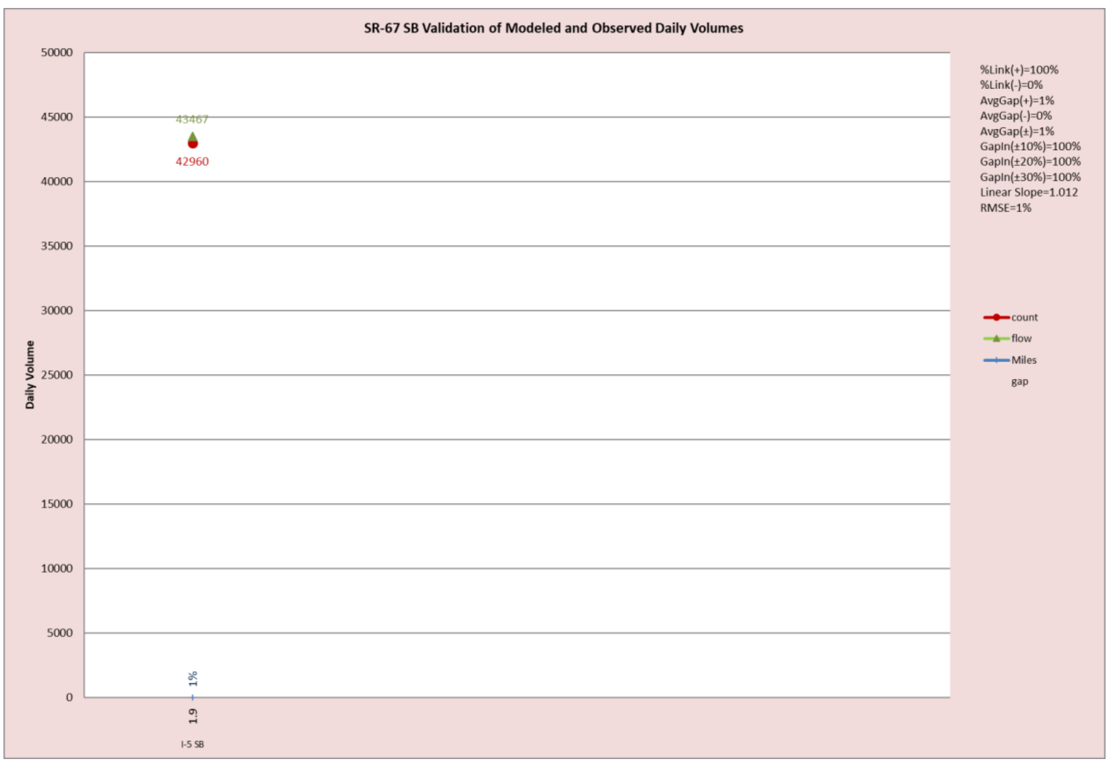

FIGURE 91: KEY CORRIDOR VALIDATION - SR-75 SB

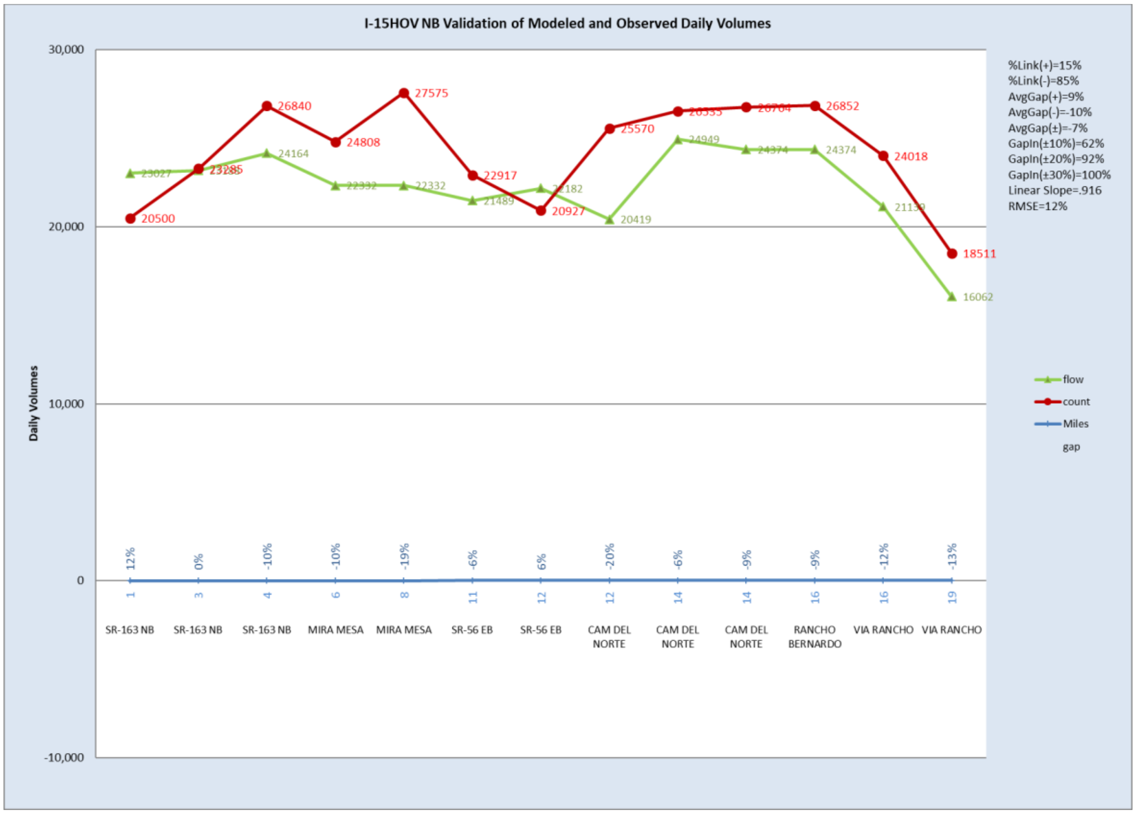

FIGURE 92: KEY CORRIDOR VALIDATION – I-15 HOV NB

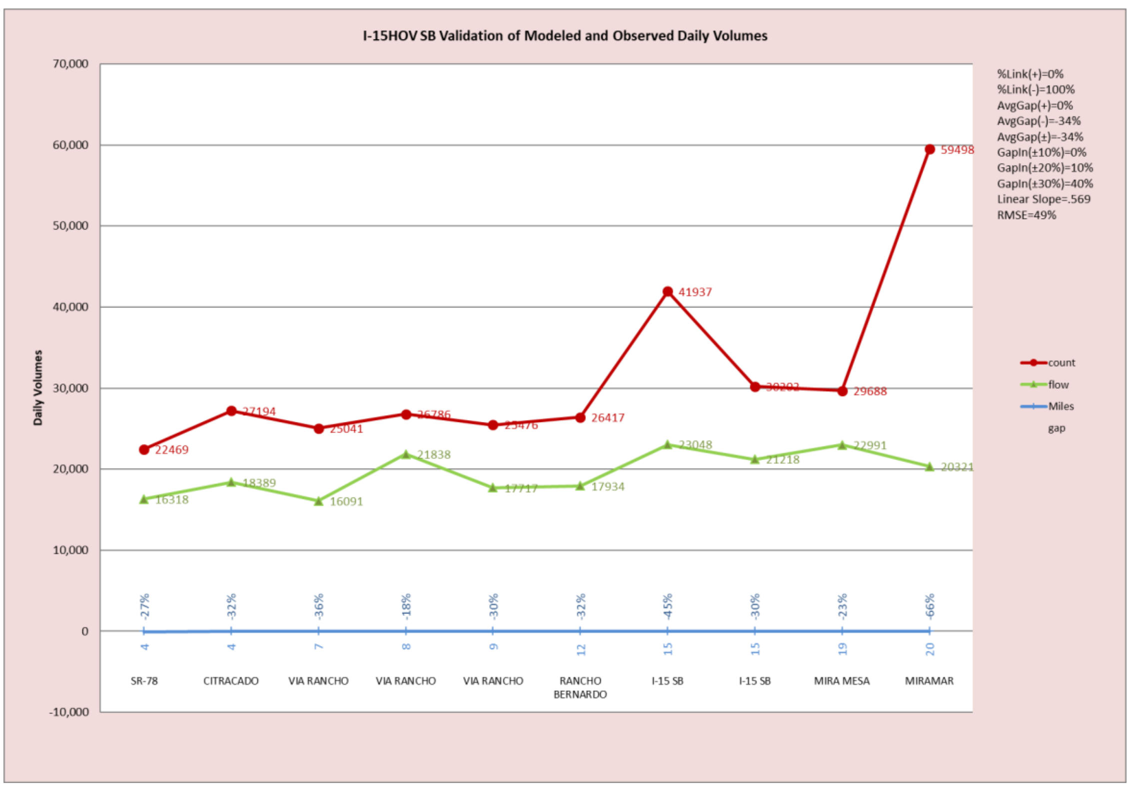

FIGURE 93: KEY CORRIDOR VALIDATION – I-15 HOV SB

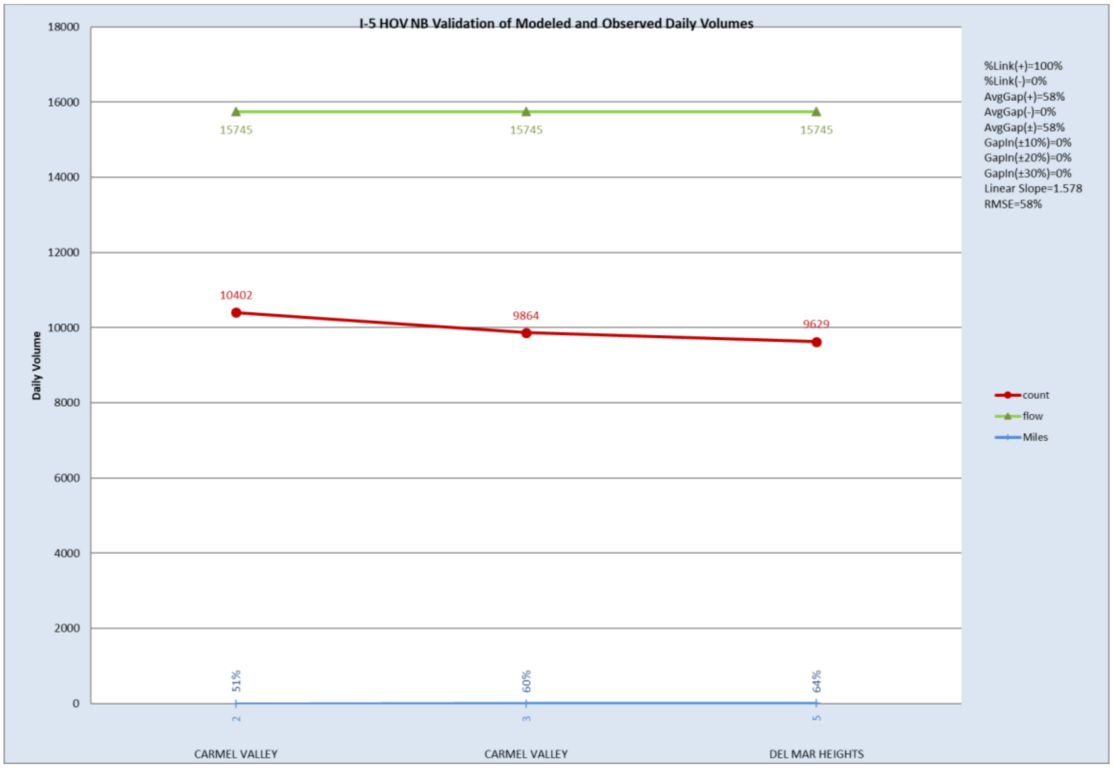

FIGURE 94: KEY CORRIDOR VALIDATION – I-5 HOV NB

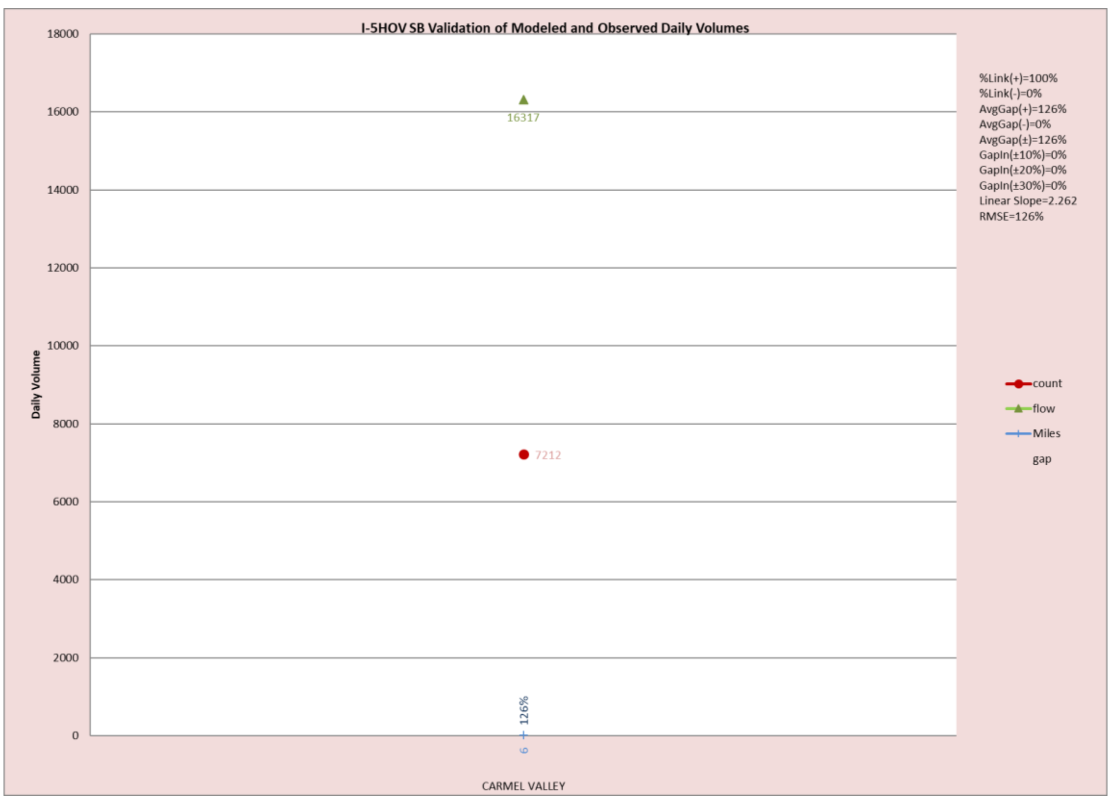

FIGURE 95: KEY CORRIDOR VALIDATION – I-5 HOV SB

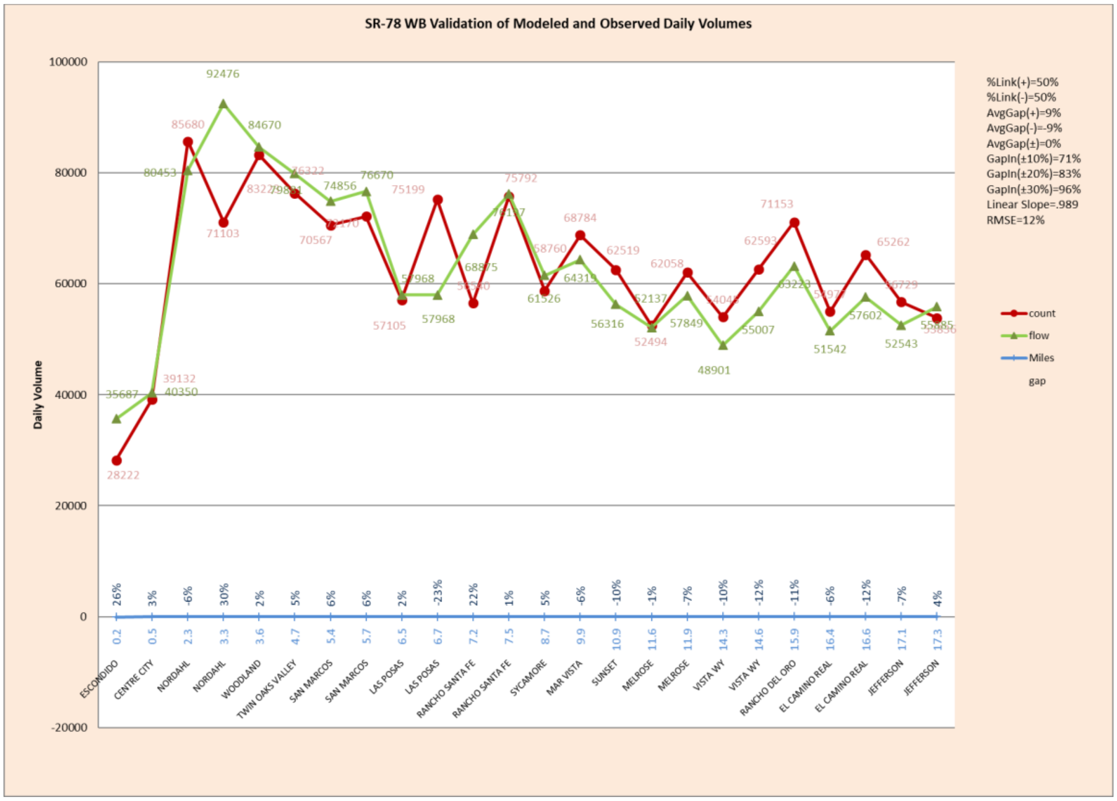

FIGURE 96: KEY CORRIDOR VALIDATION – SR-78 WB

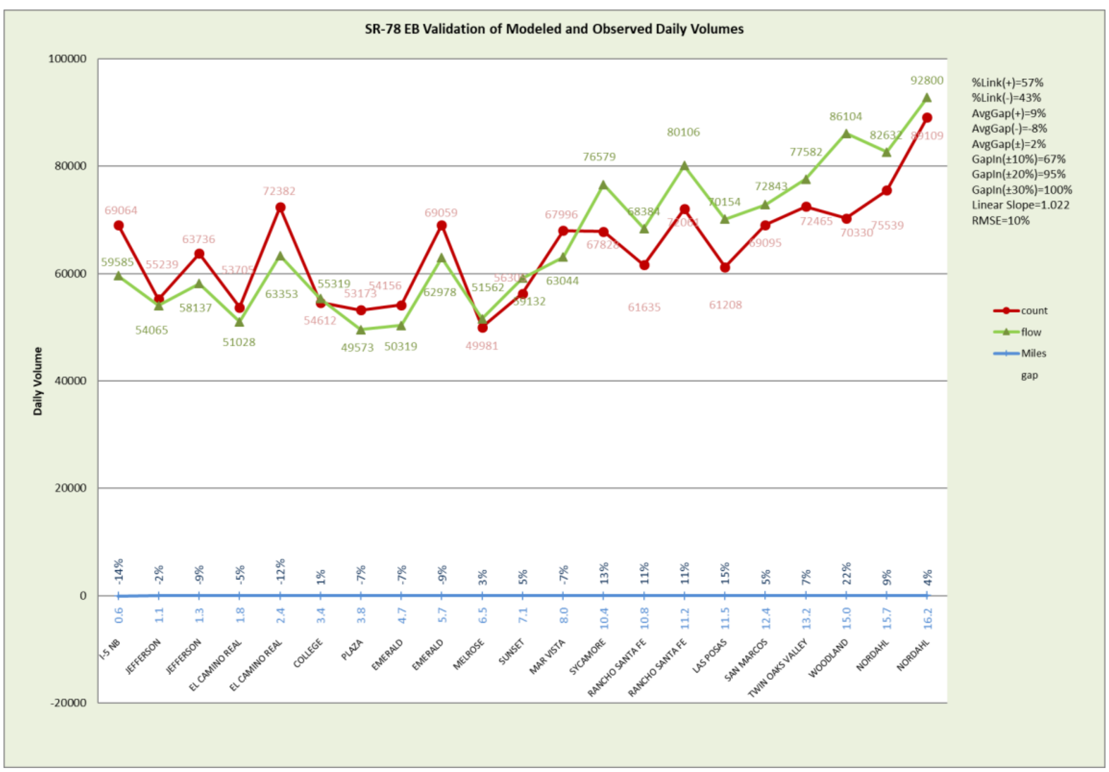

FIGURE 97: KEY CORRIDOR VALIDATION – SR-78 EB

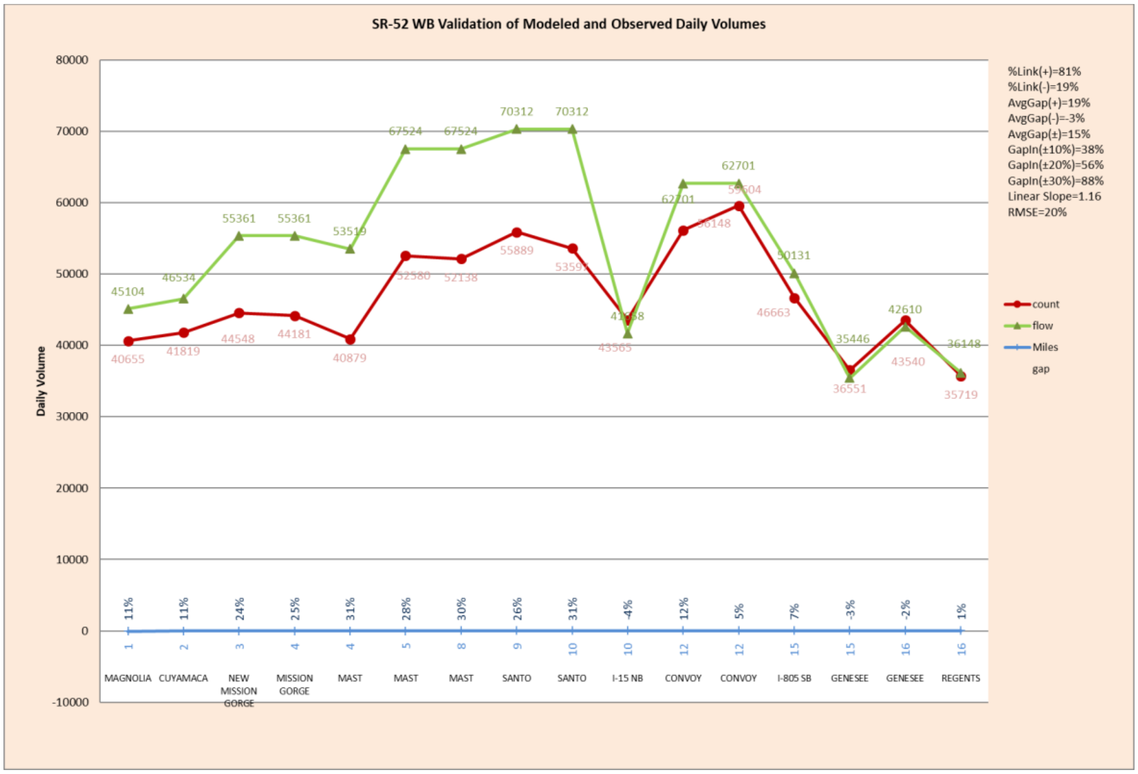

FIGURE 98: KEY CORRIDOR VALIDATION – SR-52 WB

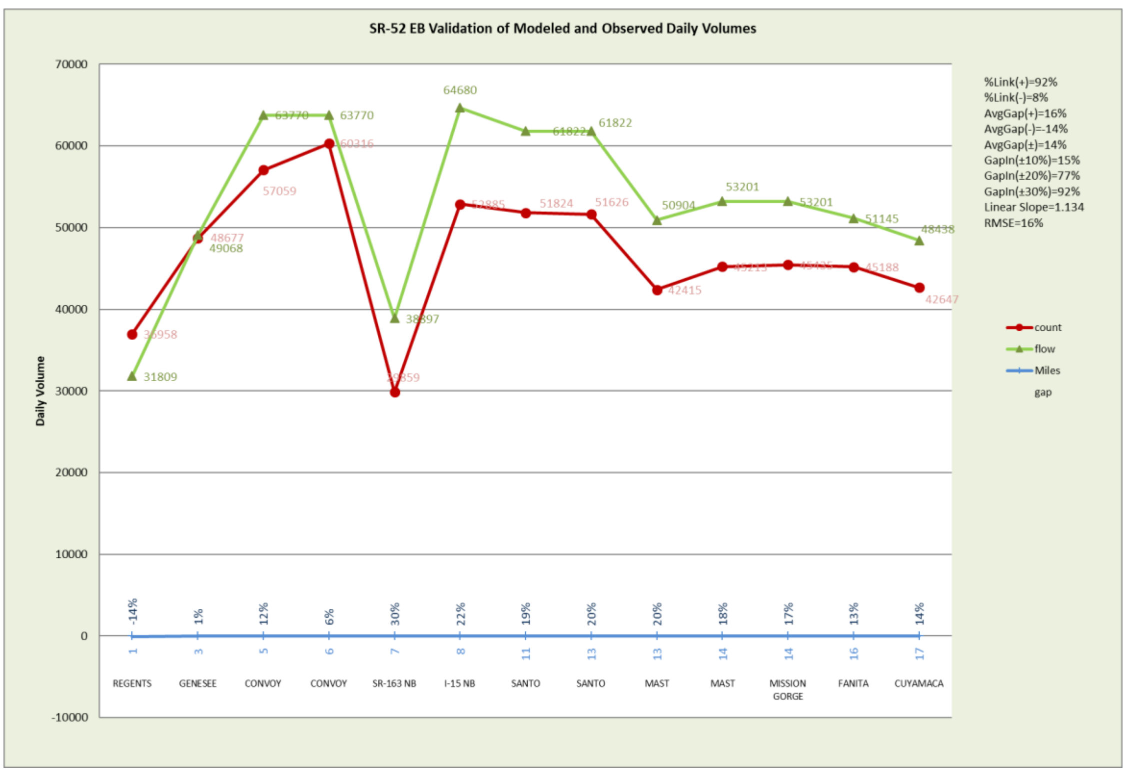

FIGURE 99: KEY CORRIDOR VALIDATION – SR-52 EB

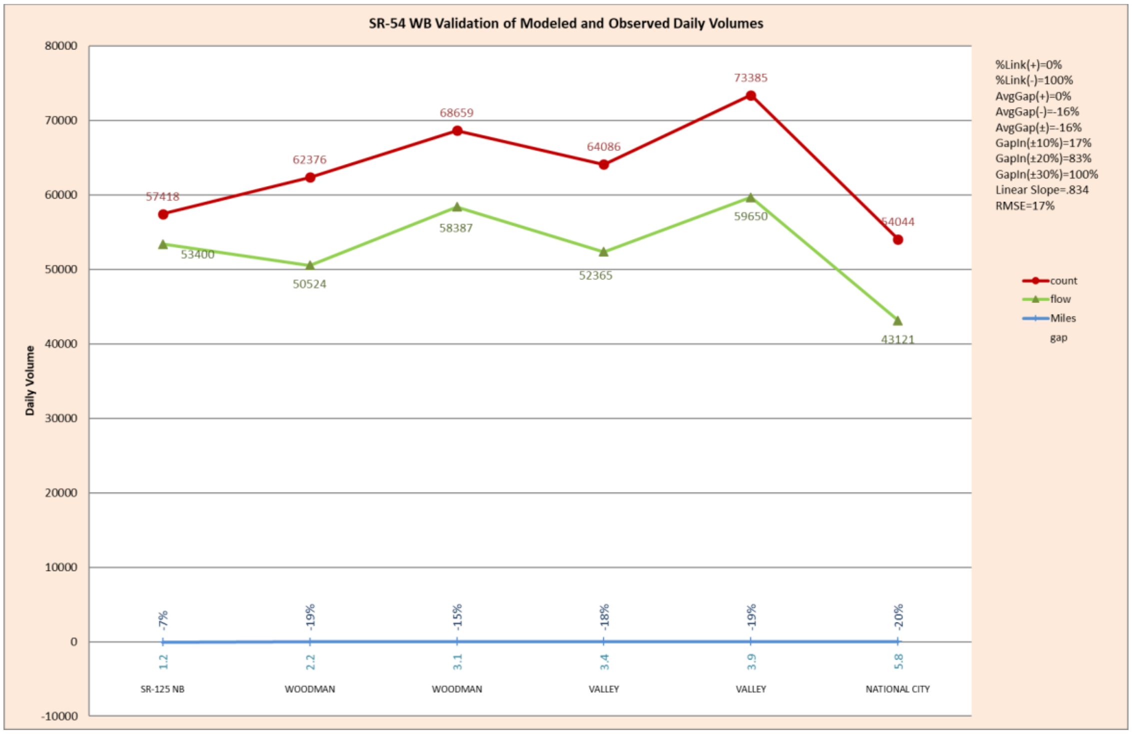

FIGURE 100: KEY CORRIDOR VALIDATION – SR-54 WB

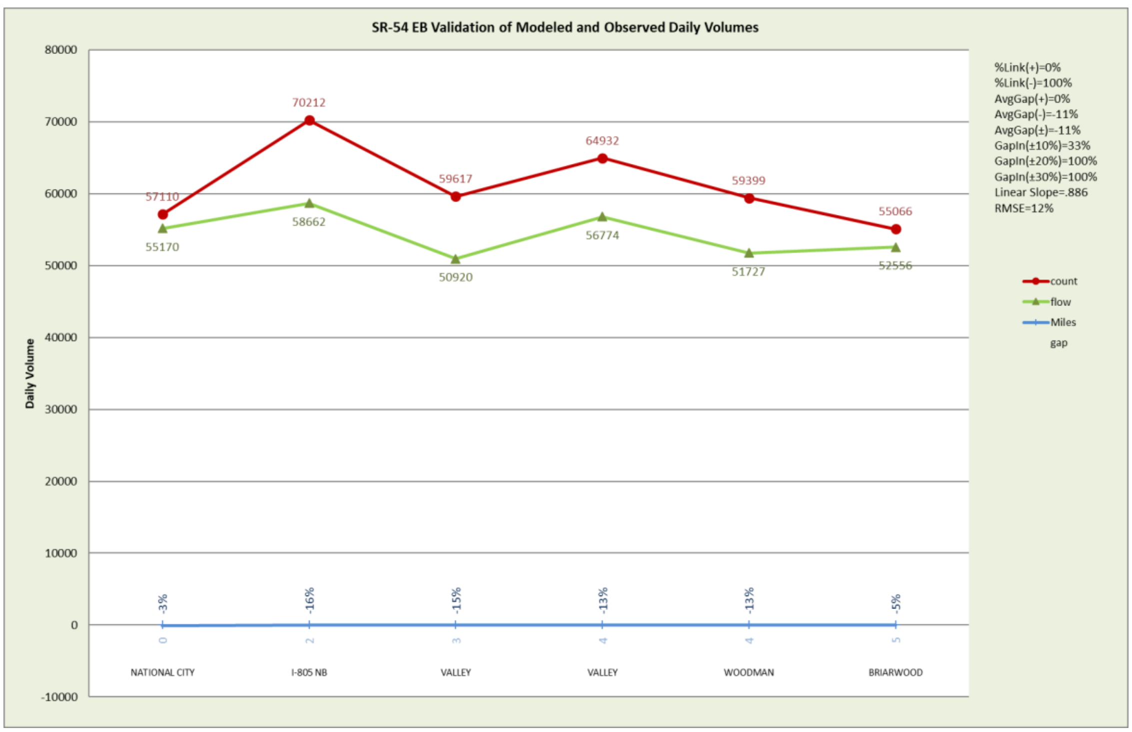

FIGURE 101: KEY CORRIDOR VALIDATION – SR-54 EB

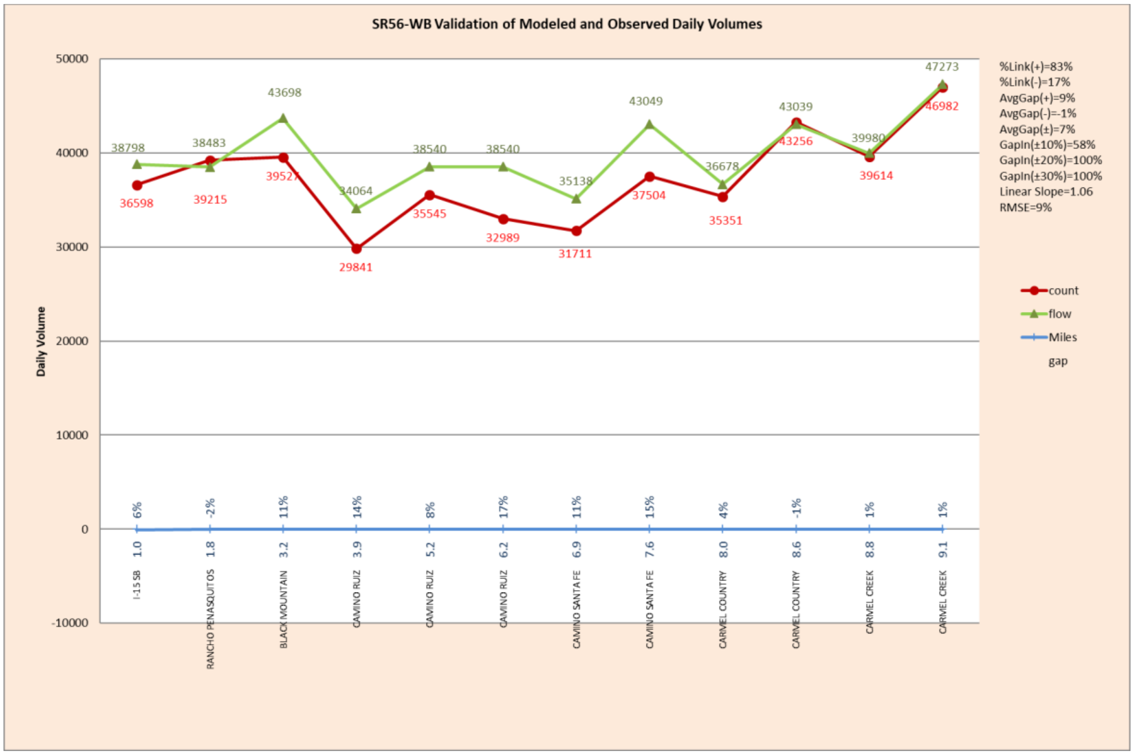

FIGURE 102: KEY CORRIDOR VALIDATION – SR-56 WB

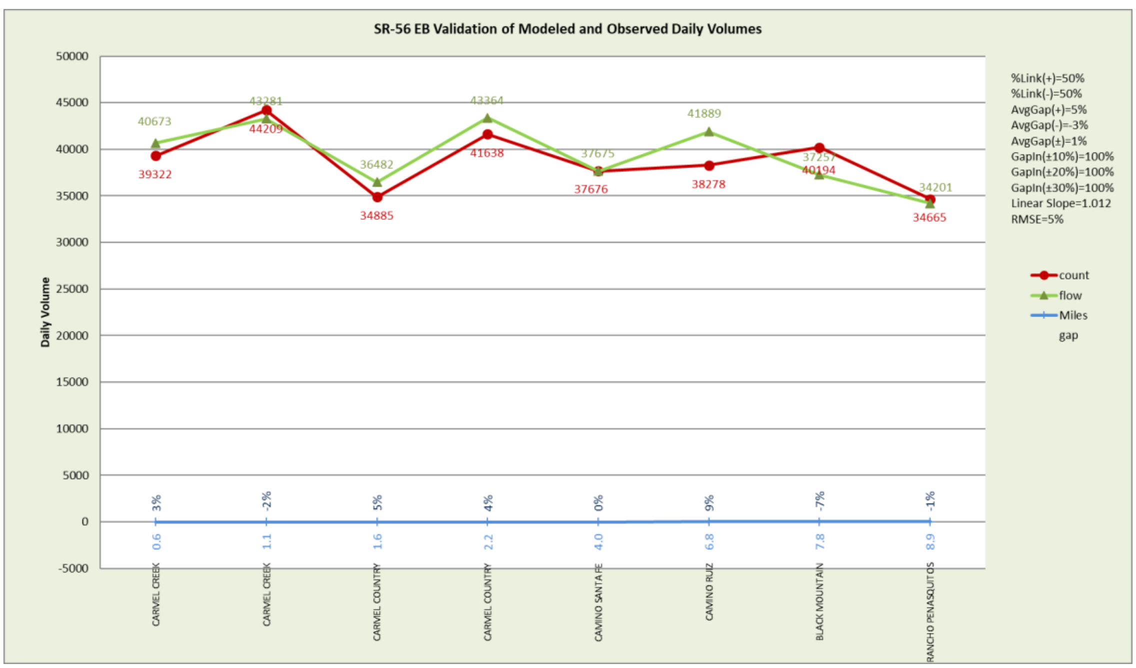

FIGURE 103: KEY CORRIDOR VALIDATION – SR-56 EB

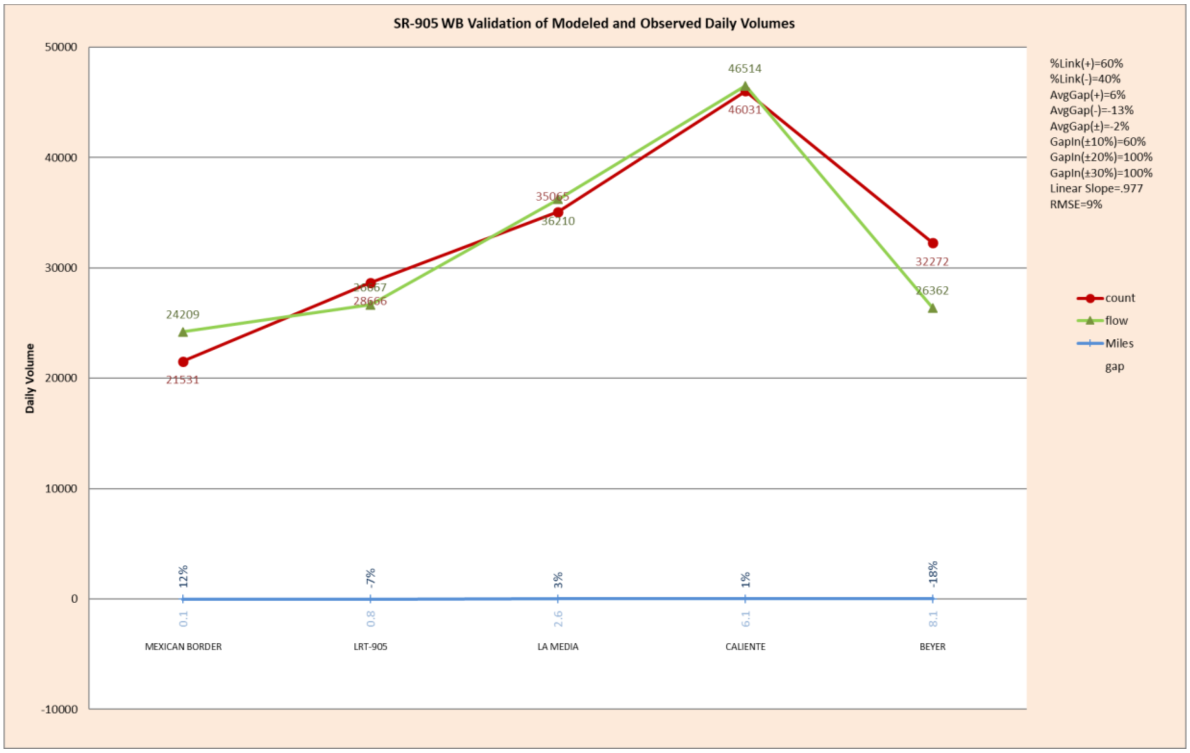

FIGURE 104: KEY CORRIDOR VALIDATION – SR-905 WB

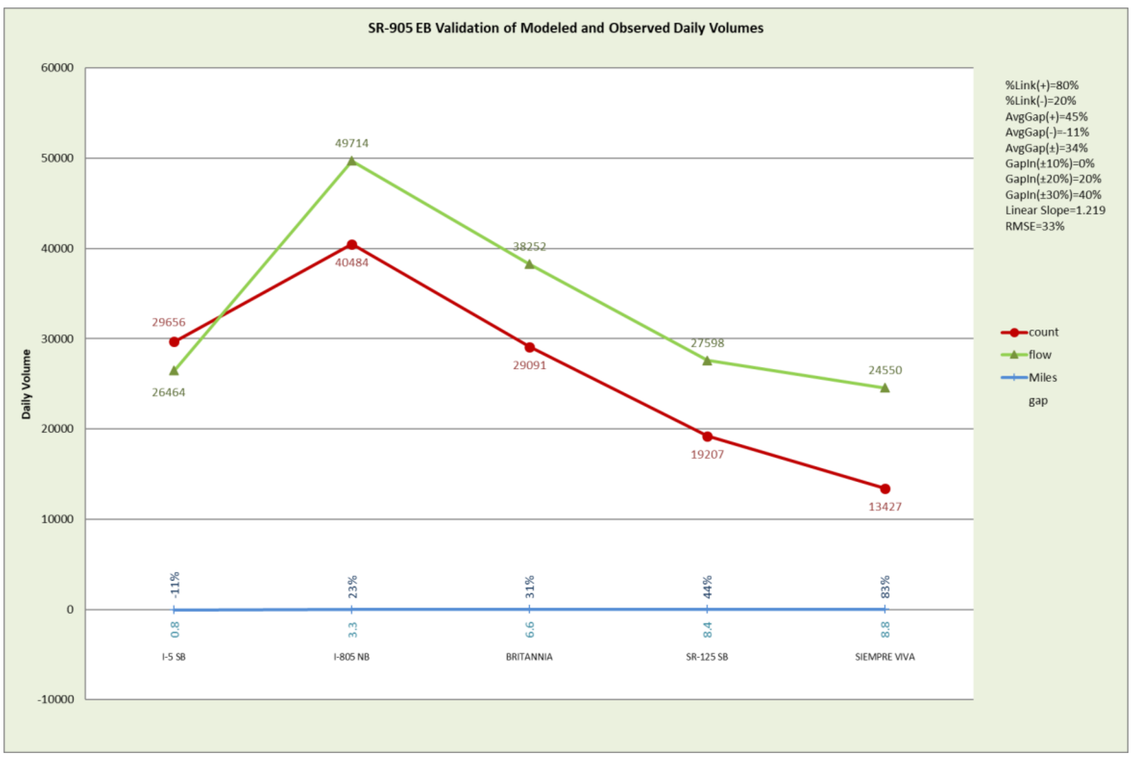

FIGURE 105: KEY CORRIDOR VALIDATION – SR-905 EB

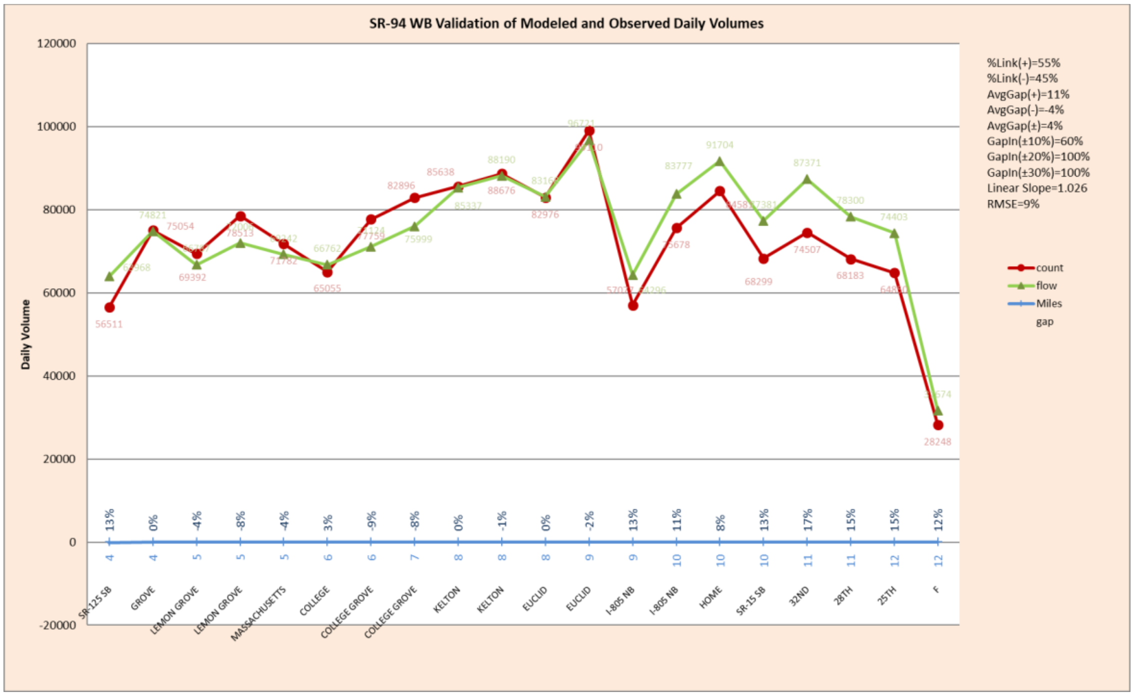

FIGURE 106: KEY CORRIDOR VALIDATION – SR-94 WB

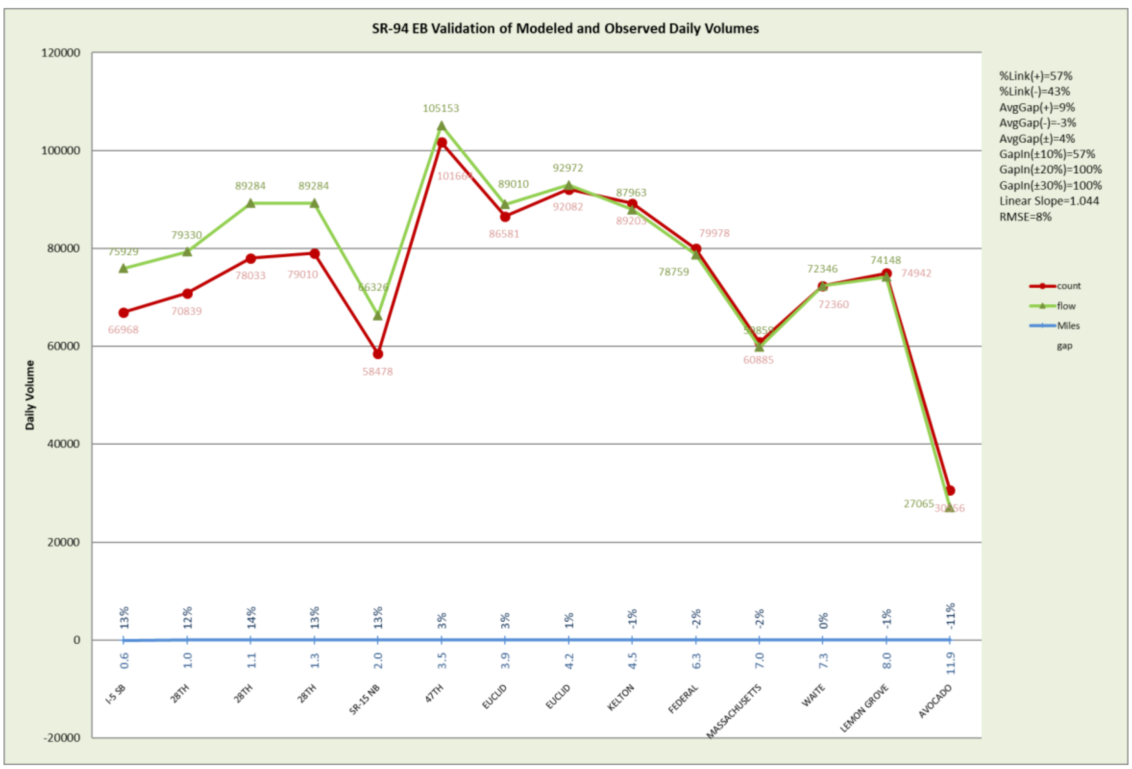

FIGURE 107: KEY CORRIDOR VALIDATION – SR-94 EB

APPENDIX G. COMMERCIAL VEHICLE MODEL (CVM) DEMAND

This appendix first presents summaries of increase in the commercial vehicle demand to offset lack of commercial vehicle travel in the new ABM. The rest of the appendix describes an analysis demonstrating low demand in the disaggregate model.

INCREASE IN CVM DEMAND

Due to the known issues of low demand in the disaggregate model, the commercial vehicle demand is increased by simply growing the light-commercial vehicle demand to 2-fold in the mid-day period. Table 83 shows magnitude of increase in travel due to boost in the CVM demand. The increased demand contains 31% more commercial vehicle trips than the original disaggregate model. This equates to 29% increase in the VMT from the CVM and resulted in 2% more VMT regionwide with CVM now contributing 8% compared to 7% with the original demand.

TABLE 83: A SUMMARY OF INCREASE IN CVM DEMAND

	ORIGINAL	BOOSTED	% DIFF
CVM trips	697,386	913,414	31%
CVM VMT	5,460,295	7,044,193	29%
Regional VMT	81,813,618	83,397,515	2%
CVM VMT /Regional VMT	7%	8%	

Table 84 and

Table 86 presents commercial vehicle trips and VMT respectively by vehicle category and time of day from the original commercial vehicle model. The same numbers after boosting the CVM demand are shown in

Table 85 and Table 87. Note that the increase of the CV demand is automated in the model work flow by providing boost factors by time of day in the main properties file.

TABLE 84: COMMERCIAL VEHICLE TRIPS

TRUCK TYPE	EA	AM	MD	PM	EV	TOTAL
Intermediate	416	4,971	14,539	4,196	2,567	26,689
Light	5,434	88,230	216,028	49,723	22,941	382,356
Medium	2,538	25,220	99,129	35,992	24,203	187,082
Heavy	2,132	20,978	52,762	15,950	9,437	101,259
TOTAL	**10,520**	**139,399**	**382,458**	**105,861**	**59,148**	**697,386**

TABLE 85: BOOSTED COMMERCIAL VEHICLE TRIPS

TRUCK TYPE	EA	AM	MD	PM	EV	TOTAL
Intermediate	416	4,971	14,539	4,196	2,567	26,689
Light	5,434	88,230	432,056	49,723	22,941	598,384
Medium	2,538	25,220	99,129	35,992	24,203	187,082
Heavy	2,132	20,978	52,762	15,950	9,437	101,259
TOTAL	**10,520**	**139,399**	**598,486**	**105,861**	**59,148**	**913,414**

TABLE 86: COMMERCIAL VEHICLE VMT

TRUCK TYPE	EA	AM	MD	PM	EV	TOTAL
Intermediate	3,842	37,119	110,682	31,535	21,524	204,703
Light	39,686	578,628	1,583,898	357,880	186,026	2,746,117
Medium	23,373	216,897	822,130	278,658	209,974	1,551,032
Heavy	21,091	193,233	510,088	143,632	90,399	958,443
TOTAL	**87,992**	**1,025,876**	**3,026,798**	**811,706**	**507,923**	**5,460,295**

TABLE 87: BOOSTED COMMERCIAL VEHICLE VMT

TRUCK TYPE	EA	AM	MD	PM	EV	TOTAL
Intermediate	3,842	37,119	110,682	31,535	21,524	204,703
Light	39,686	578,628	3,167,796	357,880	186,026	4,330,015
Medium	23,373	216,897	822,130	278,658	209,974	1,551,032
Heavy	21,091	193,233	510,088	143,632	90,399	958,443
TOTAL	**87,992**	**1,025,876**	**4,610,695**	**811,706**	**507,923**	**7,044,193**

DISAGGREGATE CV MODEL VS AGGREGATE CV MODEL

The ABM-CVM validation effort[26] compared results of the ABM run with disaggregate commercial vehicle model to the ABM run with aggregate model. A few validation summaries from the validation report are included here in Table 88 and Table 89, Table 90, Figure 108, and Figure 109.

The summaries show that the disaggregate model generates 73% fewer light-commercial vehicle trips or VMT compared to the aggregate model in the previous version of the ABM, Table 88 and Table 89. As shown in Table 90, Regionally, the VMT from the ABM with the disaggregate CV model is 10.2% lower than the ABM with the aggregate CV model. The lack of commercial vehicle demand affects (worsen) the overall highway validation as the disaggregate model shows significant underestimation with a slope of 0.91 for the scatter plot between observed and estimated traffic volumes, Figure 108. The slope with the aggregate CV model is 1.02.

[26] *Activity-Based Model and Commercial Vehicle Model Validation Report*, dated October 31, 2016

TABLE 88: TOTAL COMMERCIAL VEHICLE TRIPS BY VEHICLE TYPE

MODE	AGGREGATE MODEL	DISAGGREGATE MODEL	DIFFERENCE	PERCENT DIFFERENCE
Light commercial vehicle	1,420,313	390,105	1,030,208	73%
Light and medium-heavy trucks	130,264	221,629	(91,366)	-70%
Heavy-heavy trucks	30,455	110,281	(79,826)	-262%
Total	1,581,031	722,016	859,016	54%

TABLE 89: VEHICLE MILES OF TRAVEL BY VEHICLE TYPE

MODE	AGGREGATE MODEL	DISAGGREGATE MODEL	DIFFERENCE	PERCENT DIFFERENCE
Passenger cars and vans	63,651,188	64,295,349	(644,161)	-1%
Light commercial vehicle	11,800,897	3,197,012	8,603,885	73%
Light and medium-heavy trucks	2,509,916	2,192,974	316,942	13%
Heavy-heavy trucks	904,579	1,770,519	(865,940)	-96%
Subtotal: commercial vehicles	15,215,392	7,160,504	8,054,887	53%
Total	**78,866,579**	**71,455,854**	**7,410,726**	9%

TABLE 90: HPMS VALIDATION OF VEHICLE MILES OF TRAVEL, AGGREGATE AND DISAGGREGATE MODEL

SOURCE	VMT	PERCENT DIFFERENCE
HPMS[27]	79,585,925	NA
Aggregate Model	78,866,579	-0.9%
Disaggregate Model	71,455,854	-10.2%

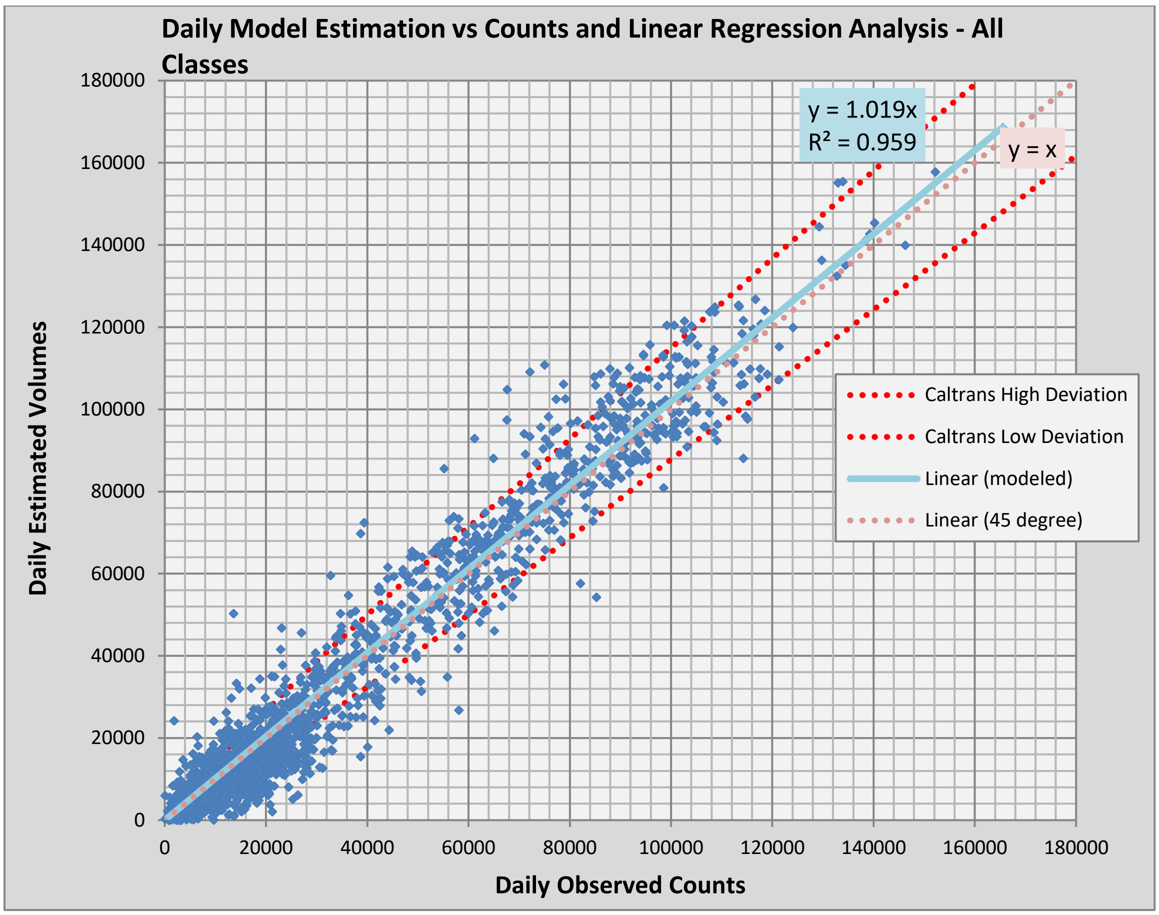

FIGURE 108: AGGREGATE MODEL ESTIMATED VS. OBSERVED VOLUME SCATTERPLOT, ALL LINK CLASSES COMBINED

[27] *2012 California Public Road Data: Statistical Information Derived from the Highway Performance Monitoring System*, California State Transportation Agency, http://www.dot.ca.gov/hq/tsip/hpms/hpmslibrary/prd/2012prd/2012PRD_Updated.pdf.

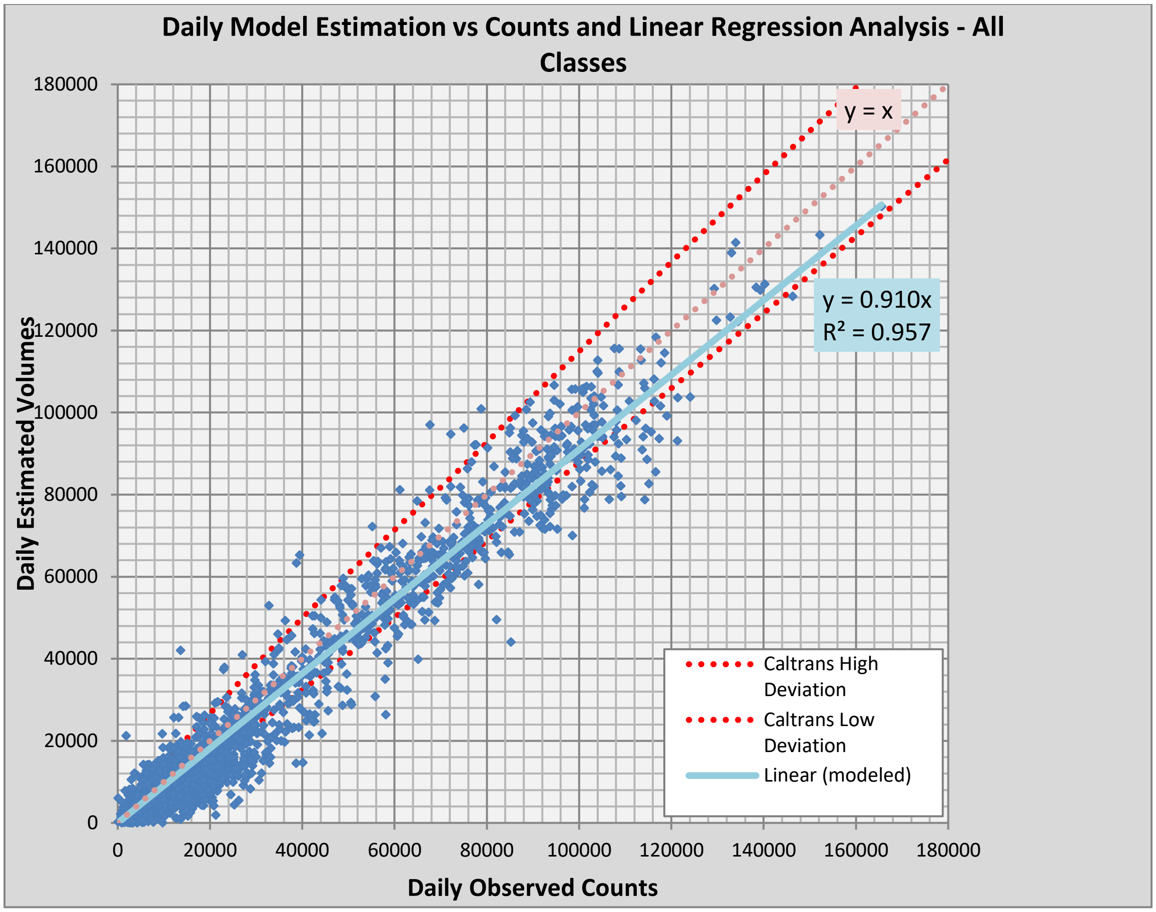

FIGURE 109: DISAGGREGATE MODEL ESTIMATED VS. OBSERVED VOLUME SCATTERPLOT, ALL LINK CLASSES COMBINED

ANALYSIS OF THE DISAGGREGATE MODEL

Table 91 compares outputs of the disaggregate model from runs with different inputs (2012 vs 2016) and with different scale factors (SF 1 vs SF 10). The comparisons show that strangely the travel rates (trips per tour and trips per employment) are lower for 2016 inputs (4.71 and 0.425) compared to 2012 inputs (4.81 and 0.476). Also, for the 2016 inputs, a higher scale factor in the disaggregate model results in higher travel rates: scale factor 10 shows 4.77 and 0.448 and scale factor 1 shows 4.71 and 0.425.

TABLE 91: COMPARISONS OF DISAGGREGATE CV MODEL

RUN	TOURS	TRIPS	TRIPS/TOUR	EMPLOYMENT	TRIPS/EMPLOYMENT
2012 SF 1	133,364	633,085	4.81	1,347,022	0.476
2016 SF 1	137,287	641,748	4.71	1,518,977	0.425
2016 SF 10	1,424,617	6,801,605	4.77	1,518,977	0.448

APPENDIX H. SQL DATABASE PROCESS

This appendix describes the SANDAG's SQL-based process of storing ABM's outputs in a database and discusses the improvements made during this project.

ACTIVITY-BASED MODEL OUTPUT FILES USED

The Extract-Transform-Load (ETL) data pipeline from ABM model run folder to database relies on the following files (Table 92) to be present in the subfolders of the model run folder.

TABLE 92: MODEL OUTPUTS FOR DATABASE LOADING

INPUT FOLDER	OUTPUT FOLDER	REPORT FOLDER
households.csv	crossBorderTours.csv	airporttripscbx.csv
hwycov.e00	householdData_<<iteration>>.csv	airporttripssan.csv
mgra_based_input<<year>>.csv	indivTourData_<<iteration>>.csv.csv	cbtrips.csv
persons.csv	jointTourData_<<iteration>>.csv	cvm_trips.csv
SANDAG_Bike_Net.shp	personData_<<iteration>>.csv	eetrip.csv
SANDAG_Bike_Node.dbf	PNRByTAP_Vehicles.csv	eitrip.csv
tap.ptype	visitorTours.csv	ietrip.csv
tapcov.shp	wsLocResults<<iteration>>.csv	indivtrips.csv
trcov.e00		hwyload_<<TOD>>.csv
trrt.csv		jointtrips.csv
trstop.csv		transit_aggflow.csv
		transit_flow.csv
		transit_onoff.csv
		trucktrip.csv
		visitortrips.csv

EXTRACT-TRANSFORM-LOAD DATA PIPELINE

Activity-Based Model Run Database Loading Request

Upon successful completion of an ABM model run, a batch file (bin\DataLoadRequest.bat) is executed as part of the model flow. This command inserts a record into the load request table in the ABM database ([data_load].[load_request]) indicating the run has successfully completed and provides all necessary information for the Extract-Transform-Load data pipeline to load the model run into the ABM database (the model run folder location, number of iterations, year of the model run, sample rate, and the ABM software version).

Each night the load request table is checked for records and any requested ABM model runs present in the table are loaded into the database.

Microsoft SQL Server Integration Services

The Extract-Transform-Load data pipeline is controlled by a Microsoft SQL Server Integration Services (SSIS) project that is run multiple times each night.

On each run of the SSIS project, if there is a record in the load request table, the project is pointed to an ABM model run folder to be loaded. A Python process takes the model run input geometry files (e00 and shp) and creates csv files containing Well-known text (WKT) representations of their geometry. Subsequently these geometry csv files and all necessary input, output, and report folder files are loaded via SSIS into staging tables in the ABM database as is. Once all raw model run data has been loaded into database staging tables it is transformed and loaded into the final ABM database tables.

IMPROVEMENTS IN DATABASE FOR ACTIVITY-BASED MODEL VERSION 14.0.0

Changes and improvements necessitating an entirely new database structure were implemented along with the release of ABM version 14.0.0 as the new model version differed significantly from previous versions.

The new ABM database relies on a star-schema model for the ABM trip list to enable and encourage in-depth reporting across hundreds of model runs in contrast to the previous relational model database trip lists. Run-time for the Extract-Transform-Load data pipeline was reduced from one hour to twenty minutes, database storage cost per scenario was reduced from forty-five gigabytes to six gigabytes, and reporting query speed and complexity were reduced significantly across the board.

DATABASE DOCUMENTATION

The database build and Extract-Transform-Load pipeline are checked into the ABM GitHub repository and are maintained alongside the ABM model. All ABM database objects are created with appropriate metadata descriptions for every schema, table, field, and programmability object. This is currently implemented as a query-able view in the database ([db_meta].[data_dictionary]) allowing for on-demand documentation and lookups by users instead of requiring a separate static document maintained outside of the database environment.

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