

Appendix T

SANDAG Travel Demand Model and Forecasting Documentation

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Attachment:

1. Telework Assumptions, Future Mobility Research Program
Memo, March 26, 2018

SANDAG Travel Demand Model Documentation

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1.0 Executive Summary

San Diego Association of Governments (SANDAG) plans for complex mobility issues facing the San Diego region through the development of a long-range Regional Transportation Plan (RTP). Transportation and land use models are used to forecast potential future scenarios of where people will live and how they will travel. Models are the principal tools used for alternatives analysis, and they provide planners and decision makers with information to help them equitably allocate scarce resources. The SANDAG transportation model, an activity-based model (ABM), provides a systematic analytical platform so that different alternatives and inputs can be evaluated in an iterative and controlled environment. An ABM simulates individual and household transportation decisions that compose their daily travel itinerary. People travel outside their home for activities such as work, school, shopping, healthcare, and recreation, and the ABM attempts to predict whether, where, when, and how this travel occurs.

The SANDAG ABM includes a number of methodological strengths. It predicts the travel decisions of San Diego residents at a detailed level, taking into account the way people schedule their day, their behavioral patterns, and the need to cooperate with other household members. When simulating a person's travel patterns, the ABM takes into consideration a multitude of personal and household attributes like age, income, gender, and employment status. The model's fine temporal and spatial resolution ensures that it is able to capture subtle aspects of travel behavior.

The SANDAG ABM strives to be as behaviorally realistic as possible and is based on empirical data collected by SANDAG, Caltrans, and the federal government. The model development has been regularly peer-reviewed by the ABM Technical Advisory Committee, a panel of national experts in the travel demand forecasting field.

2.0 SANDAG Travel Demand Model Documentation and Methodology

This document describes the SANDAG second generation Activity-Based Model system (ABM2) used in the 2019 Federal RTP. SANDAG ABM development started in 2009 and the first SANDAG ABM was applied in the 2015 Regional Plan. The ABM system has been continuously updated to ensure that the regional transportation planning process can rely on forecasting tools that are adequate for new socioeconomic environments and emerging transportation planning challenges.

The ABM2 accounts for a variety of different weekday travel markets in the region, including San Diego region resident travel, travel by Mexican residents and other travelers crossing San Diego County's borders, visitor travel, airport passengers at both the San Diego International Airport and the Cross-Border Xpress, and commercial travel. Many of the models used to represent demand are simulation-based models, such as activity-based or tour-based approaches while others use an aggregate three or four-step representations of travel. Table T.1 lists the SANDAG travel markets along several key dimensions.

There are two broad types of models and three specific types of models identified in Table T.1. Disaggregate models refer to models whose demand is generated via a stochastic simulation paradigm. Both activity-based and tour-based models are simulation-based, which rely upon a synthetic population to generate travel and stochastic processes to choose alternatives and output disaggregate demand in the form of tour and trip lists.

The resident travel model is an activity-based model, in which all tours and activities are scheduled into available time windows across the entire day. The approach recognizes that a person can be in only one place at one time and their entire day is accounted for in the model. A tour-based treatment is used for other special travel markets such as Mexican resident cross border travel, visitor travel, airport passenger travel and commercial vehicle travel. Tour-based models do not attempt to model all travel throughout the day for each person; rather, once tours are generated, they are modeled independently of each other. A tour-based model does not attempt to schedule all travel into available time windows.

Aggregate models rely upon probability accumulation processes to produce travel demand and output trip tables. The external heavy-duty truck model and certain external travel models are aggregate.

Table T.1
SANDAG ABM2 Travel Markets

Travel Market	Description	Model Type	Temporal Resolution	Spatial Resolution
San Diego resident travel (internal)	Average weekday travel made by San Diego residents within San Diego County	Disaggregate activity-based	30-minute	MGRA ¹
San Diego resident travel (internal-external)	Average weekday travel by San Diego residents between San Diego County and another county\Mexico	Disaggregate tour-based	30-minute	Internal MGRA – external cordon TAZ ²
Mexican resident cross border travel (external-internal and internal-internal)	Average weekday travel by Mexican residents into, out of, and within San Diego County	Disaggregate tour-based	30-minute	Internal MGRA – External cordon TAZ
Overnight visitor	Average weekday travel made by overnight visitors in San Diego county	Disaggregate tour-based	30-minute	MGRA
Airport passenger (San Diego Airport and CBX)	Average weekday travel made by air passengers and related trips such as taxis to/from airport	Disaggregate Trip-based	30-minute	MGRA
External-External	Average weekday travel with neither origin nor destination in San Diego County	Aggregate Trip-based	5 time periods	External cordon TAZ
Other U.S.-Internal travel	Average weekday external-internal trips made by non-San Diego and non-Mexican residents	Aggregate Trip-based	5 time periods	External cordon TAZ – Internal TAZ
Commercial vehicle model	Average weekday vehicle trips made for commercial purposes (in addition to heavy trucks includes light truck goods movements and service vehicles)	Disaggregate tour-based	5 time periods	TAZ
External heavy-duty truck model	Average weekday vehicle trips for 3 weight classes for External truck travel	Aggregate Trip-based	5 time periods	External cordon TAZ - External cordon TAZ; External cordon TAZ – Internal TAZ

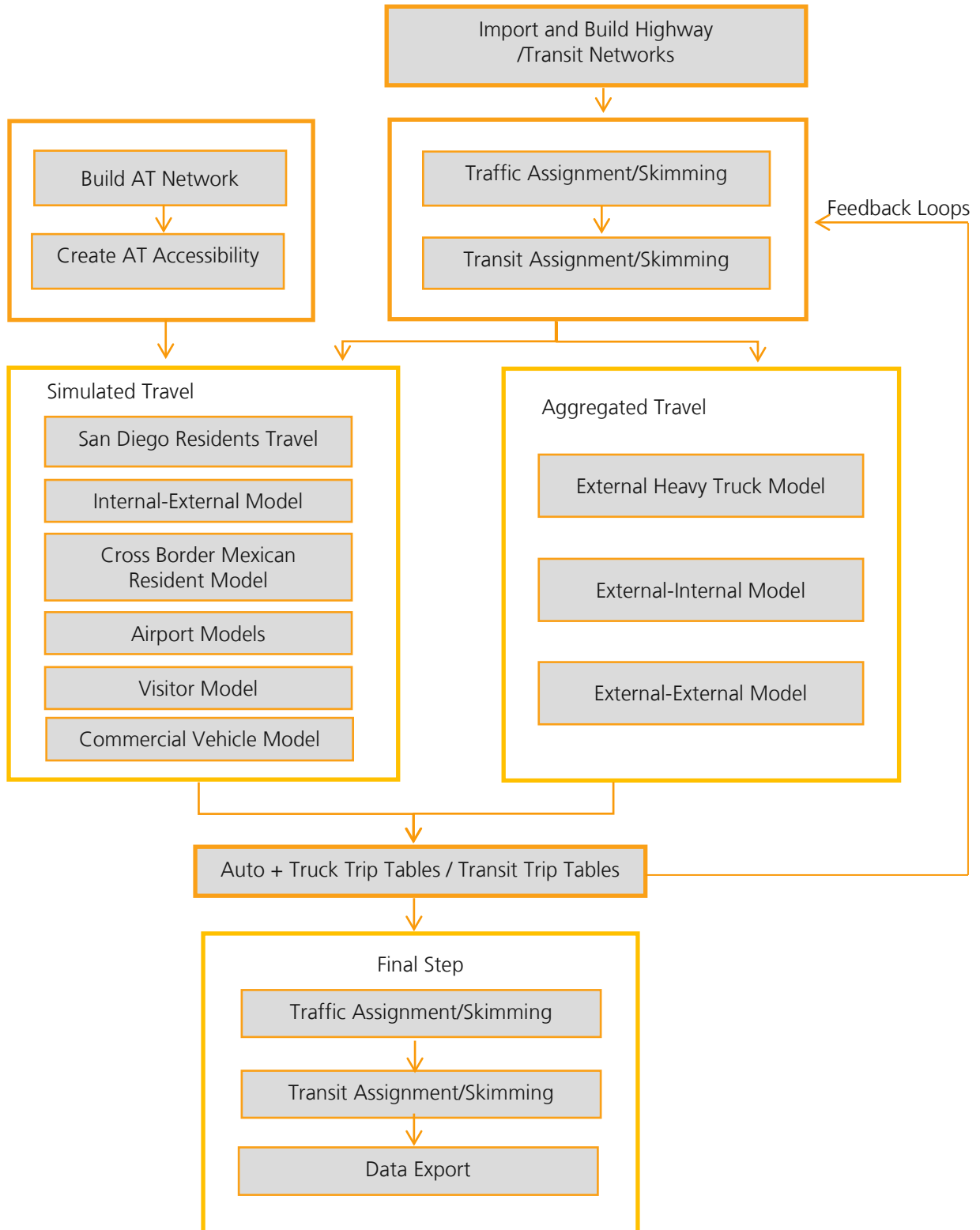
¹ MGRA = Master Geographic Reference Area; 23002 MGRAs in the Region

² TAZ = Traffic Analysis Zone; 4996 TAZs in the Region

The flow of these models is represented in Figure T.1. The SANDAG ABM2 starts with building all-street based active transportation network and creating MGRA to MGRA, and MGRA to TAP walk access files; highway and transit network building and importing into Emme (traffic modeling software licensed from INRO), then traffic and transit assignment with warm start trip tables to get the congested highway and transit skims; after the network skims and walk access files are created, the resident travel model is executed, followed by the other disaggregate models (visitor, San Diego International Airport, Cross Border Xpress airport, cross border, and commercial vehicle) and aggregate models (external heavy truck, external-external and external-internal). The trip tables from all the models are summed up by vehicle classes, time of day (TOD) and value of time (VOT) and are used by traffic assignment. The skims after the traffic assignment are used for the subsequent iteration in a three feedback loop model run. The final traffic and transit assignment and data export concludes the ABM2 modeling procedure.

In recent years new travel modes such as Transportation Network Companies (TNCs), bike-share, scooter-share, and other technologies have emerged within the San Diego region. TNCs were captured in the 2016 Household Travel Survey but the sample was not large enough to explicitly add as its own mode in the ABM2. TNC use is included in the calibration of the model, specifically in mode choice for HOV usage, and therefore is implicitly included in the model system. Additional surveying is being conducted to incorporate these new modes and technologies into the next SANDAG ABM model version.

Figure T.1
SANDAG ABM2 Flow Chart



3.0 Spatial and Temporal Resolutions

As indicated in Table T.1 different travel markets are operated in different model types with different spatial and temporal resolutions. The following section describes the treatment of space and time in the SANDAG ABM2.

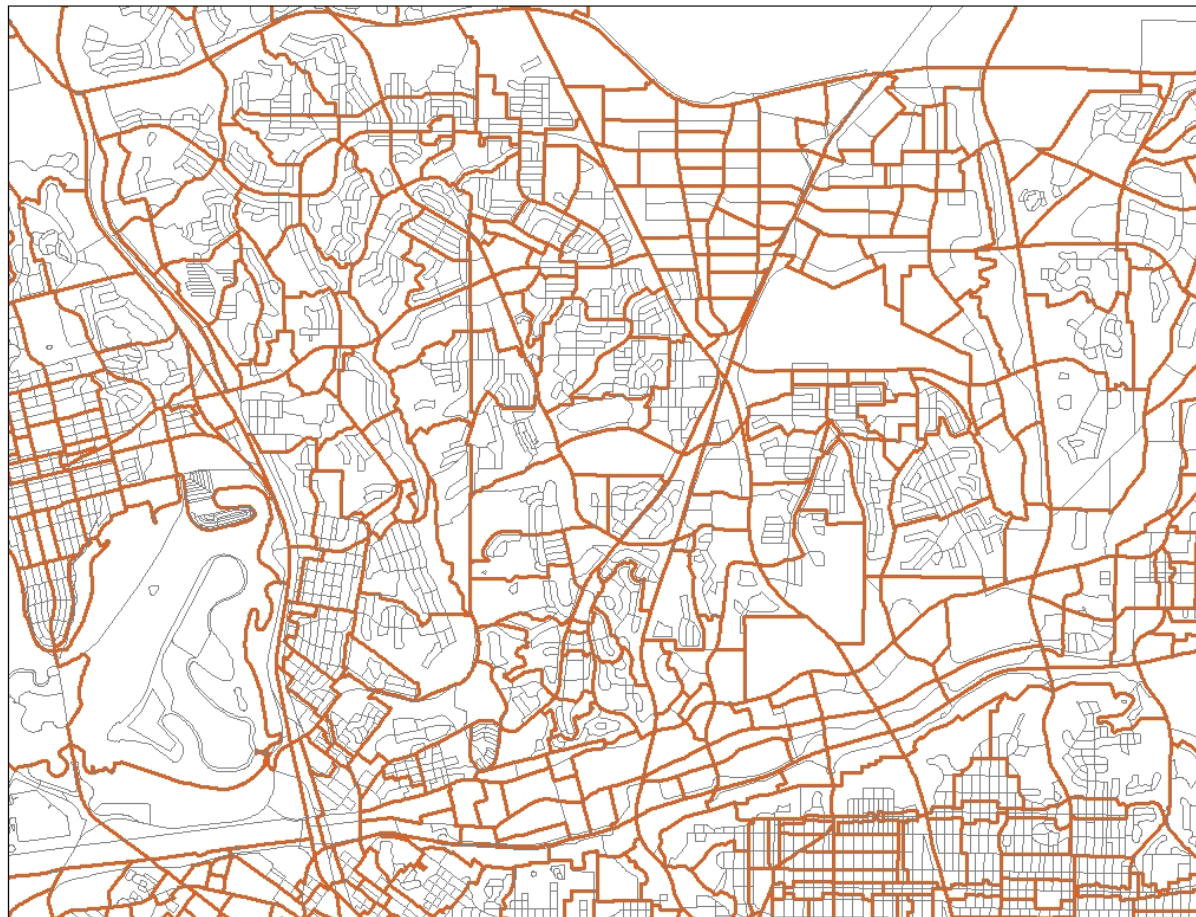
3.1 Treatment of space

Activity-based and tour-based models can exploit fine-scale spatial data, but the advantages of additional spatial detail must be balanced against the additional efforts required to develop zone and associated network information at this level of detail. The increase in model runtime and memory footprint associated primarily with path-building and assignment to more zones must also be considered.

The use of a spatially disaggregate zone system helps ensure model sensitivity to phenomena that occur at a fine spatial scale. Use of large zones may produce aggregation biases, especially in destination choice, where the use of aggregate data can lead to illogical parameter estimates due to reduced variation in estimation data, and in mode choice, where modal access may be distorted.

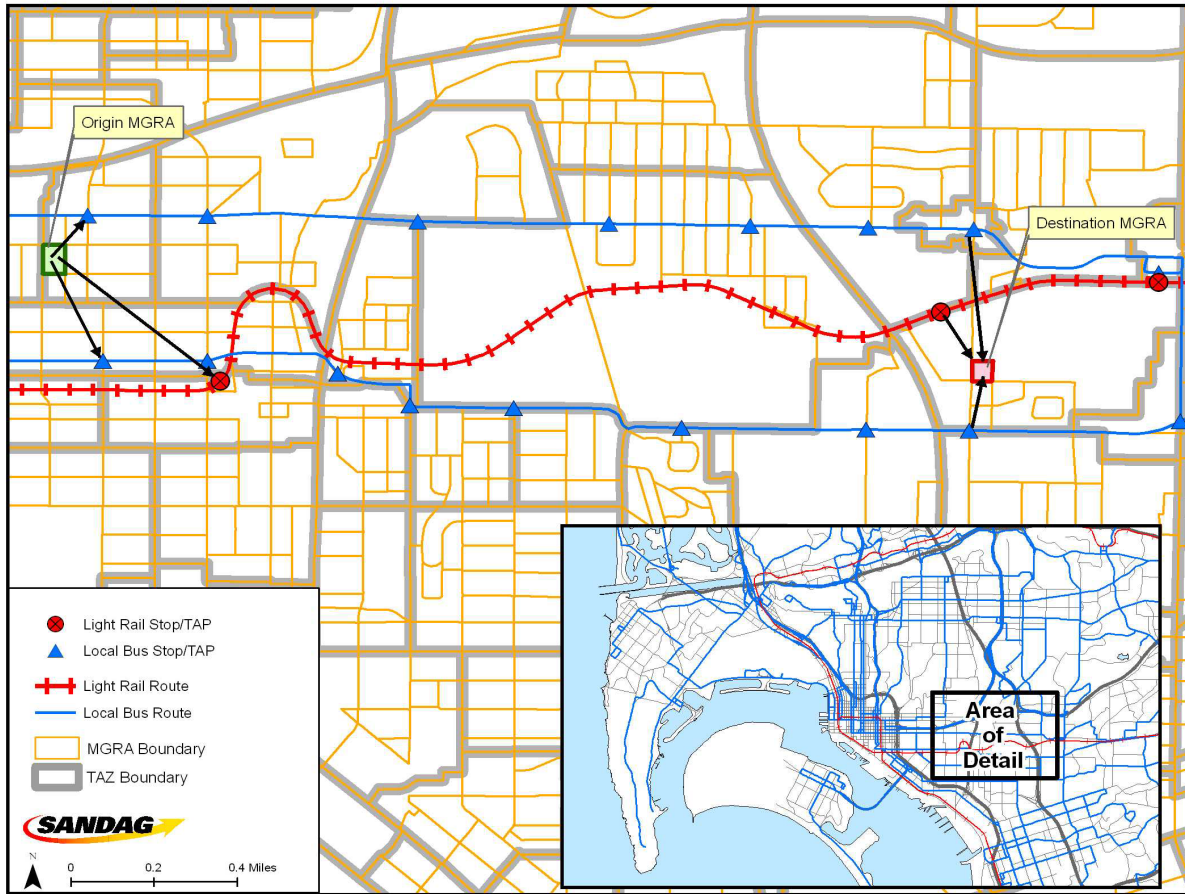
SANDAG ABM2 utilizes SANDAG Master-Geographic Reference Area (MGRA) zone system, which is the one of the most disaggregate zonal systems used in travel demand models in the United States. The SANDAG current MGRA system consists of 23,002 zones, which are roughly equivalent to Census block groups (see Figure T.2). To avoid computational burden, SANDAG relies on a 4,996 Transportation Analysis Zone (TAZ) system for roadway skims and assignment but performs transit calculations at the more detailed MGRA level. This is accomplished by generalizing transit stops into pseudo-TAZs called Transit Access Points (TAPs) and utilizing Emme modeling software to generate TAP-TAP level-of-service matrices (also known as “skims”) such as in-vehicle time, first wait, transfer wait, and fare. All access and egress calculations, as well as paths following the Origin MGRA – Boarding TAP – Alighting TAP-Destination MGRA patterns, are computed within custom-built software. These calculations rely upon detailed geographic information regarding MGRA-TAP distances and accessibilities. A graphical depiction of the MGRA – TAP transit calculations is given in Figure T.3. It shows potential walk paths from an origin MGRA, through three potential boarding TAPs (two of which are local bus, and one of which is rail), with three potential alighting TAPs at the destination end.

Figure T.2
Treatment of Space - TAZs and MGRAs



All activity locations are tracked at the MGRA level. The MGRA geography offers both the advantage of fine spatial resolution, and consistency with network levels-of-service, that makes it ideal for tracking activity locations.

Figure T.3
Example MGRA - TAP Transit Accessibility



3.2 Treatment of time

The disaggregated models function at a temporal resolution of one-half hour. These one-half hour increments begin with 3 A.M. and end with 3 A.M. the next day, though the hours between 1 A.M. and 5 A.M. are aggregated to reduce computational burden. Temporal integrity is ensured so that no activities are scheduled with conflicting time windows, except for short activities/tours that are completed within a one-half hour increment. For example, a person may have a very short tour that begins and ends within the 8:00 a.m. to 8:30 a.m. period, as well as a second longer tour that begins within this time period but ends later in the day.

Time periods are typically defined by their midpoint in the scheduling software. For example, in a model system using one-half hour temporal resolution, the 9:00 a.m. time period would capture activities of travel between 8:45 a.m. and 9:15 a.m. If there is a desire to break time periods at “round” half-hourly intervals, either the estimation data must be processed to reflect the aggregation of activity and travel data into these discrete half-hourly bins, or a more detailed temporal resolution must be used, such as half-hours (which could then potentially be aggregated to “round” half-hours).

A critical aspect of the model system is the relationship between the temporal resolution used for scheduling activities, and the temporal resolution of the network simulation periods. Although each activity generated by the model system is identified with a start time and end time in one-half hour increments, level-of-service matrices are only created for five aggregate time periods: (1) early A.M.; (2) A.M.; (3) Midday; (4) P.M.; and (5) Evening. The trips occurring in each time period reference the appropriate transport network depending on their trip mode and the mid-point trip time. All aggregated models operate on the five aggregated time periods. The definition of time periods for level-of-service matrices is given in Table T.2.

Table T.2**Time Periods for Level-of-Service Skims and Assignment**

Number	Description	Begin Time	End Time
1	Early	3:00 A.M.	5:59 A.M.
2	A.M. Peak	6:00 A.M.	8:59 A.M.
3	Midday	9:00 A.M.	3:29 P.M.
4	P.M. Peak	3:30 P.M.	6:59 P.M.
5	Evening	7:00 P.M.	2:59 A.M.

4.0 Resident Travel Model

The resident travel model is based on the CT-RAMP (Coordinated Travel Regional Activity-Based Modeling Platform) family of Activity-Based Models. This model system is an advanced, but operational, AB model that fits the needs and planning processes of SANDAG. The CT-RAMP model adheres to the following basic principles:

- The CT-RAMP design corresponds to the most advanced principles of modeling individual travel choices with maximum behavioral realism. It addresses both household-level and person-level travel choices including intra-household interactions between household members.
- Operates at a detailed temporal (half-hourly) level and considers congestion and pricing effects on travel time-of-day and peak spreading of traffic volume.
- Reflects and responds to detailed demographic information, including household structure, aging, changes in wealth, and other key attributes¹.
- Offers sensitivity to demographic and socio-economic changes observed or expected in the dynamic San Diego metropolitan region. This is ensured by the synthetic population as well as by the fine level of model segmentation. In particular, the resident travel model incorporates different household, family, and housing types including a detailed analysis of different household compositions in their relation to activity-travel patterns.

The resident travel model has its roots in a wide array of analytical developments. They include discrete choice forms (multinomial and nested logit), activity duration models, time-use models, models of individual micro-simulation with constraints, entropy-maximization models, etc. These advanced modeling tools are combined to ensure maximum behavioral realism, replication of the observed activity-travel patterns, and ensure model sensitivity to key projects and policies. The model is implemented in a micro-simulation framework. Micro-simulation methods capture aggregate behavior through the representation of the behavior of individual decision-makers. In travel demand modeling, these decision-makers are typically households and persons. The following section describes the basic conceptual framework at which the model operates.

4.1 Decision-making units

Decision-makers in the model system include both persons and households. These decision-makers are created (synthesized) for each simulation year based on tables of households and persons from census data and forecasted TAZ-level distributions of households and persons by key socio-economic categories. These decision-makers are used in the subsequent discrete-choice models to select a single alternative from a list of available alternatives according to a probability distribution. The probability distribution is generated from a logit model which takes into account the attributes of the decision-maker and the attributes of the various alternatives. The decision-making unit is an important element of model estimation and implementation and is explicitly identified for each model specified in the following sections.

4.2 Person type segmentation

A key advantage of using the micro-simulation approach is that there are essentially no computational constraints on the number of explanatory variables that can be included in a model specification. However, even with this flexibility, the model system includes some segmentation of decision-makers. Segmentation is a useful tool to both structure models such that each person type segment could have their own model for certain choices, and to characterize person roles within a household. Segments can be created for persons as well as households.

A total of eight segments of person types (shown in Table T.3) are used for the resident travel model. The person types are mutually exclusive with respect to age, work status, and school status.

Table T.3
Person Types

Number	Person type	Age	Work Status	School Status
1	Full-time worker ²	18+	Full-time	None
2	Part-time worker	18+	Part-time	None
3	College student	18+	Any	College +
4	Non-working adult	18 – 64	Unemployed	None
5	Non-working senior	65+	Unemployed	None
6	Driving age student	16-17	Any	Pre-college
7	Non-driving student	6 – 15	None	Pre-college
8	Pre-school	0-5	None	None

Further, workers are stratified by their occupation shown in Table T.4. These are used to segment destination choice size terms for work location choice, based on the occupation of the worker.

Table T.4
Occupation Types

Number	Description
1	Management Business Science and Arts
2	Services
3	Sales and Office
4	Natural Resources Construction and Maintenance
5	Production Transportation and Material Moving
6	Military

4.3 Activity type segmentation

The activity types are used in most sub model components of resident travel model, from developing daily activity patterns to predicting tour and trip destinations and modes by purpose.

The activity types are as shown in Table T.5. The activity types are grouped according to whether the activity is mandatory, maintenance, or discretionary. Eligibility requirements are assigned to determine which person types can be used for generating each activity type. The classification scheme of each activity type reflects the relative importance or natural hierarchy of the activity, where work and school activities are typically the most inflexible in terms of generation, scheduling and location, whereas discretionary activities are typically the most flexible on each of these dimensions. When generating and scheduling activities, this hierarchy is not rigid and is informed by both activity-type and activity-duration.

Each out-of-home location that a person travels to in the simulation is assigned one of these activity types.

Table T.5
Activity Types

Type	Purpose	Description	Classification	Eligibility
1	Work	Working at regular workplace or work-related activities outside the home	Mandatory	Workers and students
2	University	College +	Mandatory	Age 18+
3	High School	Grades 9-12	Mandatory	Age 14-17
4	Grade School	Grades K-8	Mandatory	Age 5-13
5	Escorting	Pick-up/drop-off children at school by parents Pick-up/drop-off passengers (auto trips only)	Maintenance	Age 16+
6	Shopping	Shopping away from home	Maintenance	5+ (if joint travel, all persons)
7	Other Maintenance	Personal business/services, and medical appointments	Maintenance	5+ (if joint travel, all persons)
8	Social/Recreational	Recreation, visiting friends/family	Discretionary	5+ (if joint travel, all persons)
9	Eat Out	Eating outside of home	Discretionary	5+ (if joint travel, all persons)
10	Other Discretionary	Volunteer work, religious activities	Discretionary	5+ (if joint travel, all persons)

4.4 Trip modes

Table T.6 lists the trip modes defined in the resident travel model. There are 18 modes available to residents, including auto by occupancy and toll/non-toll choice, walk and bike non-motorized modes, and walk and drive access to local and premium transit modes. Note that the pay modes are those that involve paying a choice or “value” toll. Tolls on bridges are counted as a travel cost, but the mode is considered “free.”

Table T.6
Trip Modes for Assignment

Number	Mode
1	Drive Alone (Non-Toll)
2	Drive Alone (Toll Eligible)
3	Auto 2 Person (Non-Toll)
4	Auto 2 Person (Toll Eligible)
5	Auto 3+ Person (Non-Toll)
6	Auto 3+ Person (Toll Eligible)
7	Walk to Transit - Local Bus Only
8	Walk to Transit – Premium Transit Only
9	Walk to Transit – Local and Premium Transit
10	Park and Ride to Transit - Local Bus Only
11	Park and Ride to Transit – Premium Transit Only
12	Park and Ride to Transit – Local and Premium Transit
13	Kiss and Ride to Transit - Local Bus Only
14	Kiss and Ride to Transit - Premium Transit Only
15	Kiss and Ride to Transit – Local and Premium Transit
16	Walk
17	Bike
18	School Bus (only available for school purpose) not in the assignment

4.5 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 understanding of how highway congestion and pricing affect travel demand. The implemented travel time reliability and pricing features 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 in ABM2. The model was not implemented in ABM1, but it was found to significantly improve model goodness-of-fit for forecasting demand on I-15 managed lanes.

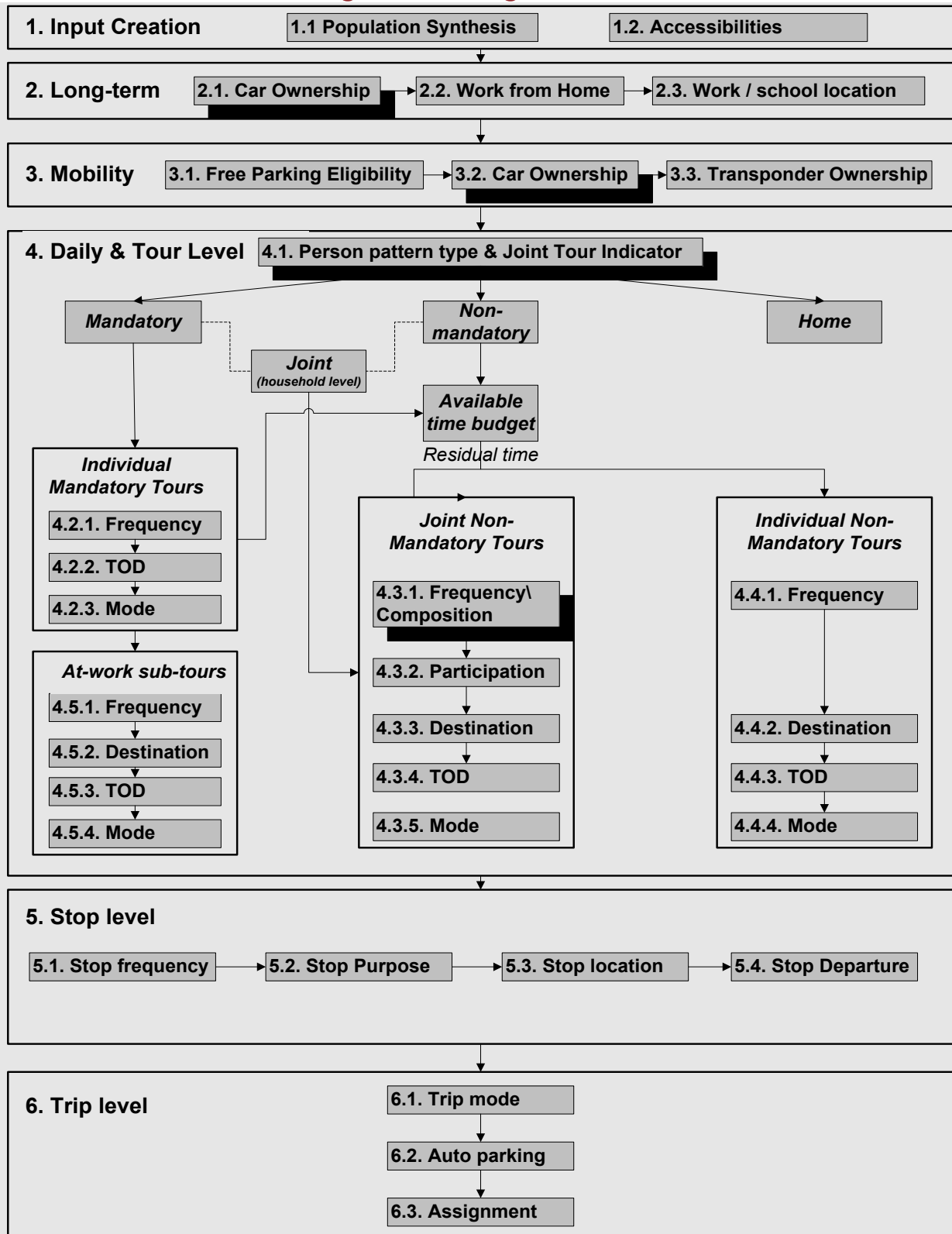
The enhanced models have been shown to match observed demand on existing toll roads in San Diego better than the previous model and demonstrate reasonable elasticities to changes in toll cost. As part of the travel time reliability enhancement, accurate representations of toll entry/exit points and costs, and the inclusion of a transponder model that constrains demand, also contributes to the improvements in the revised system.

4.6 Basic structure and flow

The resident travel model consists of a series of interdependent sub-models to simulate person and household travel. Figure T.4 illustrates the basic structure and flow.

Figure T.4

Resident Travel Model Design and Linkage Between Sub-Models



Shadowed boxes in Figure T.4 indicate choices that relate to the entire household or a group of household members and assume explicit modeling of intra-household interactions (sub-models 2.1, 3.2, 4.1, and 4.3.1). The other models are applied to individuals, though they may consider household-level influences on choices.

The resident travel model uses synthetic household population as a base input (sub-model 1.1). Certain models also utilize destination-choice logsums, which are represented as MGRA variables (sub-model 1.2). Once these inputs are created, the travel model simulation begins.

An auto ownership model is run before workplace/university/school location choice in order to select a preliminary auto ownership level for calculation of accessibilities for location choice. The model uses the same variables as the full auto ownership model, except for the work/university/school-specific accessibilities that are used in the full model. It is followed by long-term choices that relate to the workplace/university/school for each worker and student (sub-models 2.2 and 2.3). Mobility choices relate to free parking eligibility for workers in the CBD (sub-model 3.1), household car ownership (sub-model 3.2), and transponder ownership (sub-model 3.3).

The daily activity pattern (DAP) type of each household member (model 4.1) is the first travel-related sub-model in the modeling hierarchy. This model classifies daily patterns by three types: (1) mandatory (that includes at least one out-of-home mandatory activity); (2) non-mandatory (that includes at least one out-of-home non-mandatory activity but does not include out-of-home mandatory activities); and (3) home (that does not include any out-of-home activity and travel). The pattern type model also predicts whether any joint tours will be undertaken by two or more household members on the simulated day. However, the exact number of tours, their composition, and other details are left to subsequent models. The pattern choice set contains a non-travel option in which the person can be engaged in in-home activity only (purposely or because of being sick) or can be out of town. In the resident travel model, a person who chooses a non-travel pattern is not considered further in the modeling stream, except that they can make an internal-external trip. Daily pattern-type choices of the household members are linked in such a way that decisions made by some members are reflected in the decisions made by the other members.

The next set of sub-models (4.2.1 - 4.2.3) defines the frequency, time-of-day, and mode for each mandatory tour. The scheduling of mandatory activities is generally considered a higher priority decision than any decision regarding non-mandatory activities for either the same person or for the other household members. "Residual time windows," or periods of time with no person-level activity, are calculated as the time remaining after tours have been scheduled. The temporal overlap of residual time windows among household members are estimated after mandatory tours have been generated and scheduled. Time window overlaps, which are left in the daily schedule after the mandatory commitment of the household members has been made, affect the frequency of joint and individual non-mandatory tours, and the probability of participation in joint tours. At-work sub-tours are modeled next, taking into account the time-window constraints imposed by their parent work tours (sub-models 4.5.1 - 4.5.4).

The next major model component relates to joint household travel. Joint tours are tours taken together by two or more members of the same household. This component predicts the exact number of joint tours by travel purpose and party composition (adults only, children only, or mixed) for the entire household (4.3.1), and then defines the participation of each household member in each joint household tour (4.3.2). It is followed by choice of destination (4.3.3) time-of-day (4.3.4), and mode (4.3.5).

The next stage relates to individual maintenance (escort, shopping, and other household-related errands) and discretionary (eating out, social/recreation, and other discretionary) tours. All of these tours are generated by person in model 4.4.1. Their destination, time of day, and mode are chosen next (4.4.2, 4.4.3, and 4.4.4).

The next set of sub-models relate to the stop-level details for each tour. They include the frequency of stops in each direction (5.2), the purpose of each stop (5.2), the location of each stop (5.3) and the stop departure time (5.4). It is followed by the last set of sub-models that add details for each trip including trip mode (6.1) and parking location for auto trips (6.2). The trips are then assigned to roadway and transit networks depending on trip mode and time period (6.3).

4.7 Main sub-models and procedures

This section describes each model component in greater detail, including the general algorithm for each model, the decision-making unit, the choices considered, the market segmentation utilized (if any), and the explanatory variables used.

SM 1.1 Population Synthesizer

The synthetic population is derived from 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 microdata (synthetic persons and households) with 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 (for version 17 of Series 14, this is 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.

The detailed description of data methods used at each phase is in the following section:

Phase 1: First, using a set of tables from the Summary File-1 (SF1) tabulation of the 2010 Decennial Census data, microdata for individuals are created. Each individual has the following attributes: location identifier (census tract), sex, single-year age, race (one of 7 categories), Hispanic origin (binary), and role (household head, household member, member of Military Group Quarters (GQ), College GQ, Institutional GQ, or Other GQ).

Second, controlling for the household size distribution and using probabilities from the 2010 Decennial Census Public Use Microdata Sample (PUMS) data that describe the demographic attributes of household members, individuals are allocated into households by matching household members with household heads. Lastly, households are assigned to housing units using data developed from SANDAG's land use inventory.

Phase 2: In the microsimulation, demographic events (aging, death, birth) occur to individuals. Death and birth counts are based on vital statistics data from the National Center for Health Statistics. These events may add or remove people from a household as well as alter the size of or dissolve a household. Migration is not explicitly represented in this version of the model; instead, cohort-specific (age, race, Hispanic origin, and sex) annual population targets are used 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 American Community Survey PUMS data, the target population is translated into a cohort-specific estimate of householders (individuals who are the head of a household) 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.

Lastly, the final target for additional householders (cohort- and size-specific) is then developed. That target conforms to multiple constraints (e.g. the number of households and household population by jurisdiction based on the DOF's published population 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 from the special pool. Finally, these new households are assigned to the currently unoccupied housing units, the supply of which comes from new construction and housing units that became available due to the removal of households earlier in this step.

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 there are no jurisdiction-level controls. This is because there are no actual data for 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 jurisdiction's land use plans and historical trends in development.

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. The result is the percentage of households in a given census tract in each income category from the ACS will match that same group in the synthetic household file. 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 ACS data are used. However, the distribution of households by income group is adjusted for every forecast year so that the region-wide distribution of households by income group matches the expected distribution of region-wide median income. Region-wide median household income is assumed to grow at the rate of 0.3% per year.

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

1. School enrollment is predicted probabilistically as conditional on age.
2. Employment status is predicted probabilistically based on an individual's sex, age and income distribution.
3. Weeks worked, hours worked, educational attainment, and occupation status are predicted based on an individual's sex, age, income, and employment status.

The synthetic population includes household attributes such as household location at MGRA-level, household income, number of workers, household size, household type, and poverty status (based on income and the federal poverty limit definition based on household size and the age of the household head). It also includes a list of population with characteristics as such age, sex race, Hispanic origin, military status, employment status, weeks worked, hours worked, student type, person type, educational attainment, grade-level, and occupation by industry code.

SM 1.2 Accessibilities

All accessibility measures for the resident travel model are calculated at the MGRA level. The auto travel times and cost are TAZ-based and the size variables such as total weighted employment for all purposes are MGRA-based. This necessitates that auto accessibilities be calculated at the MGRA level. The resident travel model requires accessibility indices only for non-mandatory travel purposes since the usual location of work/school activity for each worker/student is modeled prior to the DAP, tour frequency, and tour destination choice for non-mandatory tours. In addition, school proximity to the residential MGRA, and travel time by transit for each student, can be used as an explanatory variable for escorting frequency. The set of accessibility measures is summarized in Table T.7.

Table T.7
Accessibility Measures

No.	Description	Model utilization	Attraction size variable S_j	Travel cost C_{ij}
1	Access to non-mandatory attractions by SOV in off-peak	Car ownership	Total weighted employment for all purposes	Generalized SOV time including tolls
2	Access to non-mandatory attractions by transit in off peak	Car ownership	Total weighted employment for all purposes	Generalized best path walk-to-transit time including fares
3	Access to non-mandatory attractions by walk	Car ownership	Total weighted employment for all purposes	SOV off-peak distance (set to 999 if >3)
4-6	Access to non-mandatory attractions by all modes except HOV	CDAP	Total weighted employment for all purposes	Off-peak mode choice logsums (SOV skims for persons) segmented by 3 car-availability groups
7-9	Access to non-mandatory attractions by all modes except SOV	CDAP	Total weighted employment for all purposes	Off-peak mode choice logsums (HOV skims for interaction) segmented by 3 car-availability groups
10-12	Access to shopping attractions by all modes except SOV	Joint tour frequency	Weighted employment for shopping	Off-peak mode choice logsum (HOV skims) segmented by 3 HH adult car-availability groups
13-15	Access to maintenance attractions by all modes except SOV	Joint tour frequency	Weighted employment for maintenance	Off-peak mode choice logsum (HOV skims) segmented by 3 adult car-availability groups
16-18	Access to eating-out attractions by all modes except SOV	Joint tour frequency	Weighted employment for eating out	Off-peak mode choice logsum (HOV skims) segmented by 3 adult HH car-availability groups
19-21	Access to visiting attractions by all modes except SOV	Joint tour frequency	Total households	Off-peak mode choice logsum (HOV skims) segmented by 3 adult car-availability groups
22-24	Access to discretionary attractions by all modes except SOV	Joint tour frequency	Weighted employment for discretionary	Off-peak mode choice logsum (HOV skims) segmented by 3 adult car-availability groups
25-27	Access to escorting attractions by all modes except SOV	Allocated tour frequency	Total households	AM mode choice logsum (HOV skims) segmented by 3 adult car-availability groups

No.	Description	Model utilization	Attraction size variable S_j	Travel cost C_{ij}
28-30	Access to shopping attractions by all modes except HOV	Allocated tour frequency	Weighted employment for shopping	Off-peak mode choice logsum (SOV skims) segmented by 3 adult car-availability groups
31-33	Access to maintenance attractions by all modes except HOV	Allocated tour frequency	Weighted employment for maintenance	Off-peak mode choice logsum (SOV skims) segmented by 3 adult car-availability groups
34-36	Access to eating-out attractions by all modes except HOV	Individual tour frequency	Weighted employment for eating out	Off-peak mode choice logsum (SOV skims) segmented by 3 car-availability groups
36-39	Access to visiting attractions by all modes except HOV	Individual tour frequency	Total households	Off-peak mode choice logsum (SOV skims) segmented by 3 car-availability groups
40-41	Access to discretionary attractions by all modes except HOV	Individual tour frequency	Weighted employment for discretionary	Off-peak mode choice logsum (SOV skims) segmented by 3 car-availability groups
43-44	Access to at-work attractions by all modes except HOV	Individual sub-tour frequency	Weighted employment for at work	Off-peak mode choice logsum (SOV skims) segmented by adult 2 car-availability groups (0 cars and cars equal or greater than workers)
45	Access to all attractions by all modes of transport in the peak	Work location, CDAP	Total weighted employment for all purposes	Peak mode choice logsums
46	Access to at-work attractions by walk	Individual sub-tour frequency	Weighted employment for at work	SOV off-peak distance (set to 999 if >3)
47	Access to all households by all modes of transport in the peak		Total weighted households for all purposes	Generalized best path walk-to-transit time including fares

The size variable is calculated as a linear combination of the MGRA LU variables with the specified coefficients. The values of coefficients in the table have been estimated by means of an auxiliary regression model that used the LU variables as independent variables and expanded trip ends by travel purpose as dependent variables. The intercept was set to zero. The regressions were applied at the MGRA level.

These travel cost functions are used in the accessibility calculations: generalized single-occupancy vehicle (SOV) time; generalized best path walk-to-transit time; SOV off-peak distance; and off-peak mode choice logsum.

SM 2.1 Pre-Mandatory Car Ownership Model

Number of Models: 1
Decision-Making Unit: Household
Model Form: Nested Logit
Alternatives: Five (0, 1, 2, 3, 4++ autos)

The car ownership models predict the number of vehicles owned by each household. It is formulated as a nested logit choice model with five alternatives, including “no car”, “one car”, “two cars”, “three cars”, and “four or more cars.” The nesting structure is shown in Figure T.5.

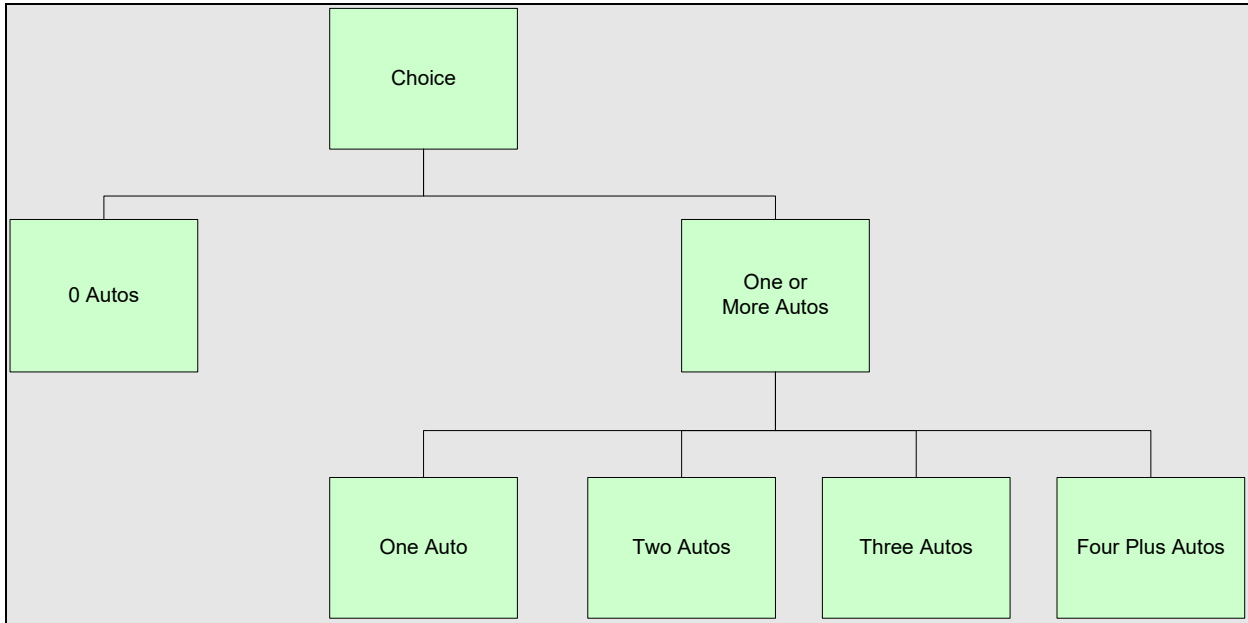
There are two instances of the auto ownership model. The first instance, model 2.1, is used to select a preliminary auto ownership level for the household, based upon household demographic variables, household '4D' variables, and destination-choice accessibility terms created in sub-model 1.2 (see above). This auto ownership level is used to create mode choice logsums for workers and students in the household, which are then used to select work and school locations in model 2.2. The auto ownership model is re-run (sub-model 3.2) in order to select the actual auto ownership for the household, but this subsequent version is informed by the work and school locations chosen by model 2.2. All other variables and coefficients are held constant between the two models, except for alternative-specific constants.

The model includes the following explanatory variables:

- Number of driving-age adults in household
- Number of persons in household by age range
- Number of workers in household
- Number of high-school graduates in household
- Dwelling type of household
- Household income
- Intersection density (per acre) within one-half mile radius of household MGRA
- Population density (per acre) within one-half mile radius of household MGRA
- Retail employment density (per acre) within one-half mile radius of household MGRA
- Non-motorized accessibility from household MGRA to non-mandatory attractions (accessibility term #3)
- Off-peak auto accessibility from household MGRA to non-mandatory attractions (accessibility term #1)
- Off-peak transit accessibility from household MGRA to non-mandatory attractions (accessibility term #2)

Note that the model includes both household and person-level characteristics, '4D' density measures, and accessibilities. The accessibility terms are destination choice (DC) logsums, which represent the accessibility of non-mandatory activities from the home location by various modes (auto, non-motorized, and transit). They are fully described under SM 1.2, above.

Figure T.5
Auto Ownership Nesting Structure



SM 2.2 Work from Home Choice

Number of Models: 1
 Decision-Making Unit: Workers
 Model Form: Binary Logit
 Alternatives: Two (regular workplace is home; regular workplace is not home)

The work from home choice model determines whether each worker works from home. It is a binary logit model, which takes into account the following explanatory variables:

- Household income
- Person age
- Gender
- Worker education level
- Whether the worker is full-time or part-time
- Whether there are non-working adults in the household
- Peak accessibility across all modes of transport from household MGRA to employment (accessibility term #45, see section SM 1.2)

SM 2.3 Mandatory (workplace/university/school) Activity Location Choice

Number of Models: 5 (Work, Preschool, K-8, High School, University)
 Decision-Making Unit: Workers for Work Location Choice; Persons Age 0-5 for Preschool, 6-13 for K-8; Persons Age 14-17 for High School; University Students for University Model
 Model Form: Multinomial Logit
 Alternatives: MGRAs

A workplace location choice model assigns a workplace MGRA for every employed person in the synthetic population who does not choose 'works at home' from Model 2.2. Every worker is assigned a regular work location zone (TAZ) and MGRA according to a multinomial logit destination choice model. Size terms in the model vary according to worker occupation, to reflect the different types of jobs that are likely to attract different (white collar versus blue-collar) workers. There are six occupation categories used in the segmentation of size terms, as shown in Table T.4. Each occupation category utilizes different coefficients for categories of employment by industry, to reflect the different likelihood of workers by occupation to work in each industry. Accessibility from the workers home to the alternative workplace is measured by a mode choice logsum taken directly from the tour mode choice model, based on peak period travel (A.M. departure and P.M. return). Various distance terms are also used.

The explanatory variables in work location choice include:

- Household income
- Work status (full versus part-time)
- Worker occupation
- Gender
- Distance
- The tour mode choice logsum for the worker from the residence MGRA to each sampled workplace MGRA using peak level-of-service
- The size of each sampled MGRA

Since mode choice logsums are required for each destination, a two-stage procedure is used for all destination choice models in order to reduce computational time (it would be computationally prohibitive to compute a mode choice logsum for over 20,000 MGRAs and every tour). In the first stage, a simplified destination choice model is applied in which all TAZs are alternatives. The only variables in this model are the size term (accumulated from all MGRAs in the TAZ) and distance. This model creates a probability distribution for all possible alternative TAZs (TAZs with no employment are not sampled). A set of alternatives are sampled from the probability distribution and, for each TAZ, an MGRA is chosen according to its size relative to the sum of all MGRAs within the TAZ. These sampled alternatives constitute the choice set in the full destination choice model. Mode choice logsums are computed for these alternatives and the destination choice model is applied. A discrete choice of MGRA is made for each worker from this more limited set of alternatives. In the case of the work location choice model, a set of 40 alternatives is sampled.

The applied procedure utilizes an iterative shadow pricing mechanism in order to match workers to input employment totals. The shadow pricing process compares the share of workers who choose each MGRA by occupation to the relative size of the MGRA compared to all MGRAs. A shadow price is computed which scales the size of the MGRA based on the ratio of the observed share to the estimated share. The model is re-run until the estimated and observed shares are within a reasonable tolerance. The shadow prices are written to a file and can be used in subsequent model runs to cut down computational time.

There are four school location choice models: (1) a pre-school model, (2) a grade school model, (3) a high school model, and (4) a university model.

The pre-school location choice model assigns a school location for pre-school children (person type 8) who are enrolled in pre-school and daycare. The size term for this model includes a number of employment types and population, since daycare and pre-school enrollment and employment are not explicitly tracked in the input land-use data. Explanatory variables include:

- Income
- Age
- Distance
- The tour mode choice logsum for the student from the residential MGRA to each sampled pre-school MGRA using peak levels-of-service
- Size of each sampled pre-school MGRA

The grade school location choice model assigns a school location for every K-8 student in the synthetic population; the size term for this model is K-8 enrollment. School district boundaries are used to restrict the choice set of potential school location zones based on residential location. The explanatory variables used in the grade school model include:

- School district boundaries
- Distance
- The tour mode choice logsum for the student from the residence MGRA to the sampled school MGRA using peak levels-of-service
- The size of the school MGRA

The high school location choice model assigns a school location for every high-school student in the synthetic population; the size term for this model is high school enrollment. District boundaries are also used in the high school model to restrict the choice set. The explanatory variables in the high school model include:

- School district boundaries
- Distance
- The tour mode choice logsum for the student from the residence MGRA to the sampled school MGRA using peak levels-of-service
- The size of the school MGRA

A university location choice model assigns a university location for every university student in the synthetic population. There are three types of college/university enrollment in the input land-use data file: (1) College enrollment, which measures enrollment at major colleges and universities; (2) other college enrollment, which measures enrollment at community colleges, and (3) adult education enrollment, which includes trade schools and other vocational training. The size terms for this model are segmented by student age, where students aged less than 30 use a 'typical' university size term, which gives a lower weight to adult education enrollment, while students age 30 or greater have a higher weight for adult education.

Explanatory variables in the university location choice model include:

- Student worker status
- Student age
- Distance
- Tour mode choice logsum for student from residence MGRA to sampled school MGRA using peak levels-of-service

SM 3.1 Employer Parking Provision Model

Number of Models:	1
Decision-Making Unit:	Workers whose workplace is in CBD or another priced-parking area (park area 1)
Model Form:	Multinomial Logit
Alternatives:	Three (Free on-site parking, parking reimbursement, and no parking provision)

The Employer Parking Provision Model predicts which persons have on-site parking provided to them at their workplaces and which persons receive reimbursement for off-site parking costs. The provision model takes the form of a multinomial logit discrete choice between free on-site parking, parking reimbursement (including partial or full reimbursement of off-site parking and partial reimbursement of on-site parking) and no parking provision.

It should be noted that free-onsite parking is not the same as full reimbursement. Many of those with full reimbursement in the survey data could have chosen to park closer to their destinations and accepted partial reimbursement. Whether parking is fully reimbursed will be determined both by the reimbursement model and the location choice model.

Persons with workplaces outside of *park area1* are assumed to receive free parking at their workplaces.

Explanatory variables in the provision model include:

- Household income
- Occupation
- Average daily equivalent of monthly parking costs in nearby MGRAs

SM 3.2 Car Ownership Model

Number of Models:	1
Decision-Making Unit:	Households
Model Form:	Nested Logit
Alternatives:	Five (0, 1, 2, 3, 4+ autos)

The car ownership model is described under SM 2.1, above. The model is re-run after work/school location choice, so that auto ownership can be influenced by the actual work and school locations predicted by sub-model 3.1.

The explanatory variables in model 3.2 include the ones listed under SM 2.1 above, with the addition of the following:

- A variable measuring auto dependency for workers in the household based upon their home to work tour mode choice logsum
- A variable measuring auto dependency for students in the household based upon their home to school tour mode choice logsum
- A variable measuring the time on rail transit (light-rail or commuter rail) as a proportion of total transit time to work for workers in the household
- A variable measuring the time on rail transit (light-rail or commuter rail) as a proportion of total transit time to school for students in the household

The household mandatory activity auto dependency variable is calculated using the difference between the single-occupant vehicle (SOV) and the walk to transit mode choice logsum, stratified by person type (worker versus student). The logsums are computed based on the household MGRA and the work MGRA (for workers) or school MGRA (for students). The household auto dependency is obtained by aggregating individual auto dependencies of each person type (worker versus student) in the household.

SM 3.3 Toll Transponder Ownership Model

Number of Models:	1
Decision-Making Unit:	Households
Model Form:	Binomial Logit
Alternatives:	Two (Yes or No)

This model predicts whether a household owns a toll transponder unit. It was estimated based on aggregate transponder ownership data using a quasi-binomial logit model to account for over-dispersion. It predicts the probability of owning a transponder unit for each household based on aggregate characteristics of the zone.

The explanatory variables in the model include:

- Percent of households in the zone with more than one auto
- The number of autos owned by the household
- The straight-line distance from the MGRA to the nearest toll facility, in miles
- The average transit accessibility to non-mandatory attractions using off-peak levels-of-service (accessibility measure #2)
- The average expected travel time savings provided by toll facilities to work
- The percent increase in time to downtown San Diego incurred if toll facilities were avoided entirely

The accessibility terms are destination choice (DC) logsums, which represent the accessibility of non-mandatory activities from the home location by various modes (auto, non-motorized, and transit).

SM 4.1 Coordinated Daily Activity Pattern (DAP) Model

Number of Models:	1
Decision-Making Unit:	Households
Model Form:	Multinomial Logit
Alternatives:	691 total alternatives, but depends on household size

This model predicts the main daily activity pattern (DAP) type for each household member. The activity types that the model considers are:

- **Mandatory pattern (M)** that includes at least one of the three mandatory activities – work, university or school. This constitutes either a workday or a university/school day and may include additional non-mandatory activities such as separate home-based tours or intermediate stops on the mandatory tours.
- **Non-mandatory pattern (N)** that includes only maintenance and discretionary tours. Note that the way in which tours are defined, maintenance and discretionary tours cannot include travel for mandatory activities.
- **At-home pattern (H)** that includes only in-home activities. At-home patterns are not distinguished by any specific activity (e.g., work at home, take care of child, being sick, etc.). Cases where someone is not in town (e.g., business travel) are also combined with this category.

Statistical analysis performed in a number of different regions has shown that there is an extremely strong correlation between DAP types of different household members, especially for joint N and H types. For this reason, the DAP for different household members should not be modeled independently, as doing so would introduce significant error in the types of activity patterns generated at the household level. This error has implications for several policy sensitivities, including greenhouse gas policies. Therefore, the model is applied across all household members simultaneously; the interactions or influences of different types of household members (e.g., the effect of a child who stays at home on the simulation day on the probability of a part-time worker also staying at home) is taken into account through a specific set of interaction variables.

The model also simultaneously predicts the presence of fully-joint tours for the household. Fully-joint tours are tours in which two or more household members travel together for all stops on the tour. Joint tours are only a possible alternative at the household level when two or more household members have an active (M or N) travel day. The joint tour indicator predicted by this model is then considered when generating and scheduling mandatory tours, in order to reflect the likelihood of returning home from work earlier in order to participate in a joint tour with other household members.

The choice structure includes 363 alternatives with no joint travel and 328 alternatives with joint travel, totaling to 691 alternatives as shown in Table T.8. Note that the choices are available based on household size. There are also two facets of the model that reduce the complexity. First, mandatory DAP types are only available for appropriate person types (workers and students). Second, and more importantly, intra-household coordination of DAP types is relevant only for the N and H patterns. Thus, simultaneous modeling of DAP types for all household members is essential only for the trinary choice (M, N, H), while the sub-choice of the mandatory pattern can be modeled for each person separately.

Table T.8
Number of Choices in CDAP Model

Household Size	Alternatives – no Joint Travel	Alternatives with Joint Travel	All Alternatives
1	3	0	3
2	$3 \times 3 = 9$	$3 \times 3 - (3 \times 2 - 1) = 4$	13
3	$3 \times 3 \times 3 = 27$	$3 \times 3 \times 3 - (3 \times 3 - 2) = 20$	47
4	$3 \times 3 \times 3 \times 3 = 81$	$3 \times 3 \times 3 \times 3 - (3 \times 4 - 3) = 72$	153
5 or more	$3 \times 3 \times 3 \times 3 \times 3 = 243$	$3 \times 3 \times 3 \times 3 \times 3 - (3 \times 5 - 4) = 232$	475
Total	363	328	691

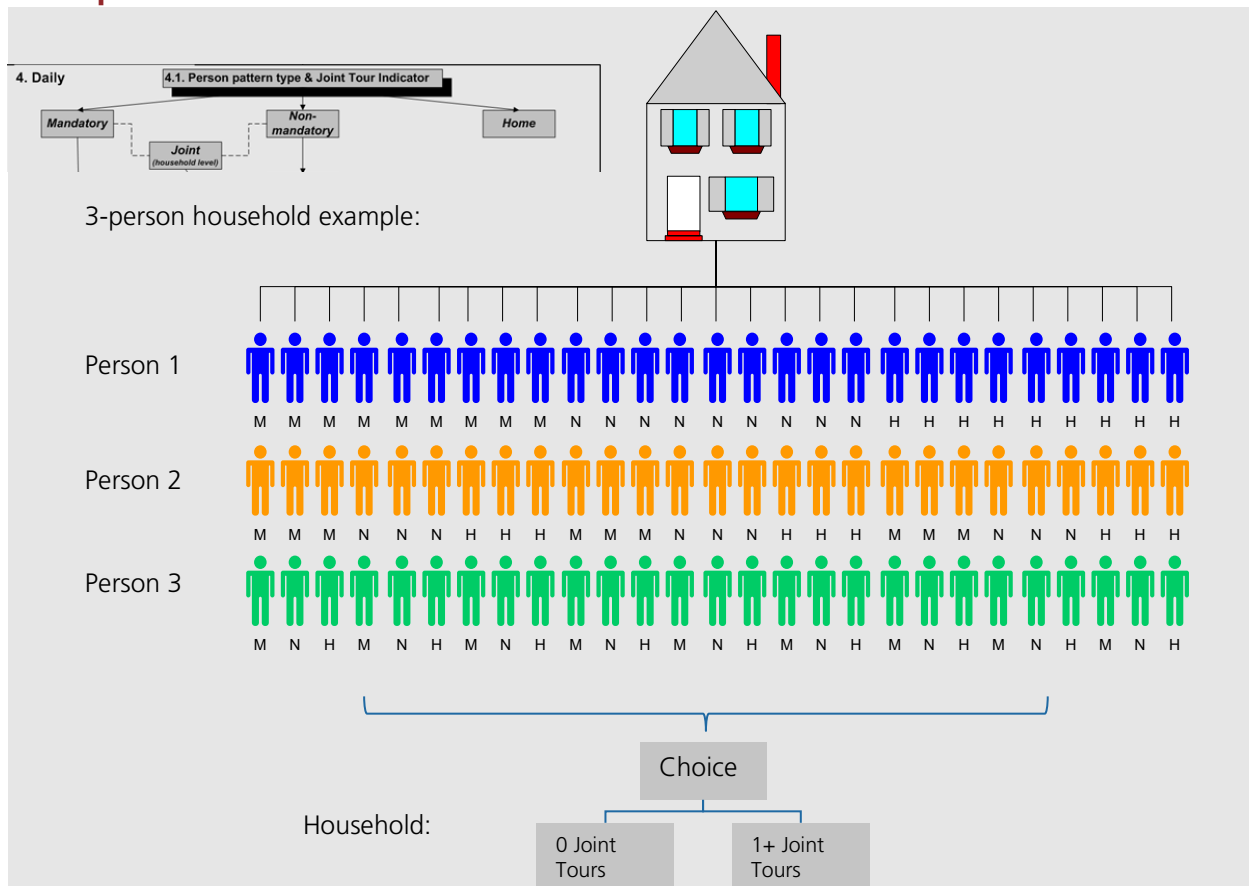
The structure is shown graphically in Figure T.6 for a three-person household. Each of the 27 daily activity pattern choices is made at the household level and describes an explicit pattern-type for each household member. For example, the fourth choice from the left is person 1 mandatory (M), person 2 non-mandatory (N), and person 3 mandatory (M). The exact tour frequency choice is a separate choice model conditional upon the choice of alternatives in the trinary choice. This structure is much more powerful for capturing intra-household interactions than sequential processing. The choice of 0 or 1+ joint tours is shown below the DAP choice for each household member. The choice of 0 or 1+ joint tours is active for this DAP choice because at least two members of the household would be assigned active travel patterns in this alternative.

For a limited number of households of size greater than five, the model is applied for the first five household members by priority while the rest of the household members are processed sequentially, conditional upon the choices made by the first five members. The rules by which members are selected for inclusion in the main model are that first priority is given to any full-time workers (up to two), then to any part-time workers (up to two), then to children, youngest to oldest (up to three).

The CDAP model explanatory variables include:

- Household Size
- Number of Adults in household
- Number of children in household
- Auto Sufficiency (see car ownership model for details)
- Household Income
- Dwelling Type
- Person type
- Age
- Gender
- Usual Work location
- The tour mode choice logsum for the worker from the residential MGRA to each sampled workplace MGRA using peak levels-of-service
- The tour mode choice logsum for the student from the residential MGRA to each sampled school MGRA using peak levels-of-service
- Accessibility across all modes of transport from household MGRA to retail employment or non-mandatory locations (accessibility term #45, see section SM 1.2 above)

Figure T.6
Example of DAP Model Alternatives for a 3-Person Household



SM 4.2.1 Individual Mandatory Tour Frequency

Number of Models:	1
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	5 (1 Work Tour, 2+ Work Tours, 1 School Tour, 2+ School Tours, 1 Work/1 School Tour)

Based on the DAP chosen for each person, individual mandatory tours, such as work, school and university tours are generated at person level. The model is designed to predict the exact number and purpose of mandatory tours (e.g., work and school/university) for each person who chose the mandatory DAP type at the previous decision-making stage. Since the DAP type model at the household level determines which household members engage in mandatory tours, all persons subjected to the individual mandatory tour model implement at least one mandatory tour. The model has the following five alternatives: (1) 1 Work Tour, (2) 2 or more Work Tours, (3) 1 School Tour, (4) 2 or more School Tours, (5) 1 Work/1 School Tour.

DAPs and subsequent behavioral models of travel generation include these explanatory variables:

- Auto sufficiency
- Household income
- Non-family household (for example Group Quarters) indicator
- Number of preschool children in household
- Number of school aged children 6-18 years old in household NOT going to school
- Person type
- Gender
- Age
- Distance to work location
- Distance to school location
- Best travel time to work location
- HOV accessibility from household MGRA to employment (accessibility terms #25, 26, 27 (by auto sufficiency), see section SM 1.2 above)

SM 4.2.2 Individual Mandatory Tour Time of Day Choice

Number of Models:	3 (Work, University, and School)
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	820 (combinations of tour departure half-hour and arrival half-hour back at home, with aggregation between 1 AM and 5 AM)

After individual mandatory tours have been generated, the tour departure time from home and arrival time back at home is chosen simultaneously. Note that it is not necessary to select the destination of the tour, as this has already been determined in sub-model 2.3. The model is a discrete choice construct that operates with tour departure from home and arrival back home time combinations as alternatives. The proposed utility structure is based on “continuous shift” variables and represents an analytical hybrid that combines the advantages of a discrete choice structure (flexible in specification and easy to estimate and apply) with the advantages of a duration model (a simple structure with few parameters, and which supports continuous time). The model has a temporal resolution of one-half hour that is expressed in 820 half-hour departure/arrival time alternatives. The model utilizes direct availability rules for each subsequently scheduled tour, to be placed in the residual time window left after scheduling tours of higher

priority. This conditionality ensures a full consistency for the individual entire-day activity and travel schedule as an outcome of the model.

In the CT-RAMP model structure, the tour-scheduling model is placed after destination choice and before mode choice. Thus, the destination of the tour and all related destination and origin-destination attributes are known and can be used as variables in the model estimation.

The following practical rules are used to set the alternative departure/arrival time combinations:

- Each reported/modeled departure/arrival time is rounded to the nearest half-hour. For example, the half-hour “17” includes all times from 10:45 A.M. to 11:14 A.M.
- Any times before 5 A.M. are shifted to 5 A.M., and any times after 1 A.M. are shifted to 1 A.M. This typically results in a shift for relatively few cases and limits the number of half-hours in the model to 41.
- Every possible combination of the 41 departure half-hours with the 41 arrival half-hours (where the arrival half-hour is the same or later than the departure hour) is an alternative. This gives $41 \times 42/2 = 861$ choice alternatives.

The network simulations to obtain travel time and cost skims are implemented for five broad periods: (1) early A.M., (2) A.M. peak, (3) midday, (4) P.M. peak, and (5) night (evening, and late night) for the three mandatory tour purposes (work, university, and school).

The model includes the following explanatory variables:

- Household income
- Person type
- Gender
- Age
- Mandatory tour frequency
- Auto travel distance
- Destination employment density
- Tour departure time
- Tour arrival time
- Tour duration
- The tour mode choice logsum by tour purpose from the residence MGRA to each sampled MGRA location

SM 4.2.3 Individual Mandatory Tour Mode Choice Model

Number of Models: 3 (Work, University, K-12)

Decision-Making Unit: Person

Model Form: Nested Logit

Alternatives: 26 (See Figure T.7)

This model determines how the “main tour mode” (used to get from the origin to the primary destination and back) is determined. The tour-based modeling approach requires a certain reconsideration of the conventional mode choice structure. Instead of a single mode choice model pertinent to a four-step structure, there are two different levels where the mode choice decision is modeled:

- The tour mode level (upper-level choice)
- The trip mode level (lower-level choice conditional upon the upper-level choice)

The tour mode choice model considers the following alternatives:

- Drive-alone
- Shared-Ride 2
- Shared-Ride 3+
- Walk
- Bike
- Walk-Transit
- Park-and-Ride Transit (drive to transit station and ride transit)
- Kiss-and-Ride Transit (drop-off at transit station and ride transit)
- School Bus (only available for grade school and high school tour purposes)

The mode of each tour is identified based on the combination of modes used for all trips on the tour, according to the following rules:

- If any trip on the tour is Park-and-Ride Transit, then the tour mode is Park-and-Ride Transit.
- If any trip on the tour is Kiss-and-Ride Transit, then the tour mode is Kiss-and-Ride Transit.
- If any trip on the tour is School Bus, then the tour mode is School Bus.
- If any trip on the tour is Walk-Transit, then the tour mode is Walk-Transit.
- If any trip on the tour is Bike, then the tour mode is Bike.
- If any trip on the tour is Shared-Ride 3+, then the tour mode is Shared-Ride 3+
- If any trip on the tour is Shared-Ride 2, then the tour mode is Shared-Ride 2.
- If any trip on the tour is Drive-Alone, then the tour mode is Drive-Alone.
- All remaining tours are Walk.

These tour modes create a hierarchy of importance that ensures that transit is available for trips on tours with transit as the preferred mode, and that high-occupancy vehicle lanes are available for trips on tours where shared-ride is the preferred mode. It also ensures that if drive-transit is utilized for the outbound trip on the tour, that mode is also available for the return journey (such that the traveler can pick up their car at the parking lot on the way home).

Modes for the tour mode choice model are shown in Figure T.7. The model is distinguished by the following characteristics:

- Segmentation of the HOV mode by occupancy categories, which is essential for modeling specific HOV/HOT lanes and policies.
- An explicit modeling of toll vs. non-toll choices as highway sub-modes, which is essential for modeling highway pricing projects and policies.
- Distinguishing between certain transit sub-modes that are characterized by their attractiveness, reliability, comfort, convenience, and other characteristics beyond travel time and cost (such as Express Bus, Bus-Rapid Transit, Light-Rail Transit, and Commuter Rail).
- Distinguishing between walk and bike modes if the share of bike trips is significant.

Note that non-toll and toll eligible alternatives for each auto mode provide an opportunity for toll choice as a path choice within the nesting structure. This requires separate non-toll and toll eligible skims to be provided as inputs to the model (where non-toll paths basically “turn off” all toll and HOT lanes). Three transit skims are 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 (Premium modes include express bus, bus rapid transit (BRT), light-rail transit (LRT), and/or commuter rail.), 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.

The tour mode choice model is based on the round-trip (outbound and return) level-of-service (LOS) between the tour anchor location (home for home-based tours and work for at-work sub-tours) and the tour primary destination. The tour mode choice model assumes that the mode of the outbound journey is the same as the mode for the return journey in the consideration of level-of-service information. This is a simplification that results in a model with a relatively modest number of alternatives and allows the estimation process to utilize data from an on-board survey in which the mode for only one direction is known. Only these aggregate tour modes are used in lower level model components such as stop frequency, stop location, and as constraints in trip mode choice.

However, the model calculates utilities for a more disaggregate set of modes in lower level alternatives that are consistent with the more detailed modes in trip mode choice. This allows the tour mode choice model to consider the availability of multiple transit modes and/or managed lane route choices in the choice of tour mode, with their specific levels-of-service and modal constants. The more aggregate tour modes act as constraints in trip mode choice; for example, if walk-transit is chosen in tour mode choice, only shared-ride, walk, and walk-transit modes are available in trip mode choice. Ultimately, trips are assigned to networks using the more disaggregate trip modes.

The lower level nest mode choices (which are the same as the trip mode choice model alternatives) are:

- Drive-alone Non-Toll
- Drive-Alone Toll Eligible
- Shared-Ride 2 Non-Toll (General Purpose Lane)
- Shared-Ride 2 Toll Eligible
- Shared-Ride 3+ Non-Toll (General Purpose Lane)
- Shared-Ride 3+ Toll Eligible
- Walk
- Bike
- Walk to Transit
- Park and Ride (PNR) to Transit
- Kiss and Ride (KNR) to Transit
- School Bus

The appropriate skim values for the tour mode choice are a function of the MGRA of the tour origin and MGRA of the tour primary destination. As described in the section on Treatment of Space, all transit level-of-service and certain non-motorized level of service (for MGRAs within 1.5 miles of each other) are computed “on-the-fly” in mode choice. Transit access and egress times are specifically determined via detailed MGRA-to-TAP distances computed within Geographic Information System (GIS) software. Actual TAP-TAP pairs used for the MGRA-pair, and therefore actual transit levels-of-service, ranks and retains the best *four* (a user-defined variable) TAP pairs regardless of line haul mode.

Figure T.7

Tour Mode Choice Model Structure

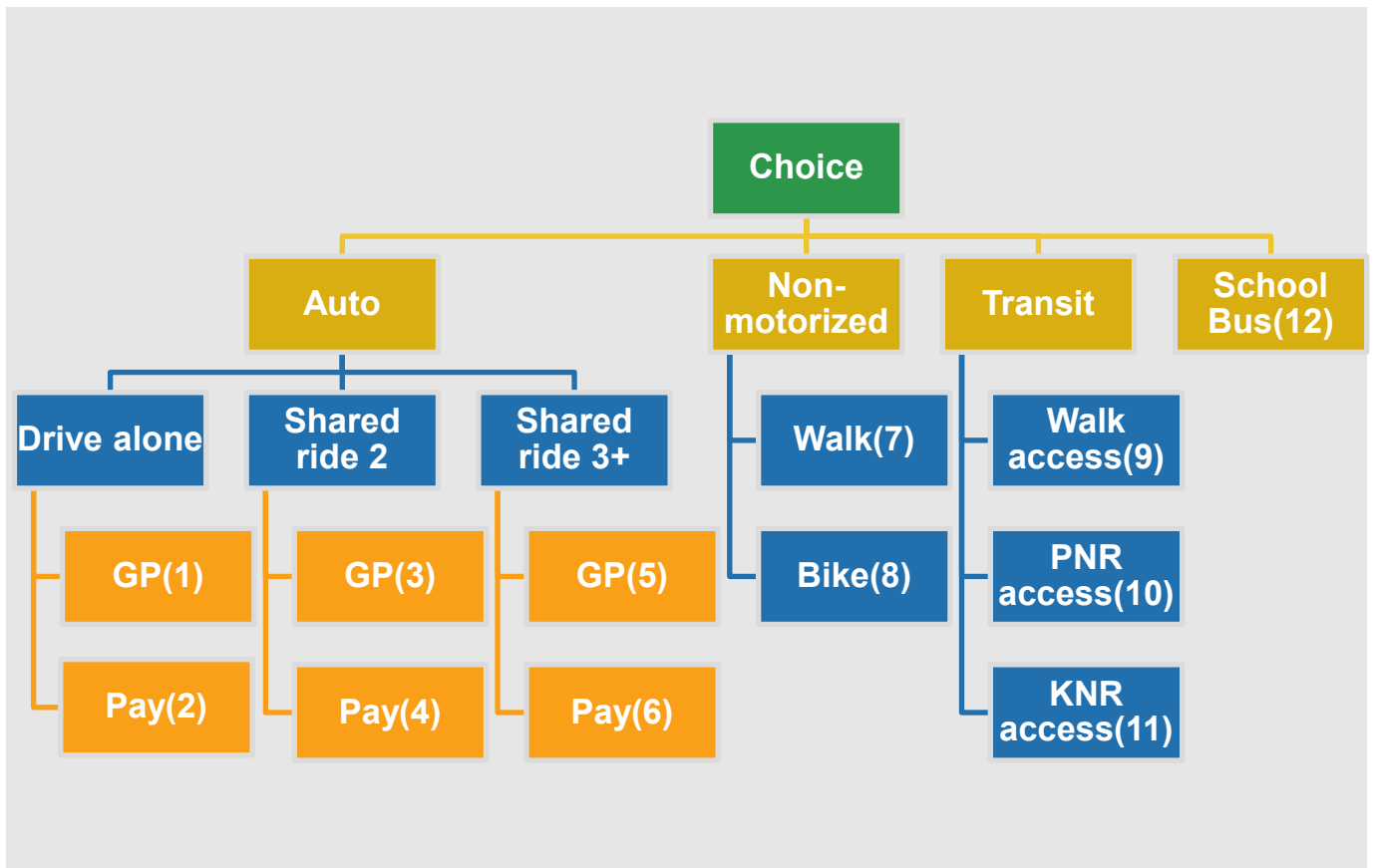


Table T.9
Skims Used in Tour Mode Choice (by Value of Time)

Mode	Skims
Drive-alone Non-Toll	All general purpose lanes available. HOV lanes, HOT lanes, and toll lanes unavailable. Toll bridges are available.
Drive-alone Toll Eligible	All general purpose lanes and toll lanes are available. HOV lanes are unavailable. HOT lanes are available for the SOV toll rate. Toll bridges are available.
Shared-2 Non-Toll	All general purpose and HOV lanes available. HOT lanes are for free and available up to 2034 (as set by policy in the 2019 RTP), and toll lanes unavailable. Toll bridges are available.
Shared-2 Toll Eligible	All general purpose lanes and 2+ occupancy HOV lanes are available for free. HOT lanes where 2+ occupant vehicles go free are available up to 2034 for free. HOT lanes where 2-occupant vehicles are tolled at the 2-occupant toll rate in 2035 and after (as set by policy in the 2019 RTP). Toll lanes and Toll bridges are available.
Shared-3+ Non-Toll	All general purpose lanes, HOV lanes and HOT lanes available for free, and toll lanes unavailable. Toll bridges are available.
Shared-3+ Toll Eligible	All general purpose lanes, HOV lanes and HOT lanes available for free. Toll lanes and Toll bridges are available.
Walk	Roadway distance, excluding freeways, but allowing select bridges with sidewalks. This is used for any MGRA-pair whose distance is greater than 1.5 miles. The walk time for MGRA-pairs whose distance is less than 1.5 miles relies on the GIS-based walk distances.
Bike	Roadway distance, excluding freeways, but allowing select bridges with bike lanes. This is used for any MGRA-pair whose distance is greater than 1.5 miles. The bike time for MGRA-pairs whose distance is less than 1.5 miles relies on the GIS-based bike distances.
Transit-Local bus Only	Local Bus TAP-to-TAP skims, including in-vehicle time, first wait time, transfer wait time, and fare.
Transit-Premium Only	Premium TAP-to-TAP skims, including in-vehicle time, first wait time, transfer wait time, and fare. Premium mode includes express bus, bus rapid transit, light rail, and commuter rail.
Transit-Local and Premium	Local plus premium TAP-to-TAP skims (with a required transfer), including in-vehicle time, first wait time, transfer wait time, and fare.

The individual mandatory tour mode choice model contains the following explanatory variables:

- Auto sufficiency
- Household size
- Age
- Gender
- In-vehicle time (auto and transit)
- Walk and bike time
- Auto operating cost
- Auto parking cost
- Auto terminal time
- Auto toll value
- Transit first wait time
- Transit transfer time
- Number of transit transfers
- Transit walk access time
- Transit walk egress time
- Transit walk auxiliary time
- Transit fare
- Transit drive access time
- Transit drive access cost
- Intersection density
- Employment density
- Dwelling unit density

SM 4.2.4 School Escort Model

Multi-occupant vehicles accounts for a significant portion of overall transportation demand and most of multi-occupant vehicles are made up of members of the same household. Some of this joint travel occurs by household members picking up and dropping off (i.e. 'escorting') other household members including for mandatory activity purposes such as school. A school escort model was added in ABM2 to explicitly handle intra-household coordinated activity for escorting children to and from school.

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 escortees in a choice model whose alternatives consist of 'bundles' of escortees with chauffeurs for each half tour. 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.

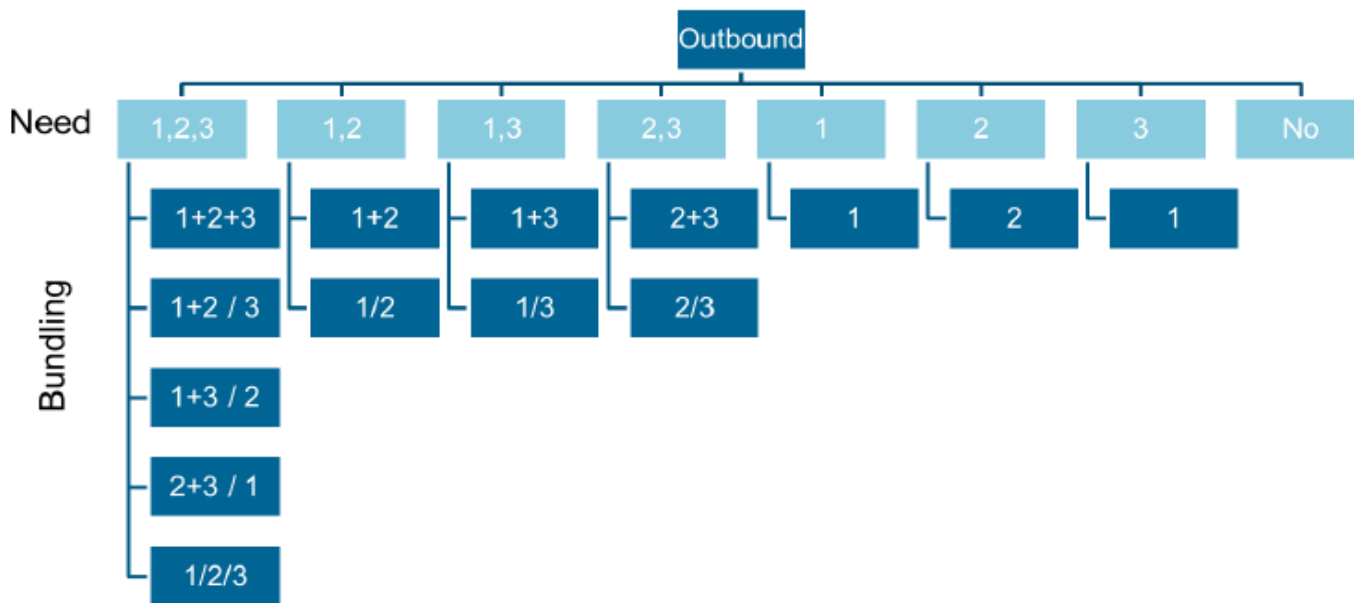
The model classifies each child’s school tour into three types:

- No escorting: the child walks, bikes, takes transit, drives, or takes a school bus to/from school.
- 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.
- 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 T.8 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). 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.

Figure T.8
School Escort Model Example of Bundling Children by Half-Tour



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)
- 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.

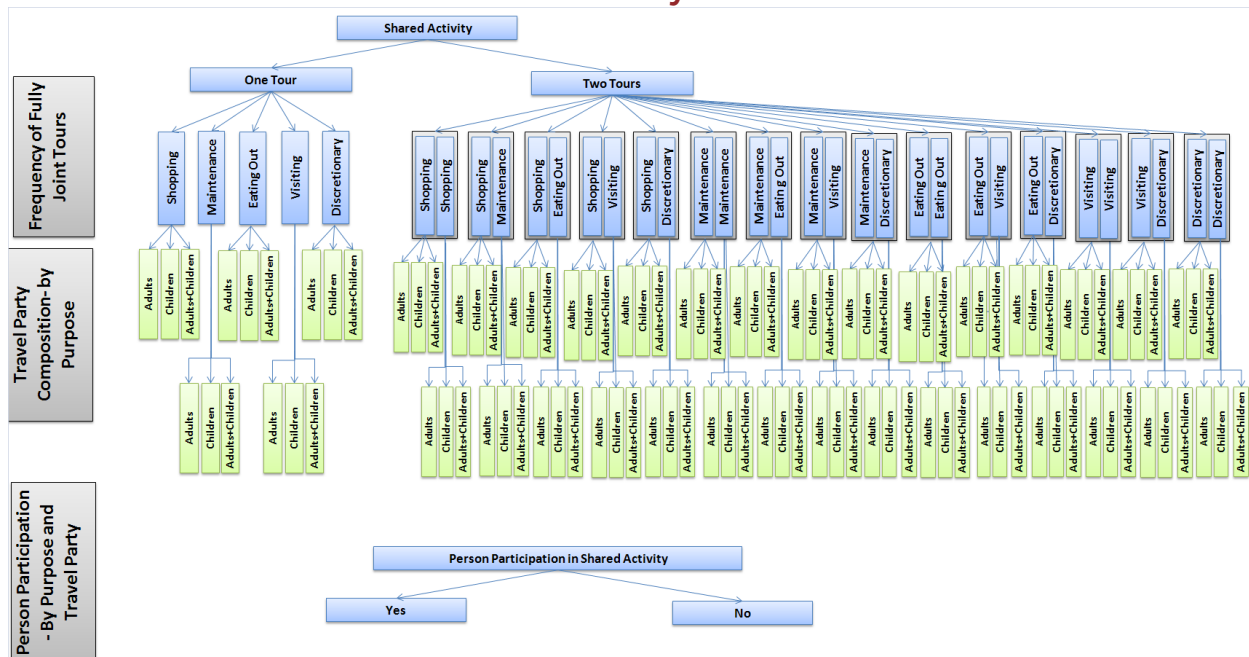
SM 4.3 Generation of Joint Household Tours

In the CT-RAMP structure, joint travel for non-mandatory activities is modeled explicitly in the form of fully joint tours (where all members of the travel party travel together from the beginning to the end and participate in the same activities). This accounts for more than 50 percent of joint travel.

Each fully joint tour is considered a modeling unit with a group-wise decision-making process for the primary destination, mode, frequency and location of stops. Modeling joint activities involves two linked stages – see Figure T.9.

- A tour generation and composition stage that generates the number of joint tours by purpose/activity type made by the entire household. This is the joint tour frequency model.
- A tour participation stage at which the decision whether to participate or not in each joint tour is made for each household member and tour.

Figure T.9
Model Structure for Joint Non-Mandatory Tours



Joint tour party composition is modeled for each tour. Travel party composition is defined in terms of person categories (e.g., adults and children) participating in each tour. Person participation choice is then modeled for each person sequentially. In this approach, a binary choice model is calibrated for each activity, party composition and person type. The model iterates through household members and applies a binary choice to each to determine if the member participates. The model is constrained to only consider members with available time-windows overlapping with the generated joint tour. The approach offers simplicity but at the cost of overlooking potential non-independent participation probabilities across household members. The joint tour frequency, composition, and participation models are described below.

SM 4.3.1 Joint Tour Frequency and Composition

Number of Models:	1
Decision-Making Unit:	Households with a Joint Tour Indicator predicted by the CDAP model
Model Form:	Multinomial Logit
Alternatives:	105 (1 Tour segmented by 5 purposes and 3 composition classes, 2 tours segmented by 5 purposes and 3 composition classes)

Joint tour frequencies (1 or 2+) are generated by households, purpose, and tour composition (adults only, children only, adults and children). Later models determine who in the household participates in the joint tour. The model is only applied to households with a joint tour indicator at the household level, as predicted by the CDAP model.

The explanatory variables in the joint tour frequency model include:

- Auto sufficiency
- Household income
- Number of full time workers in household
- Number of part time workers in household
- Number of university students in household
- Number of non-workers in household
- Number of retirees in household
- Number of driving age school children in household
- Number pre-driving age school children in household
- Number of preschool children in household
- Number of adults in household not staying home
- Number of children in household not staying home
- Shopping HOV Accessibility from household MGRA to employment (accessibility terms #10, 11, 12 (by auto sufficiency), see section SM 1.2 above)
- Maintenance HOV Accessibility from household MGRA to employment (accessibility terms #13, 14, 15 (by auto sufficiency), see section SM 1.2 above)
- Discretionary HOV Accessibility from household MGRA to employment (accessibility terms #22, 23, 24 (by auto sufficiency), see section SM 1.2 above)
- Presence and size of overlapping time-windows, which represent the availability of household members to travel together after mandatory tours have been generated and scheduled

SM 4.3.2 Joint Tour Participation

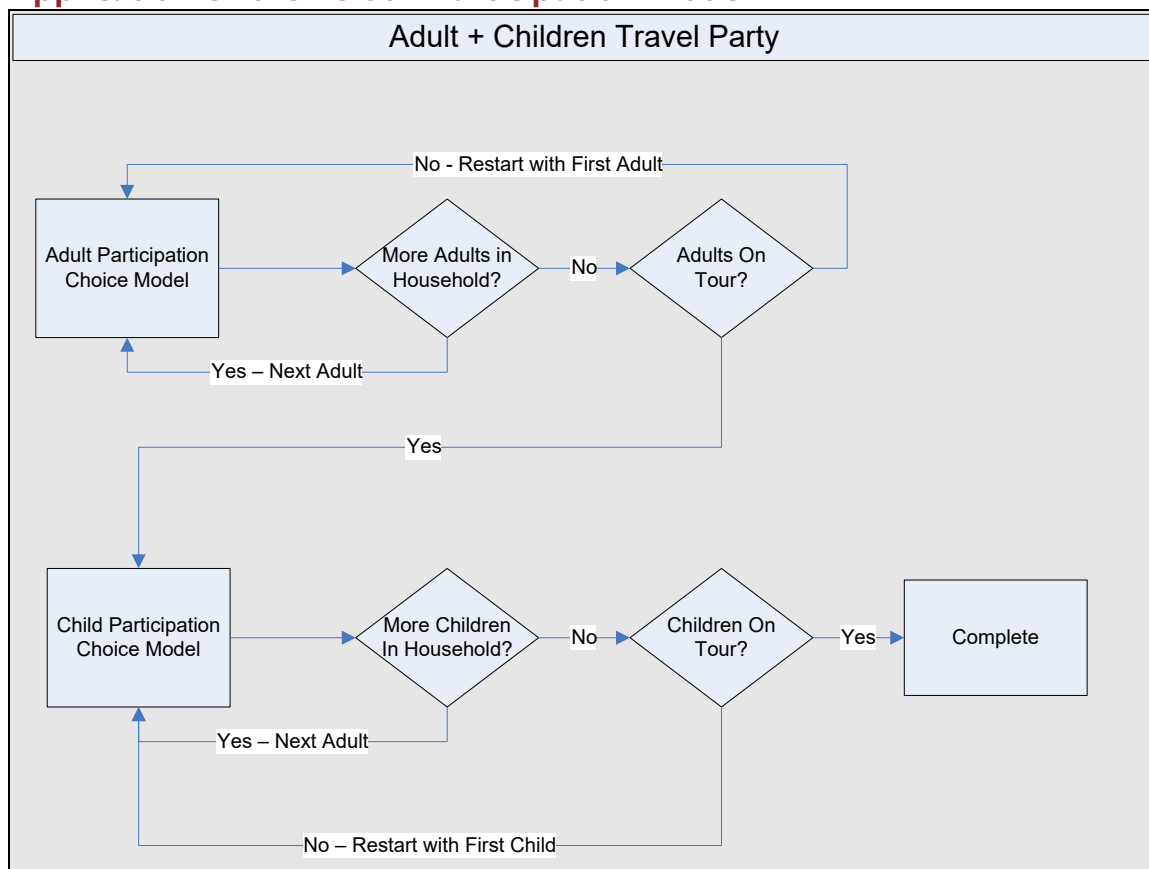
Number of Models: 1
 Decision-Making Unit: Persons
 Model Form: Multinomial Logit
 Alternatives: 2 (Yes or No)

Joint tour participation is modeled for each person and each joint tour. If the person does not correspond to the composition of the tour determined in the joint tour composition model, they are ineligible to participate in the tour. Similarly, persons whose daily activity pattern type is home are excluded from participating. The model relies on heuristic process to assure that the appropriate persons participate in the tour as per the composition model. The model follows the logic depicted in Figure T.10.

The explanatory variables in the participation model include:

- Auto sufficiency
- Household income
- Frequency of joint tours in the household
- Number of adults (not including decision-maker) in household
- Number of children (not including decision-maker) in household
- Person type
- Maximum pair-wise overlaps between the decision-maker and other household members of the same person type (adults or children)

Figure T.10
Application of the Person Participation Model



SM 4.3.3 Joint Tour Primary Destination Choice

Number of Models: 1
Decision-Making Unit: Tour
Model Form: Multinomial Logit
Alternatives: MGRAs

The joint tour primary destination choice model determines the location of the tour primary destination. The destination is chosen for the tour and assigned to all tour participants. The model works at an MGRA level, and sampling of destination alternatives is implemented in order to reduce computation time.

The explanatory variables for the joint tour primary destination choice model include:

- Household income
- Gender
- Age
- Maximum pair-wise overlaps between the decision-maker and other household members of the same person type (adults or children)
- Number of tours left over (including the current tour) to be scheduled
- Off-peak MGRA to MGRA distance
- The tour mode choice logsum for the person from the residence MGRA to each sampled MGRA location
- Non-mandatory HOV accessibility from household MGRA to employment (accessibility terms #7, 8, 9 (by auto sufficiency), see section SM 1.2 above)
- The size of each sampled MGRA by tour purpose (see section SM 1.2 above)

SM 4.3.4 Joint Tour Time of Day Choice

Number of Models: 1
Decision-Making Unit: Persons
Model Form: Multinomial Logit
Alternatives: 861 (combinations of tour departure half-hour and arrival half-hour back at home)

After joint tours have been generated and assigned a primary location, the tour departure time from home and arrival time back at home is chosen simultaneously. The model is fully described under sub-model 4.2.2, above. However, a unique condition applies when applying the time-of-day choice model to joint tours. That is, the tour departure and arrival period combinations are restricted to only those available for each participant on the tour, after scheduling mandatory activities. Once the tour departure/arrival time combination is chosen, it is applied to all participants on the tour.

The model includes the following explanatory variables:

- Household income
- Person type
- Gender
- Age
- Mandatory tour frequency
- Auto travel distance
- Destination employment density

- Tour Departure time
- Tour Arrival time
- Tour duration
- The tour mode choice logsum by tour purpose from the residence MGRA to each sampled MGRA location

SM 4.3.5 Joint Tour Mode Choice Model

Number of Models: 2 (Maintenance, Discretionary)

Decision-Making Unit: Person

Model Form: Nested Logit

Alternatives: 23 (See Figure T.7 under the Individual Mandatory Tour Mode Choice Section)

Like the individual mandatory tour mode choice model, the joint tour model determines how the “main tour mode” (used to get from the origin to the primary destination and back) is determined.

The joint tour mode choices are (drive alone, and school bus is eliminated for this model):

- Shared-Ride 2 Non-Toll (General Purpose Lane)
- Shared-Ride 2 Toll Eligible
- Shared-Ride 3+ Non-Toll (General Purpose Lane)
- Shared-Ride 3+Toll Eligible
- Walk
- Bike
- Walk to Transit
- PNR to Transit
- KNR to Transit

The joint tour mode choice model contains the following explanatory variables:

- Auto sufficiency
- Household size
- Age
- Gender
- In-vehicle time (auto and transit)
- Walk and bike time
- Auto operating cost
- Auto parking cost
- Auto terminal time
- Auto toll value
- Transit first wait time
- Transit transfer time
- Number of transit transfers
- Transit walk access time
- Transit walk egress time

- Transit walk auxiliary time
- Transit fare
- Transit drive access time
- Transit drive access cost
- Intersection density
- Employment density
- Dwelling unit density

SM 4.4.1 Individual Non-Mandatory Tour Frequency

Number of Models: 1

Decision-Making Unit: Households (at least one household member must have a DAP type of M or N)

Model Form: Multinomial Logit

Alternatives: Approximately 197 alternatives, composed of 0-1+ or 2+ tours of each type of maintenance activity (Escort, Shop, Other Maintenance, Eat Out, Visit, and Other Discretionary)

Allocated tours cover non-mandatory activities taken on by an individual on behalf of the household and include escort, shopping, other maintenance, eat out, visit, and other discretionary tours. They are generated by the household and later assigned to an individual in the household based on their residual time window. The choices include the number (0-2) and type of tours generated by each of the non-mandatory tour purposes. The explanatory variables include:

- Auto sufficiency
- Household income
- Dwelling type
- Number of full-time workers in household
- Number of part time workers in household
- Number of university students in household
- Number of non-workers in household
- Number of retirees in household
- Number of driving age school children in household
- Number pre-driving age school children in household
- Number of preschool children in household
- Number of adults in household not staying home
- Number of children in household not staying home
- Gender
- Age
- Education level
- Indicator variable for whether person works at home regularly
- Number of individual/joint tours per person by tour purpose
- Population density at the origin
- Work Accessibility from household MGRA to employment (accessibility terms #45, see section SM 1.2 above)

- School Accessibility from household MGRA to employment (accessibility terms #45, see section SM 1.2 above)
- Escorting HOV Accessibility from household MGRA to employment (accessibility terms #25, 26, 27 (by auto sufficiency), see section SM 1.2 above)
- Shopping SOV/HOV Accessibility from household MGRA to employment (accessibility terms #10, 11, 12, 28, 29, 30 (by auto sufficiency), see section SM 1.2 above)
- Maintenance SOV/HOV Accessibility from household MGRA to employment (accessibility terms #13, 14, 15, 31, 32, 33 (by auto sufficiency), see section SM 1.2 above)
- Eating Out SOV/HOV Accessibility from household MGRA to employment (accessibility terms #16, 17, 18, 34, 35, 36 (by auto sufficiency), see section SM 1.2 above)
- Walk Accessibility from household MGRA to non-mandatory activities (accessibility terms #3, see section SM 1.2 above)

SM 4.4.2 Individual Non-Mandatory Tour Primary Destination Choice

Number of Models: 6 (Escort, Shop, Other Maintenance, Eat Out, Visit, and Other Discretionary)
 Decision-Making Unit: Person
 Model Form: Multinomial Logit
 Alternatives: MGRAs

The six non-mandatory tour purposes are: (1) escorting, (2) shopping, (3) other maintenance, (4) eating out, (5) visiting, and (6) other discretionary. The non-mandatory tour primary destination choice model determines the location of the tour primary destination for each of the six non-mandatory tour purposes. The model works at an MGRA level, and sampling of destination alternatives is implemented in order to reduce computation time. Note that the mode choice logsum used is based on a 'representative' time period for individual non-mandatory tours, which is currently off-peak, since the actual time period is not chosen until sub-model 4.4.3.

The explanatory variables in non-mandatory tour location choice models include:

- Household income
- Age of the traveler
- Gender
- Distance
- The tour mode choice logsum for the traveler from the residence MGRA to each sampled destination MGRA using off-peak level-of-service
- Time Pressure calculated as the log of the maximum time divided by number of tours left to be scheduled
- The size of each sampled MGRA

SM 4.4.3 Individual Non-Mandatory Tour Time of Day Choice

Number of Models: 6 (Escort, Shop, Other Maintenance, Eat Out, Visit, and Other Discretionary)
 Decision-Making Unit: Person
 Model Form: Multinomial Logit
 Alternatives: 861 (combinations of tour departure half-hour and arrival half-hour back at home)

After individual non-mandatory tours have been generated, allocated, and assigned a primary location, the tour departure time from home and arrival time back at home is chosen simultaneously. The tour departure and arrival period combinations are restricted to only those available for each participant on the tour, after scheduling individual mandatory tours and joint tours.

The model includes the following explanatory variables:

- Household Income
- Person type
- Gender
- Age
- Mandatory tour frequency
- Joint tour indicator
- Auto travel distance
- Tour Departure time
- Tour Arrival time
- Tour duration
- Time Pressure calculated as the log of the maximum time divided by number of tours left to be scheduled
- The tour mode choice logsum by tour purpose from the residence MGRA to each sampled MGRA location

SM 4.4.4 Individual Non-Mandatory Tour Mode Choice Model

Number of Models: 2 (Maintenance, Discretionary)

Decision-Making Unit: Person

Model Form: Nested Logit

Alternatives: 25 (See Figure T.7 under the Individual Mandatory Tour Mode Choice Section)

Like the individual mandatory tour mode choice model, the individual non-mandatory tour model determines how the “main tour mode” (used to get from the origin to the primary destination and back) is determined.

The individual non-mandatory tour mode choices are (school bus is eliminated):

- Drive-alone Non-Toll
- Drive-Alone Toll Eligible
- Shared-Ride 2 Non-Toll (General Purpose Lane)
- Shared-Ride 2 Toll Eligible
- Shared-Ride 3+ Non-Toll (General Purpose Lane)
- Shared-Ride 3+ Toll Eligible
- Walk
- Bike
- Walk to Transit
- PNR to Transit
- KNR to Transit

The individual non-mandatory tour mode choice model contains the following explanatory variables:

- Auto sufficiency
- Household size
- Age
- Gender
- In-vehicle time (auto and transit)
- Walk and bike time
- Auto operating cost
- Auto parking cost
- Auto terminal time
- Auto toll value
- Transit first wait time
- Transit transfer time
- Number of transit transfers
- Transit walk access time
- Transit walk egress time
- Transit walk auxiliary time
- Transit fare
- Transit drive access time
- Transit drive access cost
- Intersection density
- Employment density
- Dwelling unit density

SM 4.5.1 At-Work Sub-Tour Frequency

Number of Models: 1

Decision-Making Unit: Persons

Model Form: Multinomial Logit

Alternatives: 6 (None, 1 eating out tour, 1 work tour, 1 other tour, 2 work tours, 2 other tours, and a combination of eating out, work, and other tours)

At-work based sub-tours are modeled last and are relevant only for those persons who implement at least one work tour. These underlying activities are mostly individual (e.g., business-related and dining-out purposes), but may include some household maintenance functions as well as person and household maintenance tasks. There are seven alternatives in the model, corresponding to the most frequently observed patterns of at-work sub-tours. The alternatives define both the number of at-work sub-tours and their purpose.

The at-work sub tour frequency model includes the following explanatory variables:

- Household income
- Number of driving age adults
- Number of preschool children
- Person type
- Gender
- Number of individual and joint mandatory and non-mandatory tours generated in the day
- Employment density at the work place
- Mixed use category at the work place
- Non-motorized eating out accessibility from work MGRA to destination MGRA (accessibility terms #46, see section SM 1.2 above)

SM 4.5.2 At-Work Sub-Tour Primary Destination Choice

Number of Models: 1
Decision-Making Unit: Person
Model Form: Multinomial Logit
Alternatives: MGRAs

The at-work sub-tour primary destination choice model determines the location of the tour primary destination. The model works at an MGRA level, and sampling of destination alternatives is implemented in order to reduce computation time. Note that the mode choice logsum used is based on a 'representative' time period for individual non-mandatory tours, which is currently off-peak, since the actual time period is not chosen until model SM 4.5.3. The model is constrained such that only destinations within a reasonable time horizon from the workplace are chosen, such that the tour can be completed within the total available time window for the sub-tour.

The explanatory variables in the at-work sub tour choice models include:

- Person type
- Distance
- The tour mode choice logsum for the traveler from the residence MGRA to each sampled destination MGRA using off-peak level-of-service
- The size of each sampled MGRA

SM 4.5.3 At-Work Sub-Tour Time of Day Choice

Number of Models: 1
Decision-Making Unit: Person
Model Form: Multinomial Logit
Alternatives: 861 (combinations of tour departure half-hour and arrival half-hour back at home, with aggregation of time between 1 AM and 5 AM)

After at-work sub-tours have been generated and assigned a primary location, the tour departure time from workplace and arrival time back at the workplace is chosen simultaneously. The model is fully described under SM 4.5.2, above. The tour departure and arrival period combinations are restricted to only those available based on the time window of the parent work tour.

The model includes the following explanatory variables:

- Household Income
- Sub-tour purpose
- Auto travel distance
- Tour Departure time
- Tour Arrival time
- Tour duration
- Maximum Available Continuous Time Window (in hours) between 5 a.m. to 11 p.m. before this tour is scheduled
- The tour mode choice logsum from the work MGRA to each sampled MGRA location

SM 4.5.4 At-Work Sub-Tour Mode Choice Model

Number of Models: 1

Decision-Making Unit: Person

Model Form: Nested Logit

Alternatives: 25 (See Figure T.7 under the Individual Mandatory Tour Mode Choice Section)

Like the individual mandatory tour mode choice model, the at-work sub-tour model determines the main sub-tour mode used to get from the workplace to the primary destination and back.

The at-work sub-tour mode choices are (school bus is eliminated):

- Drive-alone Non-Toll
- Drive-Alone Toll-Eligible
- Shared-Ride 2 Non-Toll (General Purpose Lane)
- Shared-Ride 2 Toll-Eligible
- Shared-Ride 3+ Non-Toll (General Purpose Lane)
- Shared-Ride 3+ Toll-Eligible
- Walk
- Bike
- Walk-Local Bus
- Walk- Premium Transit
- PNR-Local Bus
- PNR- Premium Transit
- KNR-Local Bus
- KNR- Premium Transit

The at work sub-tour mode choice model contains the following explanatory variables

- Auto sufficiency
- Household size
- Age
- Gender
- In-vehicle time (auto and transit)
- Walk and bike time
- Auto operating cost
- Auto parking cost
- Auto terminal time
- Auto toll value
- Transit first wait time
- Transit transfer time
- Number of transit transfers
- Transit walk access time
- Transit walk egress time
- Transit walk auxiliary time
- Transit fare
- Transit drive access time
- Transit drive access cost
- Intersection density
- Employment density
- Dwelling unit density

SM 5.1 Intermediate Stop Frequency Model

Number of Models: 9 (By purpose plus one model for at-work subtours)

Decision-Making Unit: Person

Model Form: Multinomial Logit

Alternatives: 16, with a maximum of 3 stops per tour direction, 6 total stops on tour

The stop frequency choice model determines the number of intermediate stops on the way to and from the primary destination. The SANDAG model allowed more than one stop in each direction (up to a maximum of three) for a total of eight trips per tour (four on each tour leg). An additional constraint placed on this model was that no stops were allowed on drive-transit tours. This was enforced to ensure that drivers who drive to transit picked up their cars at the end of the tour.

The stop frequency model was based on the following explanatory variables:

- Household income
- Number of full time workers in the household
- Number of part time workers in the household
- Number of non-workers in the household
- Number of children in the household
- Number of individual/joint mandatory and non-mandatory tours made by household
- Person type
- Age
- Tour mode
- Tour distance from anchor location (home) to primary destination
- Maintenance accessibility (#s31, 32, 33)
- Discretionary accessibility (#s40, 41,42)

SM 5.2 Intermediate Stop Purpose Choice Model

Number of Models: 1
Decision-Making Unit: Stop
Model Form: Lookup Table
Alternatives: 9 Stop Purposes (Work, University, School, Escort, Shop, Maintenance, Eating Out, Visiting, or Discretionary)

The stop purpose choice model is a lookup table of probabilities based upon tour purpose, stop direction, departure time, and person type.

SM 5.3 Intermediate Stop Location Choice Model

Number of Models: 1
Decision-Making Unit: Person
Model Form: Multinomial Logit
Alternatives: MGRA

The stop location choice model predicts the location (the Master Geographic Reference Area, or MGRA) of each intermediate stop (each location other than the origin and primary destination) on the tour. In this model, a maximum of three stops in outbound and three stops in inbound direction are modeled for each tour. Since there are a large number (over 23,000) of alternative destinations it is not possible to include all alternatives in the estimation dataset. A sampling-by-importance approach was used to choose a set of alternatives. Each record was duplicated 20 times, then different choice sets with 30 alternatives each were selected based on the size term and distance of the alternative destination. This approach is statistically equivalent to selecting 600 alternatives for the choice set. It is not straightforward to segment the model by purpose because size (or attraction) variables are related to purpose of the stop activity while impedance variables are strongly related to the tour characteristics – primary tour purpose, primary mode used for the tour, etc. Therefore, a single model is estimated with size variables based on stop purpose and utility variables based on both stop and tour characteristics.

The stop location choice model includes the following explanatory variables:

- Household Income
- Gender
- Age
- Mode choice logsum
- Distance deviation or “out-of-the-way” distance for stop location when compared to the half-tour distance without detour for any stop
- Distance of stop location from tour origin and destination is used to define closeness to tour origin or destination.
- Stop purpose
- Tour purpose
- Tour mode
- Stop Number
- Direction of the half-tour

Size variables:

- Employment by categories
- Number of households
- School enrollments – pre-school, K to 6th grade, and 7th to 12th grade, based on type of school child in the household
- University and other college enrollments

SM 5.4 Intermediate Stop Departure Model

Number of Models:	1
Decision-Making Unit:	Trips other than first trip and last trip on tour
Model Form:	Lookup Table
Alternatives:	40 (stop departure half-hour time periods, with aggregation between 1 AM and 5 AM)

The stop departure model is a lookup table of probabilities based upon tour purpose, stop direction, tour departure time, and stop number.

SM 6.1 Trip Mode Choice Model

Number of Models:	6 (Work, University, K-12, Maintenance, Discretionary, and At-work subtours)
Decision-Making Unit:	Person
Model Form:	Multinomial Logit
Alternatives:	26 (See Figure T.7)

The trip mode choice model determines the mode for each trip along the tour. Trip modes are constrained by the main tour mode. The linkage between tour and trip levels is implemented through correspondence rules (which trip modes are allowed for which tour modes). The model can incorporate asymmetric mode combinations, but in reality, there is a great deal of symmetry between outbound and inbound modes used for the same tour. Symmetry is enforced for drive-transit tours, by excluding intermediate stops from drive-transit tours.

The tour and trip mode correspondence rules are shown in Table T.10. Note that in the trip mode choice model, the trip modes are the same as the modes in the tour mode choice model. However, every trip mode is not necessarily available for every tour mode. The correspondence rules depend on a hierarchy with the following rules:

- The highest occupancy across all trips is used to code the occupancy of the tour.
- There is no mode switching on walk and bike tour modes.
- Shared-ride trips are allowed on walk-transit tours.
- Drive-alone is disallowed for walk-transit and KNR-transit tours, since driving on a trip leg in combination with walk-transit would imply PNR-transit as a tour mode.
- Walk trips are allowed on all tour modes except for driving alone and biking, since these modes imply that the traveler is attached to the mode of transport (the auto or bike) for the entire tour.
- Note that cases in which a traveler parks at a lot and then walks to their destination are treated as a single trip in the context of trip mode choice. A subsequent parking location choice model breaks out these trips into the auto leg and the walk leg, for trips to parking-constrained locations.
- An additional restriction on availability is imposed on work-based sub-tours, where drive-alone is disallowed if the mode to work is not one of the three auto modes (drive-alone, shared 2, or shared 3+).

The school bus tour mode, which is only available for the School tour purpose, implies symmetry – all trips on school bus tours must be made by school bus.

The trip mode choice model’s explanatory variables include:

- | | |
|---------------------------------------|-------------------------------|
| • Household Size | • Auto toll value |
| • Auto sufficiency | • Transit first wait time |
| • Age | • Transit transfer time |
| • Gender | • Number of transit transfers |
| • Tour mode | • Transit walk access time |
| • Individual or joint tour indicator | • Transit walk egress time |
| • Number of outbound and return stops | • Transit walk auxiliary time |
| • First and last stop indicators | • Transit fare |
| • In-vehicle time (auto and transit) | • Transit drive access time |
| • Walk and bike time | • Transit drive access cost |
| • Auto operating cost | • Intersection density |
| • Auto parking cost | • Employment density |
| • Auto terminal time | • Dwelling unit density |

Table T.10
Tour and Trip Mode Correspondence Rules

Trip Mode	Tour Mode							
	Drive-Alone	Shared 2	Shared 3+	Walk	Bike	Walk-Transit	PNR-Transit	KNR-Transit
Drive-alone Non-Toll	A	A	A				A	
Drive-Alone Toll Eligible	A	A	A				A	
Shared-Ride 2 Non-Toll (GP Lane)		A	A			A	A	A
Shared-Ride 2 Toll Eligible		A	A			A	A	A
Shared-Ride 3+ Non-Toll (GP Lane)			A			A	A	A
Shared-Ride 3+ Toll Eligible			A			A	A	A
Walk		A	A	A		A	A	A
Bike					A			
Walk-Local Bus						A	A	A
Walk-Premium						A	A	A
PNR-Local Bus							A	
PNR- Premium							A	
KNR-Local Bus								A
KNR- Premium								A

School Bus

Available for school bus tour mode only, on school tours.

A = Trip mode is available by that particular tour mode.

SM 6.2 Parking Location Choice

Number of Models:	2 (Work, and other)
Decision-Making Unit:	Trips with non-home destinations in areas with paid parking
Model Form:	Multinomial Logit
Alternatives:	<i>In estimation</i> , lots sampled in the parking behavior survey <i>In application</i> , MGRAs within 3/4 mile of the destination MGRA

The parking location choice model determines where vehicles are parked at the terminal end of each trip with a destination in *park area 1* (downtown San Diego area). For work trips, the model subtracts the output from the employer parking reimbursement model from the daily price of parking at each alternative destination to determine the effective price borne by the individual. The output of the model is used to obtain traffic assignments that are more accurate at small scales in the downtown area during the morning and afternoon peaks. The coefficients from the parking location choice model estimation are also used in defining the logsum-weighted average parking cost used in mode choice.

The parking location model explanatory variables include:

- Number of stalls available to the driver (size variable)
- Parking cost
- Walk distance to destination

4.8 Resident Travel Model Outputs

The outputs of resident travel model are

- household auto ownership
- household member work or school locations at MGRA level
- employer paid parking
- individual tour and trip list
- joint tour and trip list at MGRA level
- auto trips by TAZ origin to TAZ destination by 5 TOD by three VOT bins

The auto trip tables are combined with special market model output and used in traffic assignment.

5.0 Special Market Models

5.1 Cross border model

The model measures the impact of Mexican resident travel on the San Diego transport network. The model accounts for Mexican resident demand (such as auto volume, transit boarding, and toll usage) for transportation infrastructure in San Diego County. It also forecasts border crossings at each current and potential future border crossing station. The model is based on the 2010 SANDAG Cross Border Survey, Mexican resident border crossings into the United States and their travel patterns within the United States. Data was collected at the three border crossing stations – San Ysidro, Otay Mesa, and Tecate.

The model flow and inputs are shown in Figure T.11.

5.1.1 Cross Border Tour Purposes

There are six tour purposes for the Mexican resident model. They were coded based on the activity purposes engaged in by the traveler in the United States, according to a hierarchy of activity purposes as follows:

- **Work:** At least one trip on the tour is for working in the United States.
- **School:** At least one trip on the tour is made for attending school in the United States, and no work trips were made on the tour.
- **Cargo:** At least one trip on the tour was made for picking up or dropping off cargo in the United States, and no work or school trips were made on the tour.
- **Shop:** No trips on the tour were made for work, school, or cargo, and the activity with the longest duration on the tour was shopping in the United States.
- **Visit:** No trips on the tour were made for work, school, or cargo, and the activity with the longest duration on the tour was visiting friends/relatives in the United States.
- **Other:** No trips on the tour were made for work, school, or cargo, and the activity with the longest duration on the tour was other (collapsed escort, eat, personal, medical, recreation, sport, and other activity purposes).

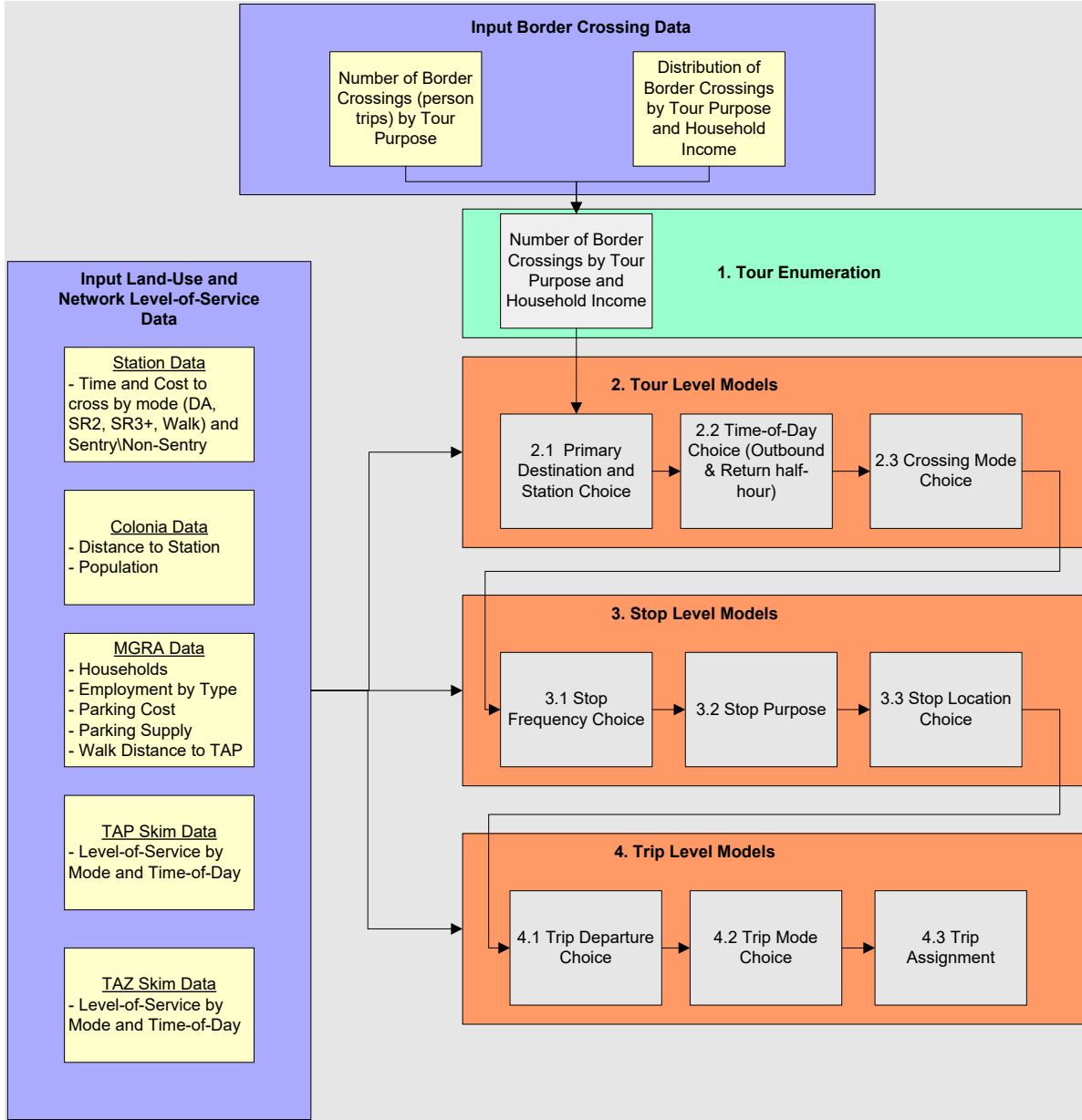
5.1.2 Tour Mode

The tour mode is the mode used to cross the border, which conditions the mode used for all trips on the tour, including the trip from the border crossing to the first destination in the United States. The tour modes are defined by whether the border was crossed via auto or by foot, the occupancy if by auto, and whether the SENTRI lane was used or not. SENTRI lanes offer expedited border crossings to pre-qualified citizens of the United States and Mexico. One must apply for a SENTRI pass, which requires extensive background checks. Mexican residents must have a valid United States Visa, Mexican passport, and contact number in the United States. This typically means that in order to obtain a pass, Mexican residents must be lawfully employed in the United States.

5.1.3 Trip Mode

The trip modes used in the Mexican resident travel model are the same modes available in the resident travel model. Note that toll and HOV usage was not asked as part of the survey. Usage of these facilities in the model is based upon the characteristics of the trips/vehicle occupancies and income (value-of-time) of travelers and validated along with resident demand models.

Figure T.11
Mexican Resident Cross Border Travel Model



5.1.4 Treatment of Space

Every trip ending in San Diego County is allocated to an MGRA. Within Tijuana, each border crossing origin is assigned to a *colonia*, or neighborhood with which survey respondents identify. Population estimates are collected by the Instituto Nacional de Estadística y Geografía (INEGI) at the level of a basic geostatistical area (Area Geostadística Básica, or AGEB, roughly equivalent to U.S. Census Tracts). AGEBs and *colonia* largely overlap within Tijuana city boundaries (though there is no coherent spatial nesting scheme), and AGEB population estimates were redistributed to *colonia* based on a proportional area operation to operationalize *colonia* trip origins in the model. Outside of Tijuana, the origins are distributed to a *localidad*, or locality. These units are similar to the Census Designated Place in the United States.

5.2 San Diego airport ground access model

The model captures the demand of airport travel on transport facilities in San Diego County, a model of travel to and from the airport for arriving and departing passengers. It allows SANDAG to test the impacts of various parking price and supply scenarios at the airport. The model is based on the 2008 San Diego International Airport (SDIA) survey of airport passengers in which data was collected on their travel to the airport prior to their departure.

The San Diego airport ground access model has the following features:

- A disaggregate micro-simulation treatment of air passengers, with explicit representation of duration of stay or trip in order to accurately represent costs associated with various parking and modal options.
- The full set of modes within San Diego County, including auto trips by occupancy, transit trips by line-haul mode (bus versus trolley), and toll/HOT/HOV lanes modes.
- Forecasts of airport ground access travel based upon the official SDIA enplanement projections.

The model flow and inputs are shown in Figure T.12 and described in detail in the following sections.

5.2.1 SDIA Airport Model Trip Purposes

Four trip purposes were coded based on the resident status of air passengers and the purpose of air travel, as follows:

- **Resident Business:** Business travel made by San Diego County residents (or residents of neighboring counties who depart from SDIA).
- **Resident Personal:** Personal travel made by San Diego County residents (or residents of neighboring counties who depart from SDIA).
- **Visitor Business:** Business travel made by visitors to San Diego County (or a neighboring county).
- **Visitor Personal:** Personal travel made by visitors to San Diego County (or a neighboring county).

5.2.2 SDIA Airport Model Trip Mode

The model of airport ground access is trip-based, since the survey did not collect the full tour from origin to airport. In addition, the survey only collected information on the trip to the airport before the passenger boarded their plane; information was not collected on the trip in which passengers arrived at the airport and traveled to a destination in San Diego County. Therefore, symmetry is assumed for the non-reported trip. Finally, the survey did not collect data on whether an HOV lane or toll lane was used for the trip, so path-level mode cannot be determined. If private auto is used to access the airport, the choice of parking versus curbside pickup/drop off is explicitly represented. For travelers that park, the chosen lot (terminal, airport remote lot, private remote lot) is explicit as well. Note that auto occupancy is not a choice for airport ground access trips. Auto occupancy is based upon travel party size, which is simulated as part of the attribution of ground access trips.

5.2.3 SDIA Airport Model Inputs

The model system requires the following exogenously-specified inputs (note that three additional data sets are required in addition to the data currently input to the resident activity-based models):

- **SDIA Enplanement Forecast:** The total number of yearly enplanements, without counting transferring passengers, at SDIA, and an annualization factor to convert the yearly enplanements to a daily estimate. This is input for each simulation year. The data is available in the Aviation Activity Forecast Report.³
- **Traveler characteristics distributions:** There are a number of distributions of traveler characteristics that are assumed to be fixed but can be changed by the analyst to determine their effect on the results. These include the following:
 - The distribution of travelers by purpose
 - The distribution of travelers by purpose and household income.
 - The distribution of travelers by purpose and travel party size.
 - The distribution of travelers by purpose and trip duration (number of nights).
 - The distribution of travelers by purpose, direction (arriving versus departing), and time period departing for airport.
- **MGRA data.** The population and employment (by type) in each MGRA, parking cost and supply, etc. This data provides sensitivity to land-use forecasts in San Diego County. These are the same data sets as are used in the resident activity-based model.
- **TAP skim data.** Transit network level-of-service between each transit access point (transit stop). This provides sensitivity to transit network supply and cost. These are the same data sets as are used in the resident activity-based model.
- **TAZ skim data.** Auto network level-of-services between each transportation analysis zone. This provides sensitivity to auto network supply and cost. These are the same data sets as are used in the resident activity-based model.

5.2.4 SDIA Airport Model Description

This section describes the model system briefly, followed by a more in-depth discussion of each model component.

1. Trip Enumeration and attribution: A total number of airport trips is created by dividing the input total enplanements (minus transferring passengers) by an annualization factor. The result is divided by an average travel party size to convert passengers to travel parties. This is converted into a list format that then is exposed to the set of traveler characteristic distributions, as identified above, to attribute each travel party with the following characteristics:

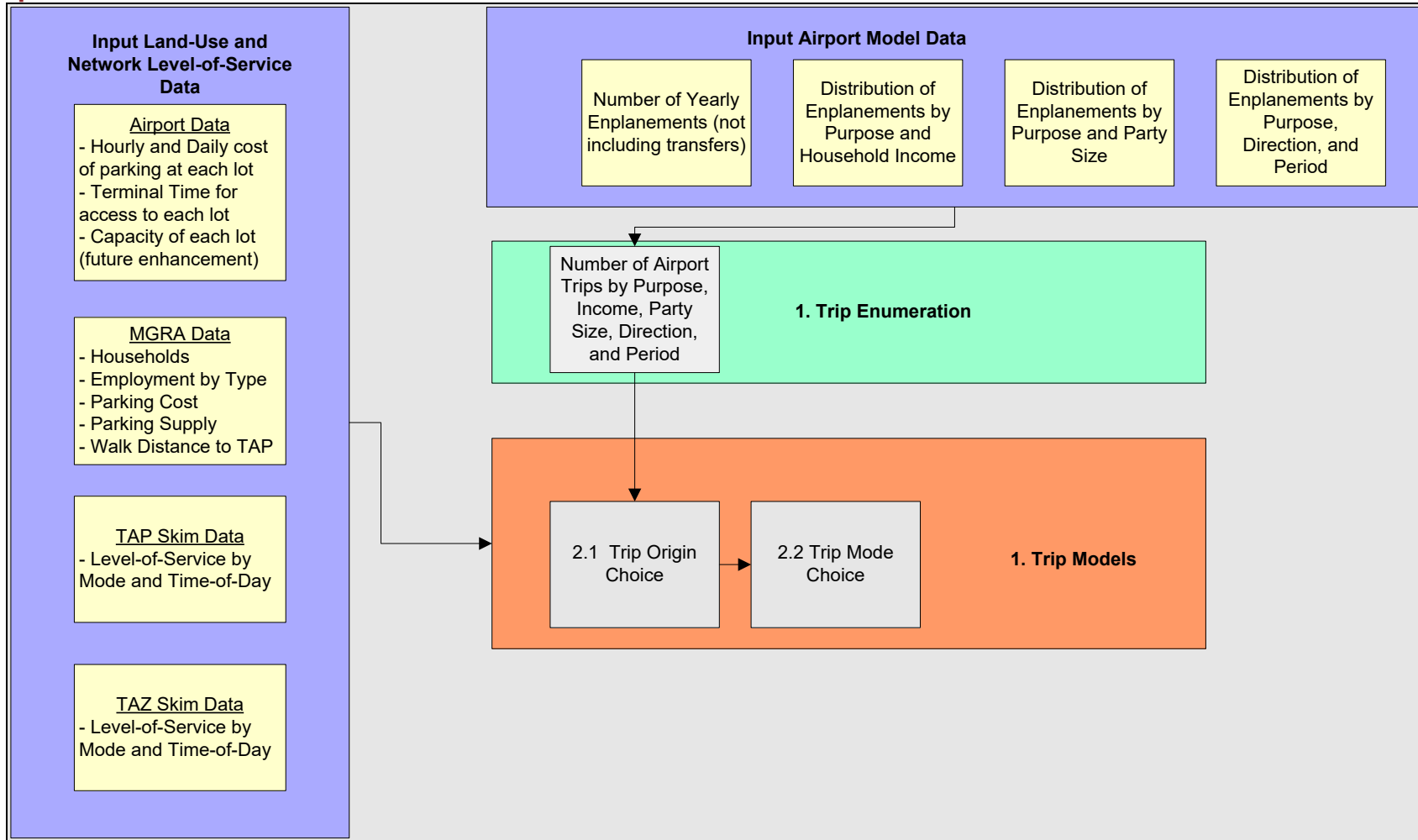
- Travel purpose
- Party size
- Duration of trip
- Household income
- Trip direction (it is assumed that 50 percent of the daily enplanements are arriving passengers and 50 percent are departing passengers)
- Departure time for airport

2. Trip Models

- 2.1 Trip origin: Each travel party is assigned an origin MGRA.
- 2.2 Trip mode: Each travel party is assigned a trip mode.

Figure T.12

SAN Airport Ground Access Travel Model



5.3 Cross-border Xpress (CBX) airport model

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.

The model segments travelers according to travel purpose, which is a combination of residence status (resident/visitor), the reported purpose of travel (business/personal) and whether the traveler's origin before departing the airport was in San Diego County or not (internal/external).

5.4 Visitor model

The visitor model captures the demand of visitor travel on transport facilities in San Diego County. The model is estimated based on the 2011 SANDAG Visitor Survey of airport passengers and hotel guests in which data was collected on their travel while visiting San Diego.

The visitor model has the following features:

- A disaggregate micro-simulation treatment of visitors by person type, with explicit representation of party attributes
- Special consideration of unique visitor travel patterns, including rental car usage and visits to San Diego attractions like Sea World
- The full set of modes within San Diego County, including auto trips by occupancy, transit trips, non-motorized trips, and toll/HOT/HOV lanes modes

The model flow and inputs are shown in Figure T.13 and described in detail in the following sections.

5.4.1 Visitor Model Inputs

The model system requires the following exogenously-specified inputs (note that three additional data sets are required in addition to the data currently input to the resident activity-based models):

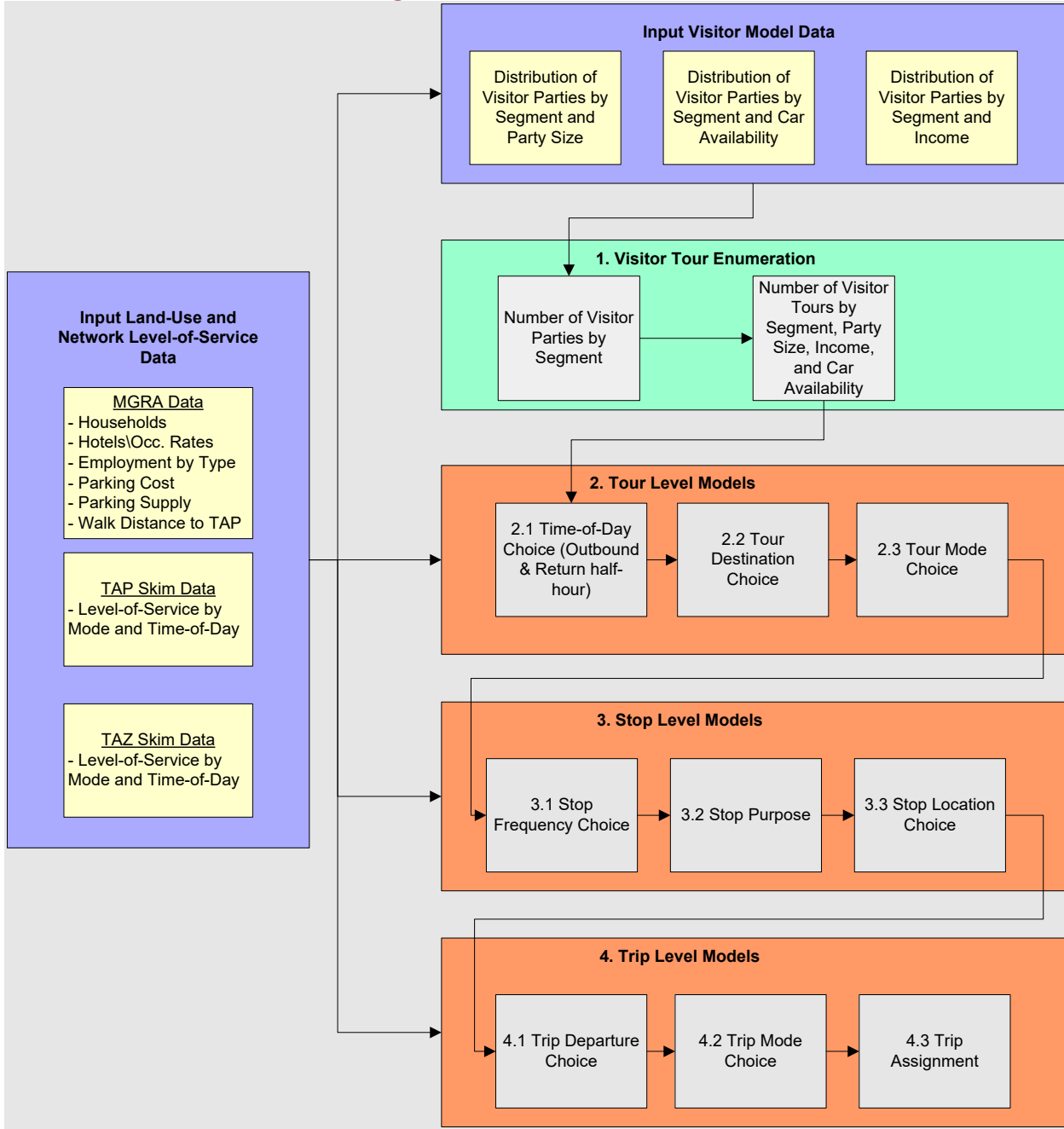
- **Traveler characteristics distributions.** There are a number of distributions of traveler characteristics that are assumed to be fixed but can be changed by the analyst to determine their effect on the results. These include the following:
 - Rates of visitor occupancy for hotels and separately for households
 - Shares of visitor parties by visitor segment for hotels and separately for households
 - The distribution of visitor parties by household income
 - The distribution of business segment travel parties by number of tours by purpose
 - The distribution of personal segment travel parties by number of tours by purpose
 - The distribution of visitor tours by tour purpose and party size
 - The distribution of visitor tours by tour purpose and auto availability

- The distribution of visitor tours by outbound and return time-of-day and tour purpose
- The distribution of visitor tours by frequency of stops per tour by tour purpose, duration, and direction
- The distribution of stops by stop purpose and tour purpose
- The distribution of stops on outbound tour legs by half-hour offset period from tour departure period and time remaining on tour
- The distribution of stops on inbound tour legs by half-hour offset period from tour arrival period and time remaining on tour
- **MGRA data.** The population, employment (by type), and number of hotel rooms in each MGRA, parking cost and supply, etc. This data provides sensitivity to land-use forecasts in San Diego County. These are the same data sets as are used in the resident activity-based model.
- **TAP skim data.** Transit network level-of-service between each transit access point (transit stop). This provides sensitivity to transit network supply and cost. These are the same data sets as are used in the resident activity-based model.
- **TAZ skim data.** Auto network level-of-services between each transportation analysis zone. This provides sensitivity to auto network supply and cost. These are the same data sets as are used in the resident activity-based model.

5.4.2 Visitor Model Description

This section describes the model system briefly.

Figure T.13
SANDAG Visitor Model Design



1. Visitor Tour Enumeration: Visitor travel parties are created by visitor segment based upon input hotels and households. Travel parties are attributed with household income. Tours by purpose are generated for each party. Each tour is attributed with auto availability and party size. The tour origin MGRA is set to the MGRA where the tour was generated.

2. Tour Level Models

2.1. Tour Time of Day: Each tour is assigned a time of day, based on probability distribution.

2.2. Tour Destination choice: Each tour is assigned a primary destination, based on the coefficients estimated through a multinomial logit model.

2.3. Tour Mode Choice: Each tour selects a preferred primary tour mode, based on an asserted nested logit model (the resident tour mode choice model).

3. Stop Models

3.1. Stop Frequency Choice: Each tour is attributed with a number of stops in the outbound direction and in the inbound direction, based upon sampling from a distribution.

3.2. Stop Purpose: Each stop is attributed with a purpose, based upon sampling from a distribution.

3.3. Stop Location Choice: Each stop is assigned a location based upon a multinomial logit model (asserted based upon resident stop location choice models)

4. Trip Level Models

4.1. Trip Departure Choice: Each trip is assigned a departure time period based upon sampling from distributions.

4.2. Trip Mode Choice: Each trip within the tours selects a preferred trip mode, based on an asserted nested logit model.

4.3. Trip Assignment: Each trip is assigned to the network.

5.5 External models

The external travel models predict characteristics of all vehicle trips and selected transit trips crossing the San Diego County border. This includes both trips that travel thru the region without stopping and trips that are destined for locations within the region. See Figure T. 14 for current crossing locations also known as cordons. Future crossing locations that can also be modeled depending on scenarios include Otay Mesa East, Jacumba, and SR 241.

5.5.1 External Model Trip Type Definition

The external-external, external-internal, and internal-external trips in San Diego County were segmented into the following trip types:

- **US-US:** External-external trips whose production and attraction are both in the United States, but not in San Diego County.
- **US-MX:** External-external trips with one trip end in the United States and the other in Mexico.
- **US-SD:** External-internal trips with a production elsewhere in the United States and an attraction in San Diego County.
- **MX-SD:** External-internal trips with a production in Mexico and an attraction in San Diego County (covered by the Mexican resident cross border model).
- **SD-US:** Internal-external trips with a production in San Diego and an attraction elsewhere in the United States.
- **SD-MX:** Internal-external trips with a production in San Diego County and an attraction in Mexico.

5.5.2 External Model Estimation of Trip Counts by Type

The total count of trips by production and attraction location was estimated in a series of steps:

1. The number of trips made by Mexican residents to attractions in San Diego was previously determined during development of the Mexican resident travel microsimulation model.
2. The trips in the resident travel survey were expanded to estimate the total number of trips made by San Diego residents to attractions in Mexico.
3. The number of MX-SD (1) and SD-MX (2) trips was subtracted from the total number of border-crossings to derive an estimate of the number of US-MX trips. The distribution of US-MX trips among external stations on the US-side of San Diego County is assumed to be proportional to the total volume at each external station, regardless of the point of entry at the Mexican border.
4. The number of US-MX trips was then subtracted from the total number of trips in the SCAG cordon survey to arrive at an estimate of the combined total of US-US, US-SD, and SD-US trips with routes through San Diego County.
5. Finally, the actual amounts of US-US, US-SD, and SD-US trips at each external station were estimated from the remaining trips (4) according to their proportions in the successfully geocoded responses in the SCAG cordon survey.

5.5.3 External Model Design Overview

The behavioral characteristics of the different types of external trip were derived from the various data sources available as follows:

- **US-US trips:** A fixed external station OD trip matrix was estimated from the SCAG cordon survey.
- **US-MX trips:** A fixed external station OD trip matrix was estimated from the SCAG cordon survey, Customs and Border Protection vehicle counts, and Mexican resident border-crossing survey as described in the previous section.
- **US-SD trips:** Rates of vehicle trips per household for each external county were developed from the SCAG cordon survey, and the trips were distributed to locations in San Diego County according to a destination choice model estimated from the interregional survey.
- **MX-SD trips:** A microsimulation model of Mexican resident cross border travel.
- **SD-US trips:** A binary logit model for a person's making a trip as a function of accessibility to external stations and demographic characteristics was developed from the San Diego County resident survey, and the trips were distributed to external stations according to their market shares in the base year, which were estimated as described in the previous section.

SD-MX trips: A binary logit model simulating an individual's decision to make a trip as a function of accessibility to external stations and demographic characteristics was developed from the San Diego County resident survey, and the trips were distributed to external stations according to their market shares in the base year, which were estimated as described in the previous section.

Diurnal and vehicle occupancy factors (Table T.11 and Table T.12) are then applied to the total daily trip tables to distribute the trips among shared ride modes and different times of day.

Table T.11
US-SD Vehicle Occupancy Factors

Vehicle Occupancy	Percent
One	58%
Two	31%
Three or more	11%
Total	100%

Table T.12
US-SD Diurnal Factors

Time Period	Work Percent		Non-Work Percent	
	Production to Attraction	Attraction to Production	Production to Attraction	Attraction to Production
Early AM	26%	8%	25%	12%
AM Peak	26%	7%	39%	11%
Midday	41%	41%	30%	37%
PM Peak	6%	42%	4%	38%
Evening	2%	2%	2%	2%
Total	100%	100%	100%	100%

5.5.5.2 External-Internal Toll Choice Model

Number of Models: 2 (Work, Non-work)
 Decision-Making Unit: Tour
 Model Form: Multinomial logit
 Alternatives: MGRAs

The trips are then split among toll and non-toll paths according to a simplified toll choice model. The toll choice model included the following explanatory variables:

- In-vehicle-time
- Toll cost

5.5.6 Internal-External (IE) Trips

5.5.6.1 IE Trip Generation Model

Number of Models:	2 (Work, Non-work)
Decision-Making Unit:	Person
Model Form:	Binary logit
Alternatives:	2 (Made an IE trip or not)

The internal-external trip generation model covers the SD-US and SD-MX trips.

The IE trip generation model explanatory variables are:

- Household income
- Vehicle ownership
- Age
- Accessibility to external stations

5.5.6.2 IE Destination Choice Model

Number of Models:	1
Decision-Making Unit:	Trip
Model Form:	Multinomial logit
Alternatives:	MGRAs

The IE trips are distributed to external stations with a destination choice model. The explanatory variables of the IE destination choice model are:

- Distance
- Size variable equal to the percent of IE trips using the external zone in the base year

5.5.6.3 IE Mode Choice Model

Number of Models:	1
Decision-Making Unit:	Trip
Model Form:	Multinomial logit
Alternatives:	Trip Modes

After choosing an external station, the IE trip-maker chooses a mode according to an asserted nested logit mode choice model. The explanatory variables in the trip mode choice model are:

- Household income
- Gender
- In-vehicle time (auto and transit)
- Walk time
- Bike time
- Auto operating cost
- Auto Parking cost
- Auto toll value
- Transit first wait time
- Transit transfer time

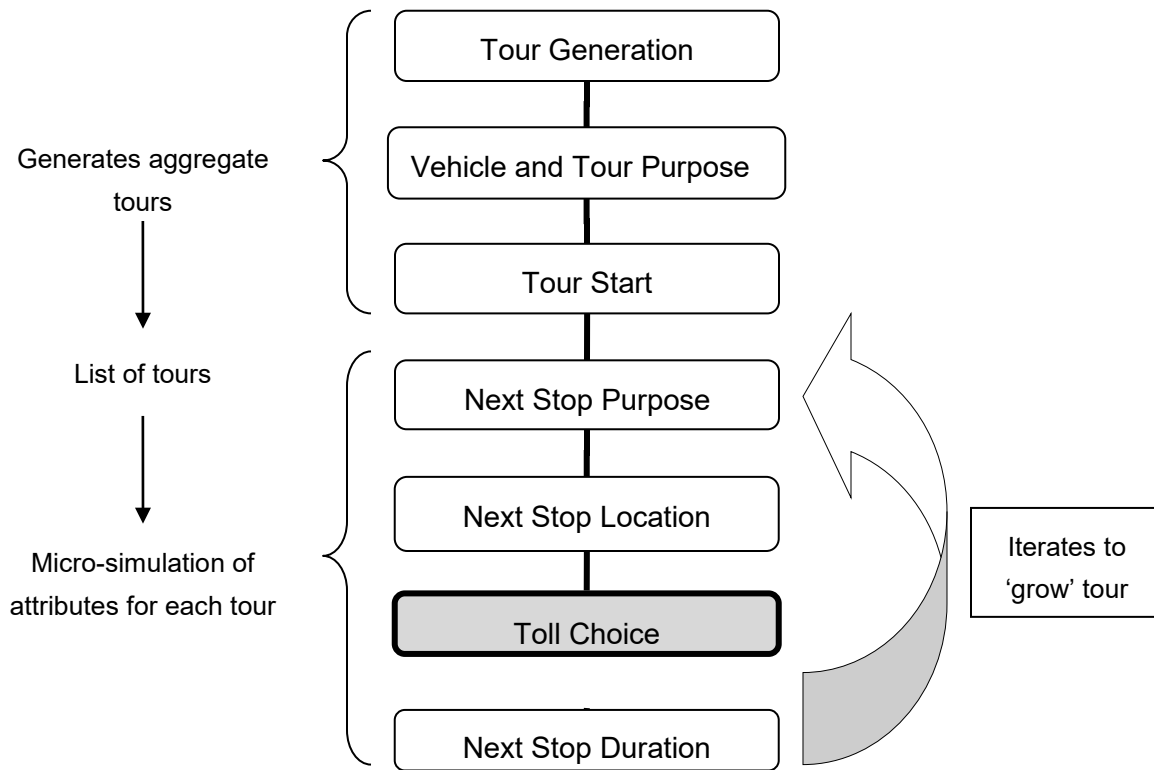
- Number of transit transfers
- Transit walk access time
- Transit walk egress time
- Transit walk auxiliary time
- Transit fare
- Drive access to transit in-vehicle time
- Drive access to transit cost

5.6 Commercial vehicle model

Commercial vehicle model (CVM) is a disaggregated tour-based model developed in 2014 by HBA Spectro Incorporated. This model was based upon a local commercial vehicle survey and replaces the aggregate intraregional Heavy-Duty Truck Model (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 Freight Analysis Framework (FAF) 4 data. The ABM2 runs the CVM with a scale factor of 1 and the generated demand for light trucks in the mid-day period is scaled to 3 times and demand for light truck in the AM and PM peak period is scaled to 2 times to compensate for the lack of commercial vehicle travel in the disaggregate CVM.

CVM was developed based on establishment work-related person and vehicle movement travel data, collected as part of the SANDAG Work-Related Travel Survey conducted between November 2012 – September 2013, together with 2013 GPS SANDAG area commercial vehicle movement data purchased by SANDAG from ATRI (American Transportation Research Institute). The tour-based CVM is a group of models that work in series. A basic schematic of the models is shown in Figure T.15.

Figure T.15
CVM Tour-based Model Structure



Tour generation of quantities by vehicle type, tour purpose, and time of day are generated for each TAZ, using logit and regression equations applied with aggregate TAZ inputs and travel accessibilities, to create a list of tours.

Individual tours generated from each TAZ are then assigned a next stop purpose, next stop location and next stop duration using a micro-simulation process.

In this process, Monte Carlo techniques are used to incrementally ‘grow’ a tour by having a ‘return-to-establishment’ alternative within the next stop purpose allocation. If the next stop purpose is not ‘return-to-establishment’, then the tour extends by one more stop. The location and duration of the next stop are then estimated. For each trip it is also determined whether a toll facility is used as part of the route choice process.

These steps are repeated until the “return to establishment” next stop purpose is chosen.

Seven establishment types are considered, based on aggregations of NAICS categories:

- Industrial (IN) – NAICS 11, 21, 23, 31-33;
- Wholesale (WH) – NAICS 42;
- Service (SE) – NAICS 61, 62, 71, 72, 81;
- Government / Office (GO) – NAICS 51, 52, 53, 54, 55, 56; 92;
- Retail (RE) – NAICS 44-45;
- Transport and Handling (TH) – NAICS 22, 48-49;

Fleet Allocator (FA) – (All but Military) (a specific type of establishment that uses a large, coordinated fleet that tends to service an area rather than specific demands – examples include mail and courier, garbage hauling, newspaper delivery, utilities and public works).

Four commercial vehicle types are used:

- Light vehicle - FHWA classes 1-3;
- Medium Truck < 8.8 short tons (17,640 pounds) – FHWA classes 5-6;
- Medium Truck > 8.8 short tons (17,640 pounds) – FHWA classes 5-6;
- Heavy Truck – FHWA classes 7-13.

Five TAZ level land use types are used in the model:

1. Low Density
2. Residential
3. Commercial
4. Industrial
5. Employment Node

The outputs of the CVM are trips by establishment type by TOD and by vehicle classes. These trips are added to all other trips prior to traffic assignment.

5.7 External heavy truck model

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 model utilizes FAF4 data, which is based on the 2012 Commodity 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 outputs of this step are External-External (EE) trip tables and estimates of Internal-External (IE) and External-Internal volume totals at each external station. In the next step, the MGRA land-use data is used to calculate heavy truck attractions for IE and EI heavy truck trips by MGRA, which are then aggregated to a TAZ level. 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 traffic assignment.

6.0 Trip Assignment

The final steps of the SANDAG ABM2 are to assign the trip demand onto the roadway and transit networks. Assignments are run for the 5 time periods identified in Table T.2.

6.1 Traffic Assignment

The traffic assignment for the ABM2 is a 24-class assignment with generalized cost. Auto vehicle classes are broken out by value of time (VOT) bins for low (\$9/hour), medium (\$18/hour) and high (\$51/hour).

The SANDAG volume-delay function (VDF) is a link-based function that consists of both a mid-block and an intersection component. 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. New volume-delay function coefficients were estimated 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 estimated alpha parameter is 0.24 and the estimated beta parameter 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. For non-freeway links, BPR factors of 4.5 and 2.0 were used, as previously-calibrated by SANDAG staff.

The traffic assignment is run using Second-Order Linear Approximation (SOLA) method in Emme modeling software to a relative gap of 5×10^{-4} . The per-link fixed costs include toll values and operating costs which vary by class of demand. Assignment matrices and resulting network flows are in PCE.

6.2 Transit Assignment

The transit assignment uses a headway-based approach, where the average headway between vehicle arrivals for each transit line is known, but not exact schedules. Passengers and vehicles arrive at stops randomly and passengers choose their travel itineraries considering the expected average waiting time.

The Emme Extended transit assignment is based on the concept of optimal strategy but extended to support a number of behavioral variants. The optimal strategy is a set of rules which define sequence(s) of walking links, boarding and alighting stops which produces the minimum expected travel time (generalized cost) to a destination. At each boarding point the strategy may include multiple possible attractive transit lines with different itineraries. A transit strategy will often be a tree of options, not just a single path. A line is considered attractive if it reduces the total expected travel time by its inclusion. The demand is assigned to the attractive lines in proportion to their relative frequencies.

The shortest "travel time" is a generalized cost formulation, including perception factors (or weights) on the different travel time components, along with fares, and other costs / perception biases such as transfer penalties which vary over the network and transit journey.

The model has three access modes to transit (walk, park-and-ride (PNR), and kiss-and-ride (KNR)) and three transit sets (local bus only, premium transit only, and local bus and premium transit sets), for 9 total demand classes by 5 TOD. These classes are assigned by slices, one at a time, to produce the total transit passenger flows on the network.

While there are 9 slices of demand, there are only three classes of skims: Local bus only, premium only, and all modes. The access mode does not change the assignment parameters or skims.

7.0 Data Sources

The SANDAG ABM2 utilizes a variety of data as inputs. The most important data source is household travel survey data. The latest household travel survey conducted for SANDAG was the 2016~2017 Household Travel Behavior Survey (HTS2016) with smartphone based travel diaries as the primary means of travel data collection. Since 1966, consistent with the state of the practice for the California Household Travel Survey, and National Household Travel Survey, SANDAG and Caltrans conduct a comprehensive travel survey of San Diego county every ten years. HTS2016 surveyed 6,139 households in San Diego County. The survey asked all household with smartphones participated using the smartphone-based GPS travel diary and survey app (rMove) for one week and accommodated participating households without smartphones by allowing them to complete their one-day travel diary online or by calling the study call center.

Additional data needed for the mode choice components of the resident travel model comes from a transit on-board survey. The most recent SANDAG survey of this kind is the 2015 Transit On-Board Survey (OBS2015). OBS2015 collected data on transit trip purpose, origin and destination address, access and egress mode to and from transit stops, the on/off stop for surveyed transit routes, number of transit routes used, and demographic information.

Table T.13 lists data sources mentioned above, along with other necessary sources of data not collected directly by SANDAG listed in Table T.14. Modeling parking location choice, and employer reimbursement of parking cost, depends on parking survey data collected from 2010 into early 2011 as well as a parking supply inventory. The transponder ownership sub-model requires data on transponder users. Data needed for model validation and calibration include traffic counts, transit-boarding data, and Caltrans Performance Measurement System (PeMS) and Highway Performance Monitoring System (HPMS) data.

Table T.13
SANDAG Surveys and Data

Survey Name	Year
Household Travel Behavior Survey	2016~2017
Transit On-Board Survey	2015
Parking Inventory Survey	2010
Parking Behavior Survey	2010
Border Crossing Survey	2011
Visitor Survey	2011
Establishment Survey	2012
Tijuana Airport Passenger Survey	2017
Beach Intercept Survey	2017
Passenger Count Program	2016

Table T.14
Outside Data Sources

San Diego International Airport (SDIA) Air Passenger Survey	2009
SDIA Passenger Forecasts - Airport Development Plan: San Diego International Airport	2013
Decennial Census Summary File-1 (SF1) tabulation	2010
American Community Survey (ACS)	2015, 2016, 2017
Transponder ownership data	2012
Freight Analysis Framework (FAF) 4	2012
Traffic and bicycle counts	2011
Jurisdiction annual traffic counts	2016
Caltrans' Performance Measurement System (PeMS)	2016
Caltrans' Highway Performance Monitoring System (HPMS) – California Public Road Data	2016
Caltrans' Traffic Census Program – Annual Average Daily Traffic	2016
INRIX Speed Data	2015, 2016
Streetlight Origin-Destination Location-Based Services Data	2017

8.0 Travel Model Validation

Model validation compares base year 2016 model outputs to independent data, not used to estimate or calibrate model parameters, to ensure that the model 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. SANDAG maintains 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 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. Estimated transit boardings from the model are validated against 2016 daily transit ridership from the SANDAG Passenger Count Program.

Roadway validations were performed at regional, sub-regional (MSA), and highway corridor levels, segmented by time of day and roadway facility types. Overall validation results are satisfactory with no systematic deviation from the 45-degree line in validation scatter plots. Estimated regional VMT matched 2016 California Public Road Data well, with a slight VMT underestimation less than 1%.

Validation by road type shows freeway results fare better than those of other road types. The model tends to underestimate volumes on arterials, ramps, and collectors. The lack of a systematic approach of collecting traffic counts on arterials and collectors could be a contributing factor to the less than ideal performances on arterials and collectors. Validation by volume shows that the larger estimated link volumes are the better they match the counts; %RMSEs decrease as the estimated volumes increase. Validation was performed on major highway corridors, including I-5, I-15, I-805, SR-67, SR-125, SR-163, I-8, SR-52, SR-54, SR-56, SR-78, and SR-94. Overall the model performs well at corridor level. Transit validations were performed by transit line haul mode, including commuter rail, LRT, express bus, rapid bus, and local bus. Overall, the model estimated transit ridership match observed 2016 transit passenger counts well, with a 6% over estimation of total regional transit ridership.

9.0 Input Assumptions

9.1 Telework

Working from home or Teleworking may contribute to reductions in driving since employees do not have to travel to a workplace. The SANDAG Activity-Based Model explicitly accounts for this reduction by identifying the work location of some workers as “home”. In the SANDAG ABM, persons who work from home do not make work trips, but they can make other trips during the simulation day which may offset the reduced home-work vehicle miles travel. Based on information from the National Household Travel Survey (NHTS), California Household Travel Survey (CHTS), SANDAG Regional Transportation Study, and the Census American Community Survey (ACS) a telework trend was developed and used to project future teleworking amounts as shown in Table T.15 . Attachment 1 documents telework assumptions prepared for the Future Mobility Research Program.

Table T.15

Telework Future Assumptions

Year	Telework always or primarily	Telework occasionally	Telework Total
2016	7.1%	5%	12.1%
2020	7.4%	5%	12.4%
2025	7.9%	5%	12.9%
2035	9.0%	5%	14.0%
2050	10.5%	5%	15.5%

9.2 Auto Operating Costs

Common modeling practice assumes that as a person considers whether to drive or take another mode of transportation, two cost components are considered: 1) fuel cost per mile of travel and 2) non-fuel operating costs. Fuel cost per mile is calculated based on forecasts for how much gas will cost, as well as the fuel efficiency of a vehicle. Non-fuel operating costs are comprised of vehicle maintenance, repair, and tires. Auto operating costs (AOC) does not typically include the costs associated with the purchase of a vehicle (purchase/lease costs, insurance, depreciation, registration and licenses fees) as these are part of a long-term decision-making process.

SANDAG uses two sources for historical and current gasoline fuel prices, the U.S. Energy Information Administration (EIA) and the Oil Price Information Service (OPIS) by HIS Markit. EIA provides data on how much California fuel costs were, as well as the U.S. overall and OPIS was purchased for San Diego County specifically.

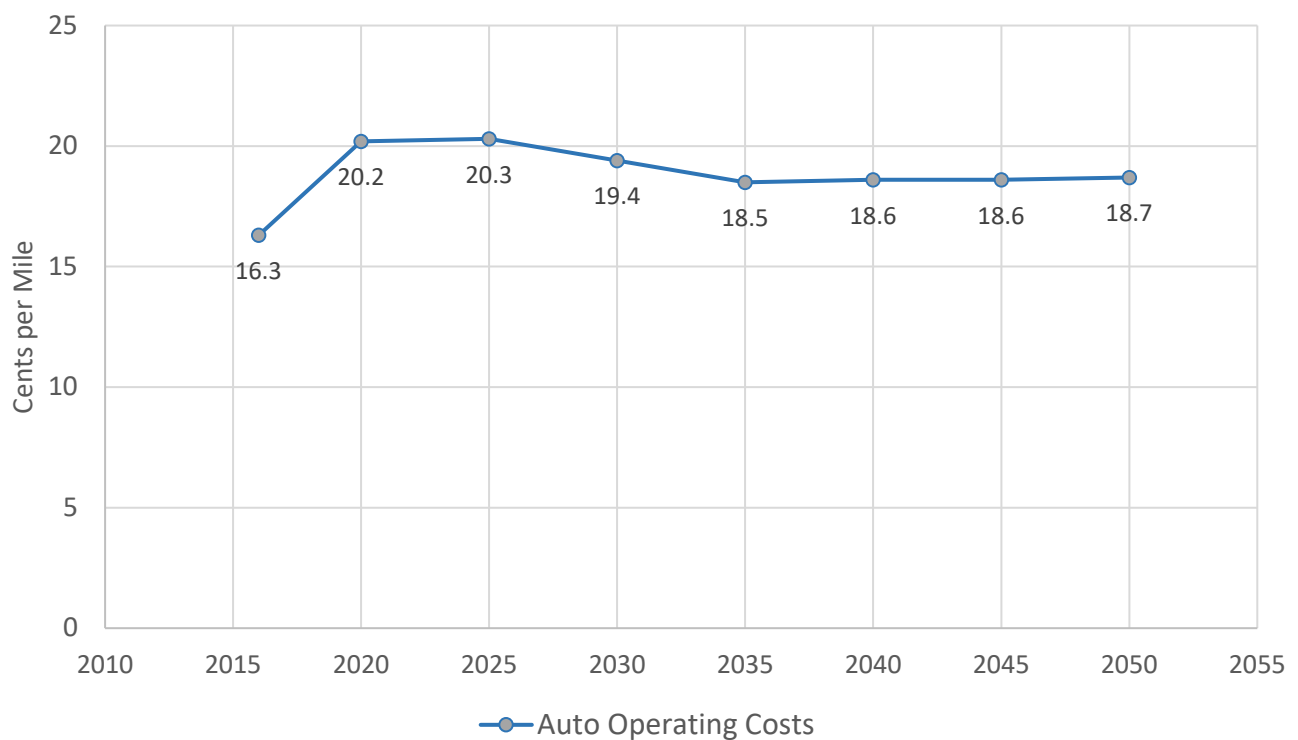
The EIA publishes an Annual Energy Outlook forecast with several variations of forecasts for economic growth, oil prices, and resources and technology based on different assumptions (which effectively results in a range of forecasts). The Big 4 MPO group in 2014 (for the second round SCS) used the U.S. EIA AEO (Annual Energy Outlook) low forecast plus 75 percent of the difference between the high and low oil price forecast with an adjustment from U.S. costs to CA costs. Another source of forecasts data is published by the California Energy Commission (CEC), which is used in the draft California Air Resources Board (CARB) AOC calculation tool. The AOC calculator provides the fuel costs for other alternative modes, amount of future miles traveled by mode, and fuel efficiency of those vehicles.

The traditional source of non-fuel related operating costs is the American Automobile Association (AAA), which has produced a publication, “Your Driving Costs”, since 1950. While the consistency of this information is a plus, potential issues include that it is a national average weighted by vehicle sales by category and is based on an average mileage range of 15,000. These vehicle categories or mileage ranges are not controlled for in the non-fuel price forecast. The 2016 AAA average cost for maintenance and tires is based on small, medium, and large sedans, whereas the 2017 AAA average cost includes those categories plus electric vehicles, hybrid vehicles, minivans, pickups, small SUVs and medium SUVs. The new CARB AOC calculator assumes static 2017 costs moving forward.

Figure T.16 shows the calculated AOC values for current and future years used in the ABM2. From 2016 to 2025 EIA projected fuel costs increase faster than fuel efficiency and alternative fuel/vehicle use. From 2025 to 2050 fuel efficiency increases offset increases in fuel costs resulting in a more stabilized auto operating cost. Model performance measures (such as vehicle miles traveled and transit mode share) between 2020 and 2030 will be impacted by the higher AOC.

Impacts of gas prices on vehicle use can be found in research sponsored by CARB (https://www3.arb.ca.gov/cc/sb375/policies/gasprice/gasprice_brief.pdf and https://www3.arb.ca.gov/cc/sb375/policies/gasprice/gasprice_bkgd.pdf).

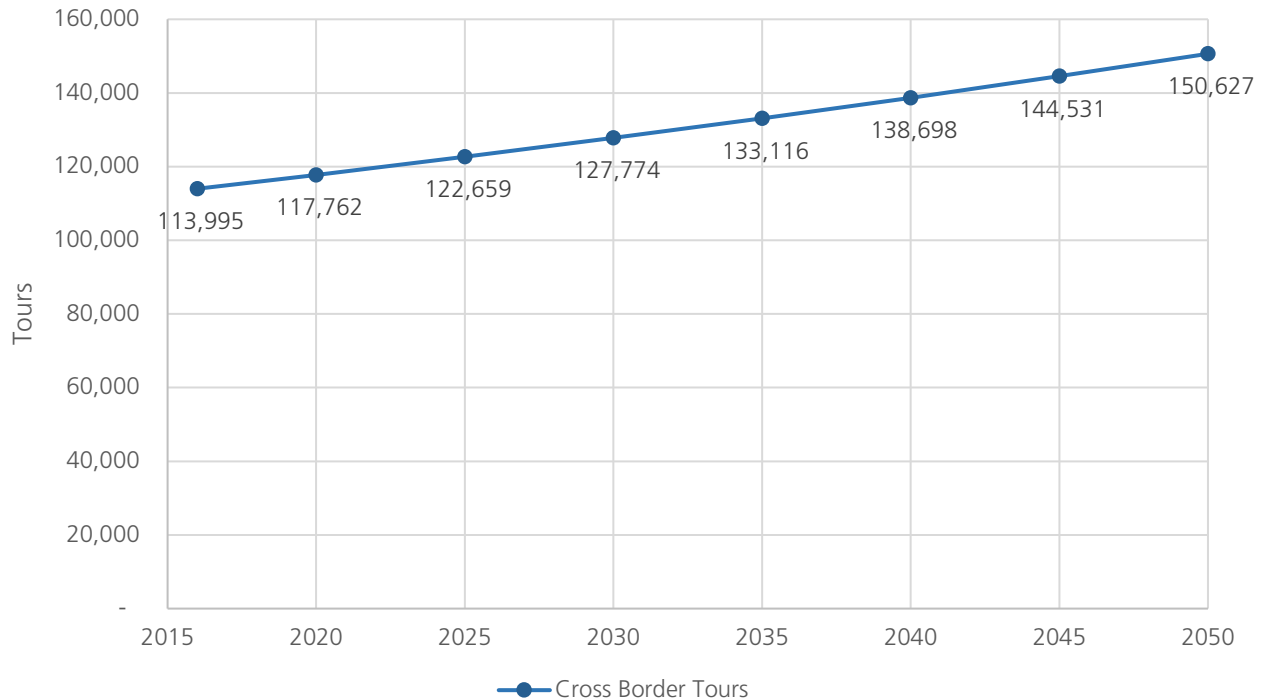
Figure T.16
ABM2 Auto Operating Costs



9.3 Cross Border Tours

The future projected increase of border tours uses 2016 crossing volumes for vehicle passengers and pedestrians as a starting point. Vehicles passengers are then grown at an annual growth of 0.7% based on information from the SR11 Otay Mesa East Traffic and Revenue Report. Pedestrian are grown at an annual growth of 1.2% based on an analysis of historical growth trends.

Figure T.17
Cross Border Tours



9.4 Airport Enplanements

As discussed earlier (in Section 5.2 San Diego airport ground access model) enplanements are a key input to the ground access model for SDIA. The total number of yearly enplanements, without counting transferring passengers, at SDIA are input for each simulation year (see Figure T.18). The data is available in the Aviation Activity Forecast Report⁴.

Figure T.18
San Diego International Airport Enplanements

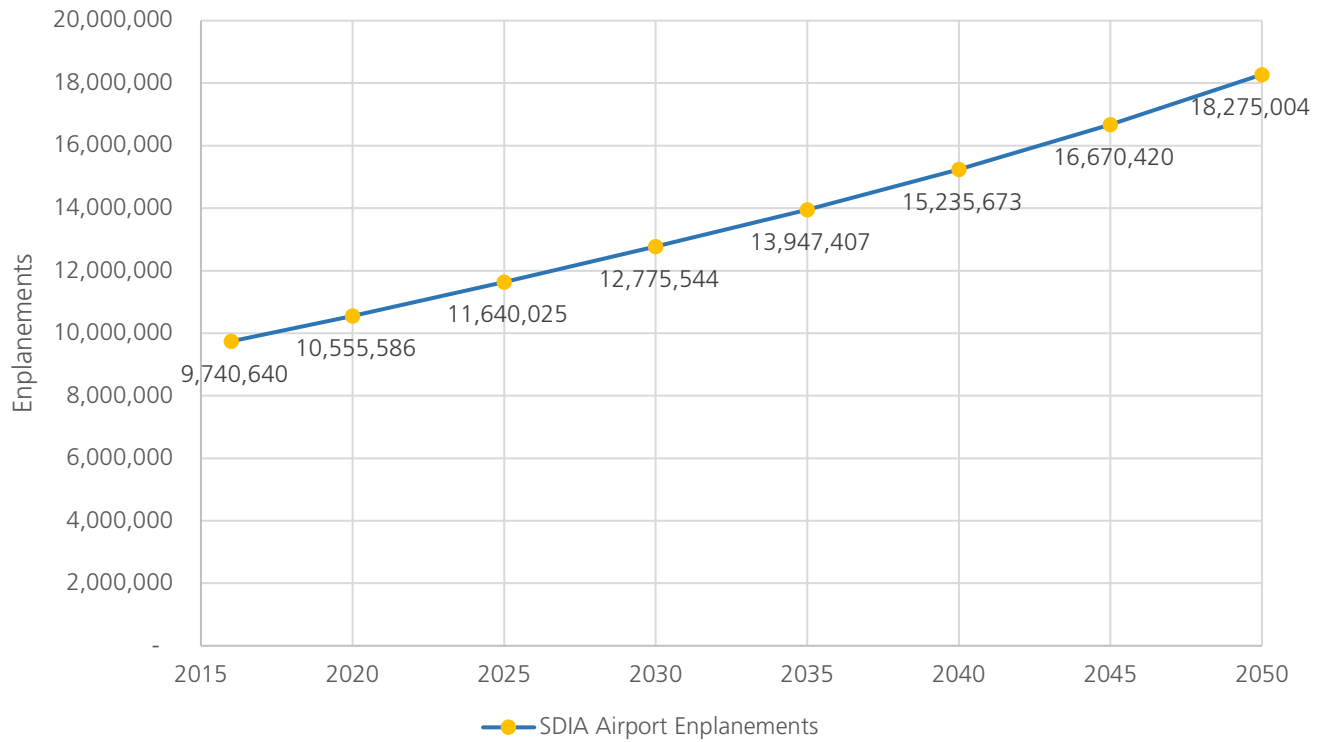
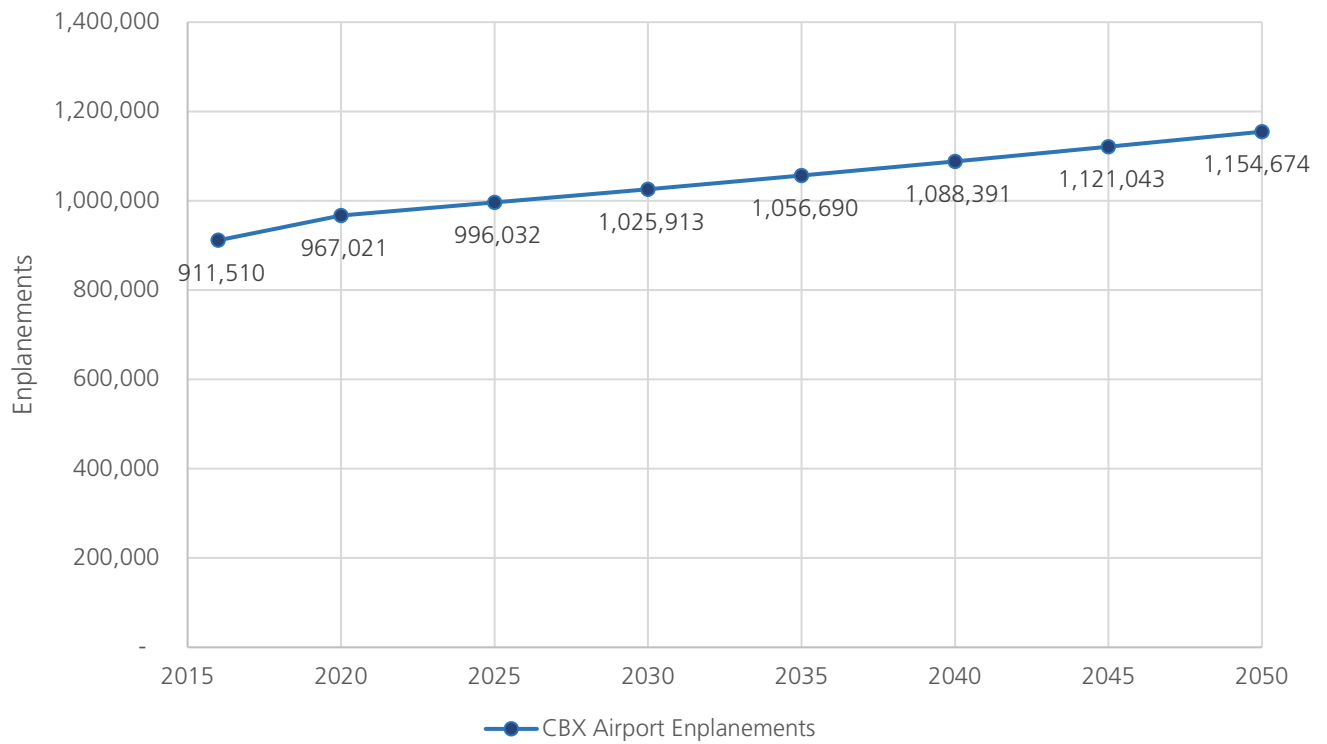


Figure T.19
CBX Enplanements



9.5 External Cordon Trips

External cordon trips are those trips originating external to the San Diego region and destined for either within the region or to another external area. External to internal trips are based on traffic counts at the cordons and projections in population growth from the CA Department of Finance.

Figure T.20
External Trips

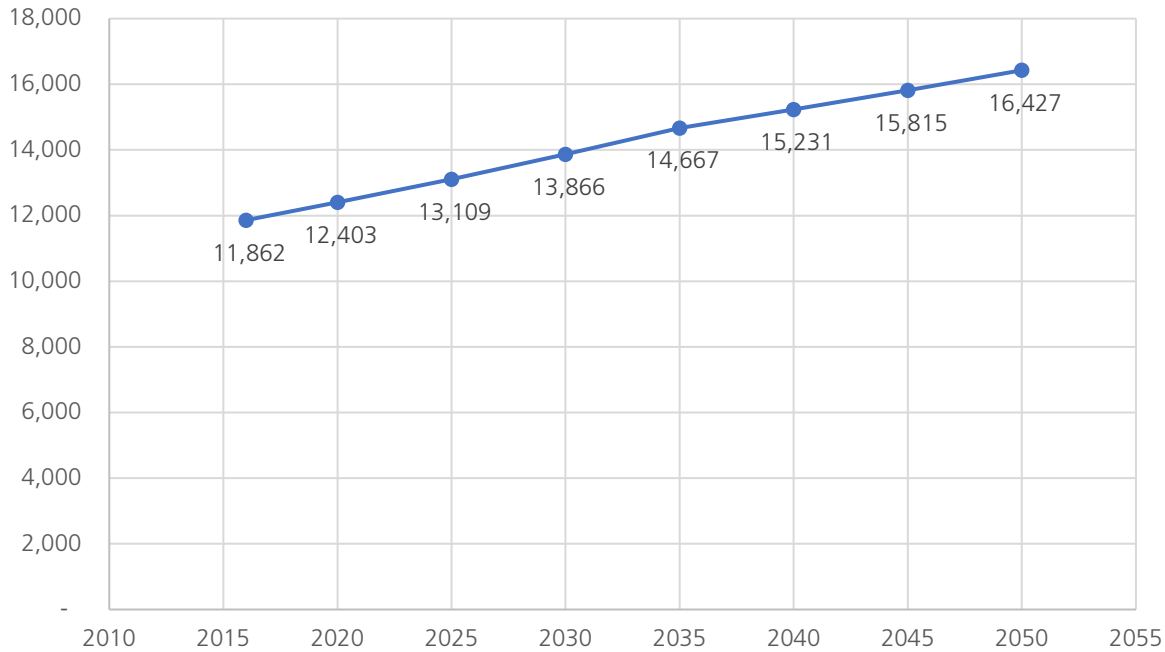
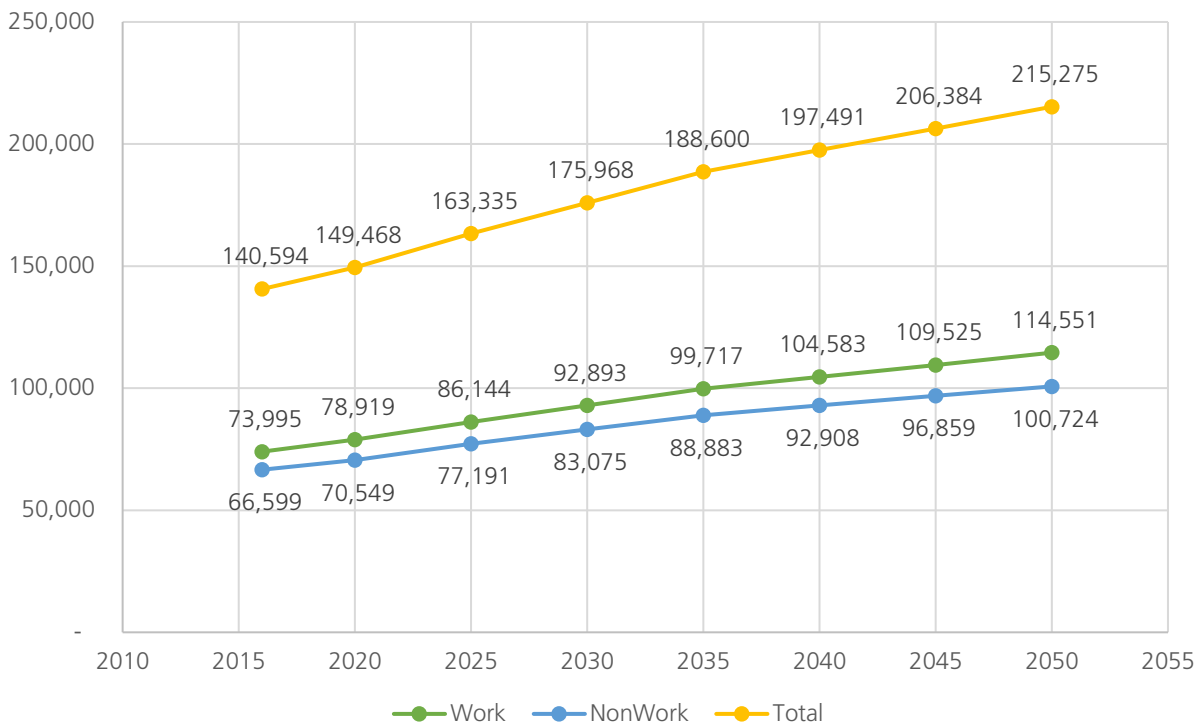


Figure T.21
Non-Cross Border External Trips into the San Diego Region



10.0 Acronyms

Table T.16 Acronyms

Acronym	Description	Acronym	Description
AAA	American Automobile Association	HTS	Household Travel Behavior Survey
ABM	Activity-Based Model	IE	Internal to External
ACS	American Community Survey	INEGI	Instituto Nacional de Estadística y Geografía
AEO	Annual Energy Outlook	KNR	Kiss and Ride
AGEB	Area Geostadística Básica	MGRA	Master-Geographic Reference Area
AOC	Auto operating costs	MSA	Major Statistical Areas
AT	Active transportation	NHTS	National Household Travel Survey
ATRI	American Transportation Research Institute	NM	Non-motorized
AWDT	Average weekday traffic	OBS	Transit On-Board Survey
Caltrans	California Department of Transportation	OPIS	Oil Price Information Service
CARB	California Air Resources Board	PCP	Passenger Counting Program
CBX	Cross Border Xpress	PeMS	Caltrans Performance Measurement System
CDAP	Coordinated daily activity pattern	PNR	Park and Ride
CEC	California Energy Commission	RTP	Regional Transportation Plan
CHTS	California Household Travel Survey	SAN	San Diego International Airport
CVM	Commercial vehicle model	SANDAG	San Diego Association of Governments
DAP	Daily activity pattern	SDIA	San Diego International Airport
DC	Destination choice	SHRP	Strategic Highway Research Program
DOF	California Department of Finance	SOLA	Second-Order Linear Approximation
EE	External to External	SOV	Single Occupancy Vehicle
EI	External to Internal	TAP	Transit access points
EIA	U.S. Energy Information Administration	TAZ	Transportation analysis zone
Emme	Modeling software made by INRO https://www.inrosoftware.com/en/products/emme/	TOD	Time of day
FAF	Freight Analysis Framework	UrbanSim	Land use modeling software https://urbansim.com/
GIS	Geographic Information System	VDF	Volume-delay function
GP	General purpose	VOT	Value of time
HDTM	Heavy-Duty Truck Model	INEGI	Instituto Nacional de Estadística y Geografía
HOV	High Occupancy Vehicle	KNR	Kiss and Ride
HPMS	Highway Performance Monitoring System	MGRA	Master-Geographic Reference Area

11.0 Endnotes

- ¹ Please refer to the SANDAG Regional Models website for additional documentation including key updates from ABM1 to ABM2.
<https://www.sandag.org/index.asp?classid=32&fuseaction=home.classhome>
- ² Full-time employment is defined in the SANDAG 2006 household survey as at least 30 hours/week. Part-time is less than 30 hours/week but works on a regular basis.
- ³ Airport Development Plan: San Diego International Airport, Leigh|Fisher, March 2013, page 47-68 (Table 22).
- ⁴ Airport Development Plan: San Diego International Airport, Leigh|Fisher, March 2013, page 47-68 (Table 22).

MEMO

TO: Project Files
FROM: Rosella Picado
SUBJECT: Telework Assumptions, Future Mobility Research Program
DATE: March 26, 2018

INTRODUCTION

Working from home or Teleworking contributes to reductions in greenhouse gases (GHG) since employees do not have to travel to a workplace. The SANDAG Activity-Based Model explicitly accounts for this reduction by identifying the work location of some workers as “home”. In the SANDAG ABM, persons who work from home do not make work trips, but they can make other trips during the simulation day. The purpose of this memorandum is to recommend a target for work from home, based on recent telecommuting data from the San Diego region.

TELEWORKING IN SAN DIEGO COUNTY

In the past five years, SANDAG has conducted two surveys that asked county workers the extent to which they work from home. Findings from these two surveys are presented below.

Employee Commute Survey

In 2013 SANDAG conducted an employee commute survey, in which a sample of 2,000 employees who work at least 30 hours per week were asked about the frequency with which they work from home or telecommute. Approximately 7% of respondents indicated that they work from home “always or primarily”, with an additional 4%-5% indicating that they worked from home on one day during the survey week. In total, approximately 12% of survey respondents indicated that they teleworked on any given day of the survey week.

Approximately 23% of employees indicated that they telework occasionally. This includes persons that said that they telework as frequently as once per week, once per month, or less than once per month. Therefore, the survey results indicate that approximately one-in-four to one-in-five persons who telework occasionally can be seen teleworking on any given weekday.

Among the persons that do not telework at all, approximately 19% responded that their job responsibilities would allow them to telework, and 26% said that their employer offers teleworking.

Workers that telework occasionally and those that do not currently telework but could do it constitute the growth market for teleworking. As shown in Table 1, this growth potential includes the 23% of

employees that currently telework occasionally, and the 18% that do not currently telework but could potentially do it.

Table 1: Frequency of Teleworking in San Diego County

Telework category	Percentage of workers
All workers	100%
Teleworked on survey week	12%
Always or primarily teleworked	7%
Occasionally teleworks	5%
Did not telework on survey week	88%
Teleworks occasionally	18%
Does not telework	70%
Job duties allow teleworking	13%
Cannot telework	57%

Source: 2013 Employee Commute Survey

Regional Transportation Study

In 2017 SANDAG conducted the Regional Transportation Study, which surveyed a sample of 6,139 households located in San Diego County. This study collected travel diaries from all members of the sampled households, in addition to household and person data such as work arrangements and school attendance information. In total, these households included 6,405 workers which reported on their usual type of work location and frequency of telecommuting. Among persons who self-identified as workers, approximately 6.4% reported that they “work at home only”. This proportion of work from home employees is comparable to the findings from the 2013 Employee Commute Survey. Similarly, the 2017 Regional Transportation Study found that approximately 27% of workers with job location type other than home report that they telecommute occasionally. Although this question was not posed to persons who had already said that they “work at home only”, a few of them indicated that they telecommute four or more times per week. Counting only persons that indicated that they telecommute no more frequently than 2-3 days a week results in a proportion of occasional telecommuters of 26%, which is somewhat higher than the proportion of occasional telecommuters identified by the Employee Commute Survey (23%).

COMPARATIVE ANALYSIS

Statistics on the proportion of San Diego County workers that work from home or telework are also available from the 2012 California Household Survey (CHTS), the 2001, 2009 and 2017 National Household Travel Surveys (NHTS), and the American Community Survey (ACS). The specific wording of the telework question varies with each survey, as shown in Table 2. Based on the survey question, one would expect that ACS and CHTS would identify workers that telework always or primarily, while NHTS captures both persons that telework at least occasionally in addition to those that do it all or most of the time. The telework statistics shown in Table 2 confirm that the percentage of teleworking reported by ACS is comparable to the 6% to 7% that the SANDAG surveys indicate are primarily teleworkers. NHTS and CHTS report approximately twice as many workers that usually work from home (15%-16%), compared to the SANDAG surveys. On the other hand, NHTS reports somewhat fewer occasional teleworkers than the SANDAG surveys (21% compared to 23% and 28%).

Table 2: Frequency of Teleworking, State and National Data Sources

Region	SANDAG Employee Commute Survey (2013)		SANDAG Regional Transportation Study (2016-2017)		ACS (2013)	CHTS (2012)	NHTS (2017)	
	Always or primarily teleworks	Teleworks on occasion	Job location type is work at home	Teleworks on occasion	Means of transportation to work is 'Work at Home'	Primary work location address type is 'Home'	Usually works from home	Has worked from home in the past 30 days (but not a usual tele-commuter)
San Diego County	7%	23%	6%	28%	6.4%	16.6%	15.2%	21%
San Francisco Bay Area					5.4%	16.6%	13.4%	31%
SCAG Region					5.1%	16.4%	15.3%	17%
SACOG Region					5.5%	16.5%	13.2%	20%

TELEWORKING TRENDS

Some evidence of the change over time in the proportion of workers that telework can be gleaned from ACS and NHTS.

Telework questions were included in the 2001, 2009 and 2017 NHTS; however, the exact wording of the question changed with each survey deployment (see Table 3). The data for San Diego County shows the percent of workers indicating that they teleworked at least once in a two-month period increasing from 18% in 2001 to 36% in 2017, an increase of nearly 20 percent points. In the same 16-year period, respondents from the San Francisco Bay also report a 20 percent point increase in the frequency of telecommuting, while persons from the SCAG and SACOG regions report an increase of 10 percent points.

Table 3: Teleworking Percentage, NHTS

	2001	2009	2017	
Region	On any day in the past two months, did you work from home instead of traveling to your usual workplace?	How many times in the last month did you work only at home for an entire work day instead of traveling to your usual workplace? ¹	In the past 30 days, how many days did you work only from home or an alternate work place? ¹	Change (2001-2017)
San Diego County	18%	28%	36%	+ 18 pts
San Francisco Bay Area	25%	35%	45%	+ 20 pts
SCAG Region	23%	25%	33%	+ 10 pts
SACOG Region	24%	29%	33%	+ 9 pts

¹ Percent of workers reporting at that they worked from home at least once.

ACS has reported the means of transportation statistics annually since 2005. Figure 1 shows the reported percentage of work from home in San Diego County, as well as the margin of error. ACS reports that the proportion of workers that telework ranges approximately between 6% and 7.5% in this 12-year period, except in 2005 which shows a much lower percentage.

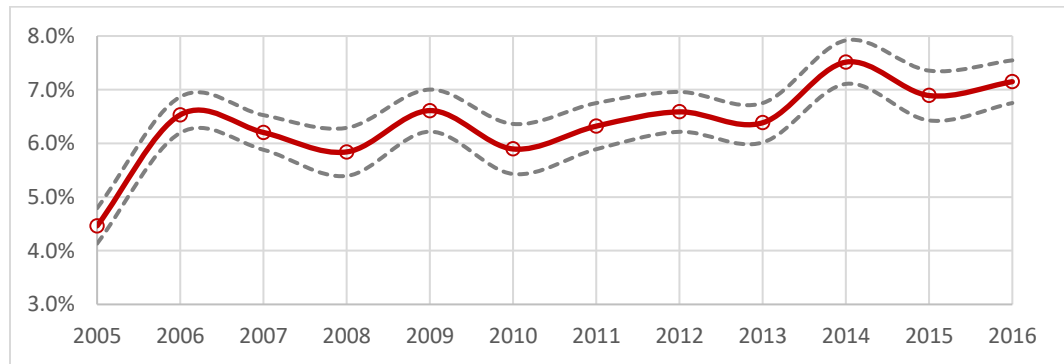


Figure 1: Telework Percent and Margin of Error, ACS

The time series show a modest rate of increase of 0.15% per year, on average, when including all 12 observations, or 0.10% if excluding 2005. At this rate of change, the percent of workers that telework “always or primarily” would grow by one percent point every 10 years, so that by 2035 it would be approximately 9%, and by 2050 it would be 10.5% -- see Figure 2.

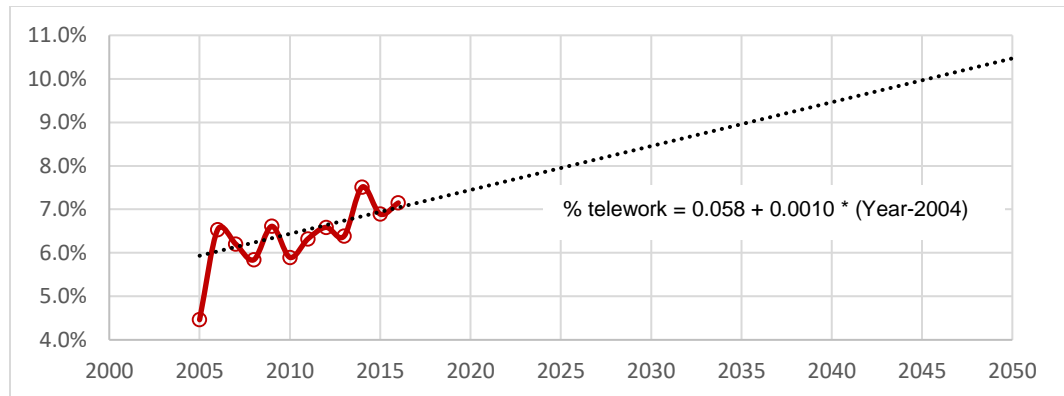


Figure 2: Projected Teleworking Percentage

Given that ACS captures only those persons that typically telework every day, then the estimates above would not include those that telework occasionally. Conservatively, assuming that the number of occasional workers would remain unchanged, they would add 4% to 5% to the ranks of those that telework on any given day.

Table 4 shows the recommended telework percentages for San Diego County for each RTP scenario year.

Table 4: Weekday Telework Recommendation for San Diego County

Year	Telework always or primarily	Telework occasionally	Telework total
2016	7.1%	5%	12.1%
2020	7.4%	5%	12.4%
2025	7.9%	5%	12.9%
2035	9.0%	5%	14.0%
2050	10.5%	5%	15.5%