Appendix T

SANDAG Travel Demand Model Documentation

Appendix Contents

SANDAG Travel Demand Model Documentation

Introduction

This document describes the San Diego Association of Governments (SANDAG) Activity-Based Model (ABM) specification. This ABM will serve as the major travel forecasting tool in the San Diego region for decades to come. This model has been developed to ensure that the regional transportation planning process can rely on forecasting tools that will be adequate for new socioeconomic environments and emerging planning challenges. It is equally suitable for conventional highway projects, transit projects, and various policy studies such as highway pricing and HOV analysis.

The SANDAG 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, which is fully described in the following section, 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. In particular, it addresses both household-level and person-level travel choices including intra-household interactions between household members. This approach is fundamentally different from the more simplified AB models developed or being developed in such regions as San Francisco County, Sacramento and Denver, where all travel choices are modeled at the person level, independently of choices made by other household members.
- CT-RAMP is a proven design, intensively tested in practice in several regions. The New York model was developed in 2002, and was used in the New York region to analyze numerous projects. The Columbus, Ohio model (the first fully-fledged member of the CT-RAMP family) was developed in 2004 and has since been applied by the MORPC for various transit and highway projects. The Lake Tahoe model was created in 2006 largely by transferring main components of the Columbus model. The Atlanta, Georgia (ARC) model has been co-developed with the MTC Model. Future developments of CT-RAMP include models for the San Diego region (SANDAG) and Jerusalem, Israel (JTMT). In each case, the model system has been tailored to address the specific issues and markets that are particular to the region.
- 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 attributes[1].
- Is implemented in the PB Common Modeling Framework, an open-source library created specifically for implementing advanced models.
- Offers sensitivity to demographic and socio-economic changes observed or expected in the dynamic San Diego metropolitan region. This is ensured by the enhanced and flexible population synthesis

procedures as well as by the fine level of model segmentation. In particular, the SANDAG ABM incorporates different household, family, and housing types including a detailed analysis of different household compositions in their relation to activity-travel patterns.

- *Accounts for the full set of travel modes*. Our experience with previously developed ABMs has shown that mode choice is one of the least transferable model components due to regional differences in mode choice and accessibility.
- *Integrates with other model components*. The CT-RAMP model is one component (person travel) and can easily integrate with other components such as the existing SANDAG truck model, a model of inter-border commuting (particularly important given the interaction of San Diego with Mexico and with Orange, Riverside, and Imperial County), models of non-resident visitor travel, airport travel, and special event travel. Furthermore, the model developed for SANDAG will be integrated with the Production, Exchange, and Consumption (PECAS) land-use model system.
- *Provides detailed inputs to traffic micro-simulation software*. The CT-RAMP model operates at a half-hour time scale, which can provide detailed inputs to traffic micro-simulation software for engineering-level analysis of corridor and intersection design.

Model Features and SANDAG Planning Needs

The SANDAG CT-RAMP model has been tailored specifically to meet SANDAG planning applications, as outlined below. These planning applications consider current and future projects and policies and also take into account the special markets that exist in the San Diego Region. The model system addresses requirements of the metropolitan planning process, relevant federal requirements, and provides support to SANDAG member agencies and other stakeholders. The ABM structure fully complies with the following major planning applications:

- *RTP, TIP, and Air Quality Conformity Analysis.* The ABM will be carefully validated and calibrated to replicate observed traffic counts and other monitoring data sources with the necessary level of accuracy. The output of traffic assignment can be processed in a format required by the emission calculation software used by SANDAG, including either EMFAC or MOVES.
- *Corridor Studies, Development Impact Studies, and other planning studies.* The ABM will have more realistic travel patterns that will lend itself to a high level of credibility with respect to routine planning studies conducted by SANDAG staff and other model users.
- *FTA New Starts Analysis.* The ABM application software package includes an option that produces the model output in a format required by FTA for the New Starts process. This output can be used as a direct input to the FTA software Summit used for calculation and analysis of the User Benefits. In order to meet the FTA "fixed total demand" requirement for comparison across the Baseline and Build alternatives, the ABM includes a run option for the Build alternative with certain travel dimensions fixed from the Baseline run.
- *Different highway pricing and managed lanes studies.* One of the advantages of an ABM over a 4-step model is a significantly improved sensitivity to highway pricing. This includes various forms of toll roads, congestion pricing, dynamic real-time pricing, daily area pricing, license plate rationing and other

innovative policies that cannot be effectively modeled with a simplified 4-step model. The explicit modeling of joint travel was specifically introduced to enhance modeling of HOV/HOT facilities.

- *Other transportation demand management measures.* There are many new policies aimed at reducing highway congestion in major metropolitan areas, including telecommuting and teleshopping, compressed work weeks, and flexible work hours. ABMs are specifically effective for modeling these types of policies since these models are based on an individual micro-simulation of daily activity-travel patterns.
- *Enhanced Environmental Justice analysis.* The model system features a full micro-simulation of the population, providing the ability to perform virtually unlimited market analysis. Environmental justice disparity analysis can be performed across highly disaggregated user groups, providing information for Title VI and other types of environmental justice studies.

General Model Design

The SANDAG ABM 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 in the ABM design 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.

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 necessary computing power associated primarily with path-building and assignment to more zones must also be considered.

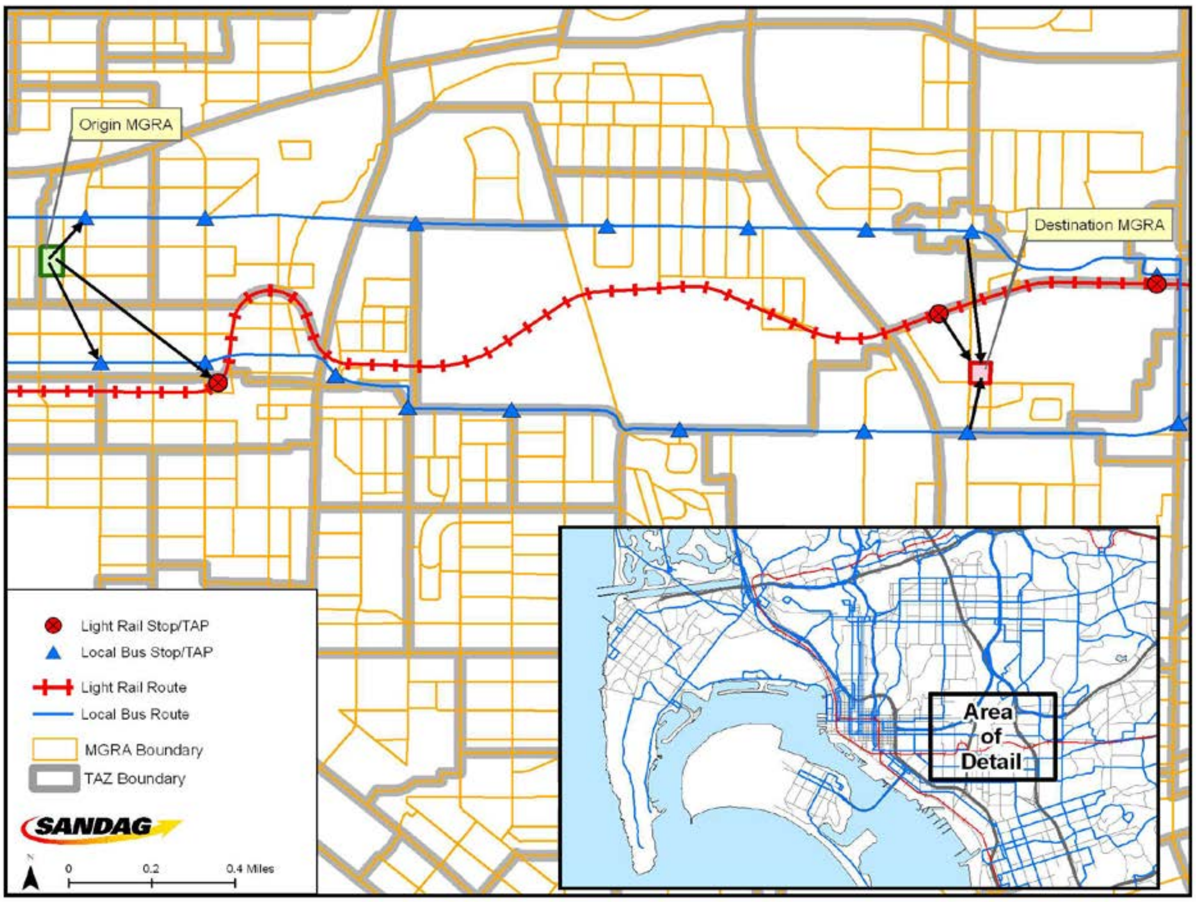
The use of a spatially disaggregate zone system helps ensure model sensitivity to phenomena that occur at a fine spatial scale. Use of large zones may produce aggregation biases, especially in destination choice, where the use of aggregate data can lead to illogical parameter estimates due to reduced variation in estimation data, and in mode choice, where modal access may be distorted. Smaller zones help minimize these effects, and can also support more detailed road network assignments. Strategies to address the modal access limitations of large zones through the use of transit sub-zonal procedures are discussed in the transit network section of this document.

The SANDAG CT-RAMP model will take advantage of SANDAG Master-Geographic Reference Area (MGRA) zone system, which is the most disaggregate zonal system currently in use in any travel demand model in the United States. Most large metropolitan area travel demand models consider between 1,500 and 4,000 zones. The SANDAG current MGRA system consists of 32,000 zones, which are roughly equivalent to Census block groups (see Figure T.2). To avoid computational burden, SANDAG relies on a 4,600 Transportation Analysis Zone (TAZ) system for highway 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 relying on TransCAD 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.1. 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.

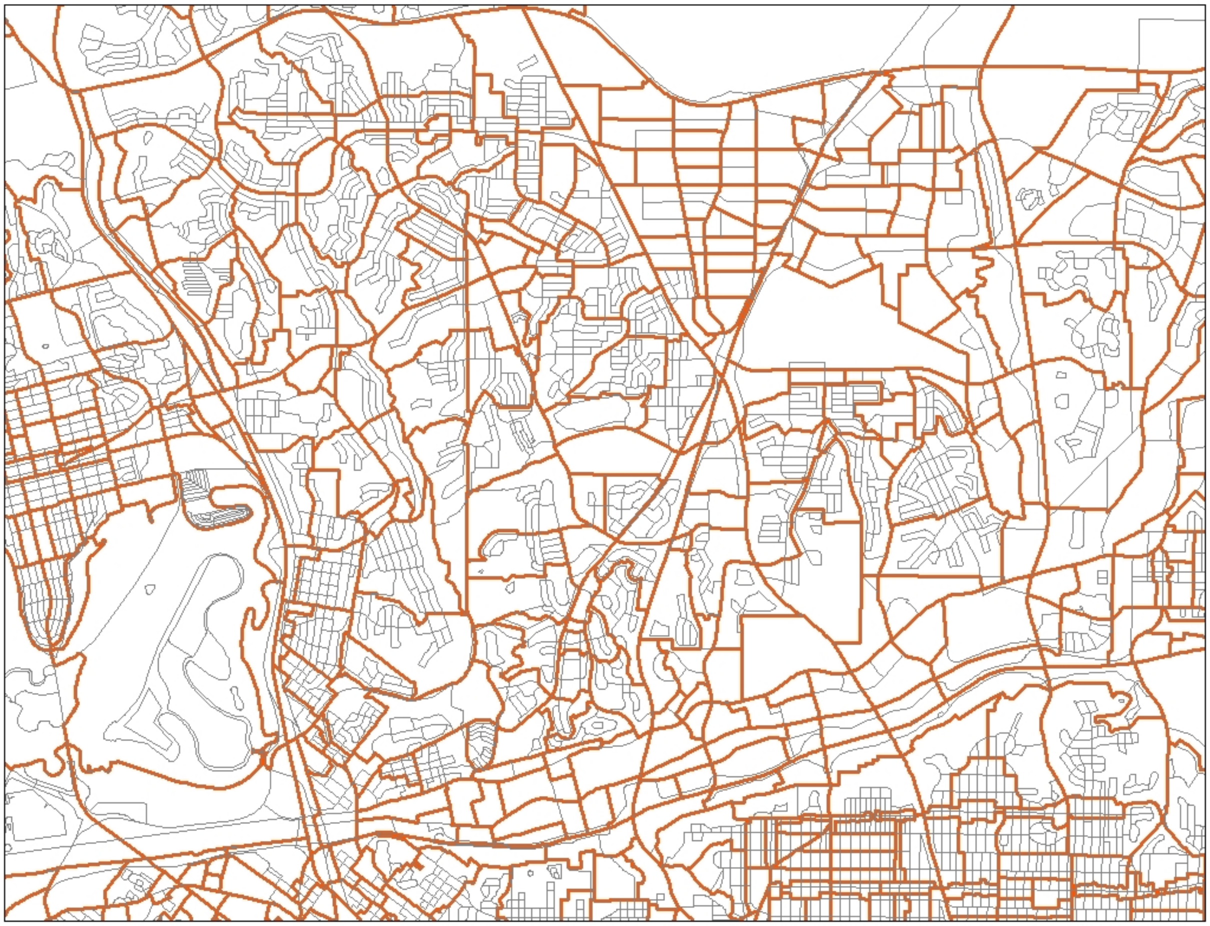
Figure T.1

Example MGRA – TAP Transit Accessibility



All activity locations are tracked at the MGRA level. There are model systems in use or under development which allocate activities to a unit smaller than the MGRA, such as a parcel. However, these model systems assume that the closest transit stop to the parcel is consistent with the zone-zone impedances calculated by the commercial transport software (TransCAD). In transit-rich environments, this may not be the case, and such assumptions can cloud User Benefit calculations required by FTA New Starts. 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.2
Treatment of Space – TAZs and MGRAs



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.

Person-type segmentation

The SANDAG ABM system is implemented in a micro-simulation framework. A key advantage of using the micro-simulation approach is that there are essentially no computational constraints on the number of explanatory variables can be included in a model specification. However, even with this flexibility, the model system will include 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.1, are used for the SANDAG model system. The person-types are mutually exclusive with respect to age, work status, and school status.

Table T.1

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, to take full advantage of information provided by the PECAS land-use model. The categories are given in Table T.2. These are used to segment destination choice size terms for work location choice, based on the occupation of the worker.

Table T.2

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

Activity type segmentation

The 2006 SANDAG home-interview survey included 24 different activity codes. Modeling all 24 activity types would add significant complexity to estimating and implementing the model system, so these detailed activity types are grouped into more aggregate activity types, based on the similarity of the activities. The activity types are used in most model system components, from developing daily activity patterns and to predicting tour and trip destinations and modes by purpose.

The proposed set of activity types is shown in Table T.3. 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.3
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 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)

Treatment of time

The model system functions 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. will be aggregated to reduce computational burden. Temporal integrity is ensured so that no activities are scheduled with conflicting time windows, with the exception of 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.-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 1/2-hour temporal resolution, the 9:00 a.m. time period would capture activities or 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 – early A.M., A.M., Midday, P.M., and night. The trips occurring in each time period reference the appropriate transport network depending on their trip mode and the mid-point trip time. The definition of time periods for level-of-service matrices is given in Table T.4,

Table T.4
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.

Trip modes

Table T.5 lists the trip modes defined in the SANDAG models. There are 26 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 five different transit line-haul 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.5

Trip Modes For Assignment

Number	Mode
1	Auto SOV (Non-Toll)
2	Auto SOV (Toll)
3	Auto 2 Person (Non-Toll, Non-HOV)
4	Auto 2 Person (Non-Toll, HOV)
5	Auto 2 Person (Toll, HOV)
6	Auto 3+ Person (Non-Toll, Non-HOV)
7	Auto 3+ Person (Non-Toll, HOV)
8	Auto 3+ Person (Toll, HOV)
9	Walk-Local Bus
10	Walk-Express Bus
11	Walk-Bus Rapid Transit
12	Walk-Light Rail
13	Walk-Heavy Rail
14	PNR-Local Bus
15	PNR-Express Bus
16	PNR-Bus Rapid Transit
17	PNR-Light Rail
18	PNR-Heavy Rail
19	KNR-Local Bus
20	KNR-Express Bus
21	KNR-Bus Rapid Transit
22	KNR-Light Rail
23	KNR-Heavy Rail
24	Walk
25	Bike
26	School Bus (only available for school purpose)

Basic design of the SANDAG CT-RAMP implementation

The general design of the SANDAG CT-RAMP model is presented in Figure T.3. The following outline describes the basic sequence of sub-models and associated travel choices:

1. Input Creation:
    1. Synthetic population creation
    2. Calculation of destination-choice accessibilities for use in mobility models and tour generation
2. Long term level:
    1. Household car ownership (based on household/person attributes and household accessibilities)
    2. Work from home model that indicates whether a worker’s regular workplace is their home
    3. The location for each mandatory activity for each relevant household member (workplace/university/school)
3. Mobility Level:
    1. Free Parking Eligibility (determines whether workers pay to park if workplace is an MGRA with parking cost)
    2. Household car ownership (based on household/person attributes, household, and mandatory accessibilities)
    3. Transponder ownership for use of toll lanes
4. Daily pattern/schedule level:
    1. Daily pattern type for each household member (main activity combination, at home versus on tour) with a linkage of choices across various person categories, and generation of a joint tour indicator at the household level.
    2. Individual mandatory activities/tours for each household member (note that locations of mandatory tours have already been determined in long-term choice model)
        - Frequency of mandatory tours
        - Mandatory tour time of day (departure/arrival time combination)
        - Mandatory tour mode choice
    3. Joint travel tours (conditional upon the available time window left for each person after the scheduling of mandatory activities, and the presence of a joint tour indicated from Model 4.1)
        - Joint tour frequency/composition, which predicts the exact number of joint tours (1 or 2), the purpose of each tour, and the composition of each tour (adults, children, or mixed)
        - Person participation in each joint tour
        - Primary destination for each joint tour
        - Joint tour time of day (departure/arrival time combination)
        - Joint tour mode choice

4. Individual non-mandatory tours (conditional upon the available time window left for each person after the scheduling of mandatory and joint non-mandatory activities)

    - Individual non-mandatory tour frequency, applied for each person
    - Individual non-mandatory tour primary destination
    - Individual non-mandatory tour departure/arrival time
    - Individual non-mandatory tour mode choice

5. At-work sub-tours (conditional upon the available time window within the work tour duration)

    - At-work sub-tour frequency, applied for each work tour
    - At-work sub-tour primary destination
    - At-work sub-tour departure/arrival time
    - At-work sub-tour mode choice

5. Stop level:

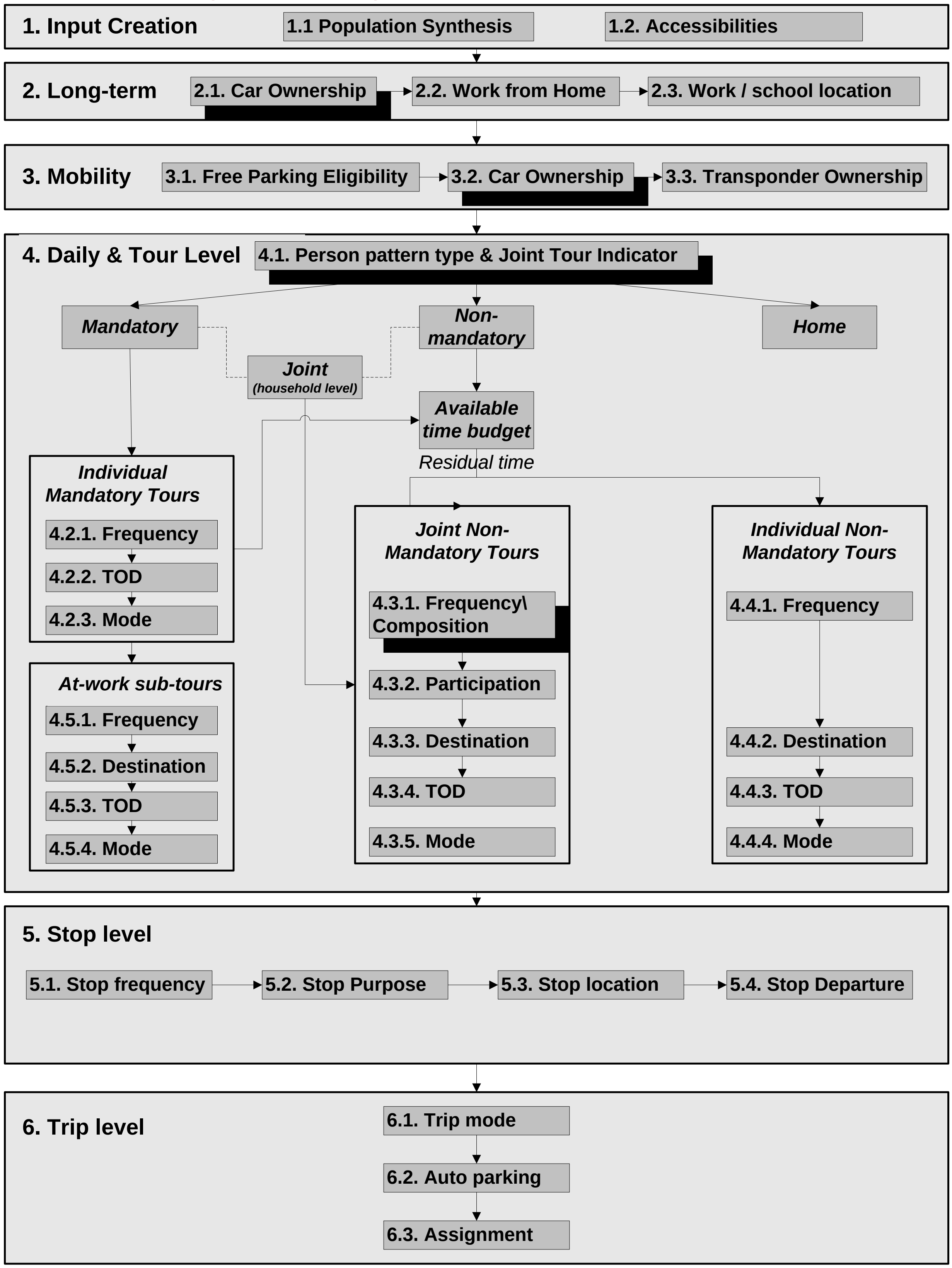
    1. Frequency of secondary stops
    2. Intermediate stop purpose
    3. Intermediate stop location choice
    4. Intermediate stop departure time choice

6. Trip level:

    1. Trip mode choice conditional upon the tour mode
    2. Auto trip parking location choice for parking constrained areas
    3. Trip assignment

Figure T.3

Basic Model Design and Linkage Between Sub-Models



Shadowed boxes in Figure T.3 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 model system 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, with the exception of 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). Medium-term 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 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 model system application, 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 highway and transit networks depending on trip mode and time period (6.3).

Main sub-models and procedures of the core demand model

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.

1.1 Population Synthesizer

The population synthesis procedure takes into account zonal and regional controls and includes a procedure to allocate households to MGRAs. A synthetic population is created using a modified open source PopSyn software originally designed for Atlanta Regional Commission (ARC). The ARC population synthesizer was developed by Parsons Brinckerhoff to be a flexible tool for creating synthetic populations for AB modeling. The population synthesizer inputs are U.S. Census data at the zonal- and regional-levels describing the distribution of households by various characteristics. The synthetic population is forced to match the zonal and regional characteristics. The ARC population synthesizer is being enhanced to consider person-level attributes in the population controls in order to match workers by occupation provided by PECAS.

The population synthesis approach includes the following steps:

- Create a sample of households in each TAZ (all households from the correspondent PUMA can be used in a simplified case).
- Balance the individual household weights to ensure the controlled totals across all person and household dimensions.
- Create a list of households by discretizing the individual weights.

The advantage of working with the list of households compared to a multi-way distribution is that both person and household variables can be incorporated. If only household or person attributes are controlled, the proposed procedure yields exactly the same multidimensional distribution as conventional matrix balancing. Also, the elimination of the drawing procedure allows for a theoretically closed formulation with no unnecessary empirical components.

General formulation

Since the procedure is applied for each TAZ separately, we formulate the model for a single TAZ. Introduce the following notation:

$i = 1,2...I$	=	household and person controls,
$n \in N$	=	seed set of households in the PUMA (or any other sample),
w_n	=	a priori weights assigned in the PUMA (or any other sample),
A^i	=	zonal controls,
$a_n^i \geq 0$	=	coefficients of contribution of household to each control.

The principal flexibility of the procedure is that the contribution coefficients can take any non-negative value. In the conventional procedure, the contribution coefficients are implied to be Boolean incidence indicators (belong or not belong). An example is shown in Table T.6 for controls specified by household size and person age brackets.

Table T.6

Controls and Contribution Coefficients

HH ID	HH size				Person age				HH initial weight
	1	2	3	4+	0-15	16-35	36-64	65+	
	$i=1$	$i=2$	$i=3$	$i=4$	$i=5$	$i=6$	$i=7$	$i=8$	ω_n
$n=1$	1							1	20
$n=2$		1			1	1			20
$n=3$			1			1	2		20
$n=4$				1		2	2		20
$n=5$				1	1	3	2		20
….									…
Control	100	200	250	300	400	400	650	250	

The first household has one person of age 65+. The second household has two persons: one age 0-15 and one age 16-35. The third household has three persons: one age 16-35 and another two aged 36-64. The fourth household has four persons: two aged 16-35 and two aged 36-64. The fifth household has size persons: one person age 0-15, three persons aged 16-35, and two persons aged 36-64.

The balancing problem can be written as a convex mathematical program of the entropy-maximization type in the following way:

$$\min_{\{x_n\}} \sum_n x_n \ln \frac{x_n}{w_n}, \qquad \text{Equation 1}$$

Subject to constraints:

$$\sum_n a_n^i x_n = A^i, (\alpha^i), \qquad \text{Equation 2}$$

$$x_n \geq 0 , \qquad \text{Equation 3}$$

where α^i represents dual variables that give rise to balancing factors.

The objective function expresses the principle of using all households uniformly (proportionally to the assigned a priori weight). The constraints ensure matching the controls.

By forming the Lagrangian and equating the derivatives to zero we obtain the following solution:

$$x_n = k \times w_n \times exp(\sum_i a_n^i \, \alpha^i) = w_n \times \prod_i [exp(\alpha^i)]^{a_n^i} = w_n \times \prod_i (\hat{\alpha}^i)^{a_n^i}, \qquad \text{Equation 4}$$

where $\hat{\alpha}^i$ represents balancing factors that have to be calculated. Note that the balancing factors correspond to the controls, not to households. For each household, the weight is calculated as a product of the initial weight by the relevant balancing factors exponentiated according to the participation coefficient. A zero participation coefficient automatically results in a balancing factor reset to 1 that does not affect the household weight.

Solution algorithm

The problem formulated in the previous section has a unique solution that can be achieved by the following iterative procedure:

Step 0: Set the iteration counter $k = 1$. Set zero-iteration weight $x_n(0,0) = w_n$.

For $k = 1$ to K (number of iterations):

For $i = 1$ to I (number of controls):

Step 1: Calculate balancing factor

$$\hat{\alpha}^i(k,i) = \frac{A^i}{\sum_n a_n^i x_n(k-1,i-1)}. \qquad \text{Equation 5}$$

Step 2: Apply balancing factor (note exponentiation!)

$$x_n(k-1,i) = x_n(k-1,i-1) \times [\hat{\alpha}^i(k,i)]^{a_n^i}. \qquad \text{Equation 6}$$

Step 3: Set starting weights for the next iteration

$$x_n(k,0) = x_n(k-1,I). \qquad \text{Equation 7}$$

Step 4: Calculate convergence criterion:

$$C(k) = \max_i \{abs[\hat{\alpha}^i(k,i) - 1]\}. \qquad \text{Equation 8}$$

If $C(k) \leq \varepsilon$ (degree of accuracy) or $k = K$ **Stop**.

Note that the solution is unique and independent of the order of controls. Normally, 100 iterations guarantee very good degree of convergence.

Base year controls

The population synthesizer first develops a "base year" population distribution using year 2000 Census or 2005-2009 ACS data, and a set of control attributes are defined. Census Summary File 1, Summary File 3, and the Census Transportation Planning Package information are used to develop single and multi-dimensional distributions of these attributes. These attributes, which are specified at the TAZ level in the base-year, include:

Household Controls:

- Housing Unit Type
- Household Size
- Household Income
- Number of Workers in Household
- Number of Units in Structure and Quality

Person Controls:

- Age
- Occupation

Once this distribution is established, the population synthesis tool samples PUMS records to create a fully enumerated representation of the population.

Household Controls

Each household is defined by eight dimensions. The dimensions are:

Household unit type (3)

Household
Non-Institutional Group Quarters
Institutional Group Quarters;

Income in 2007 dollars (5)

<$30k
$30-60k
$60-100k
$100-150k
$150k+

Household size (4)

1
2
3
4+

Number of Workers (4)

0

1

2

3+;

Number of Units in Structure & Quality (8)

Single-Family Attached/Luxury

Single-Family Attached/Economy

Single-Family Detached/Luxury

Single-Family Detached/Economy

Multi-Family/Luxury

Multi-Family/Economy

Mobile Home

Military

Person Controls

Age (9)

0-17

18-24

25-34

35-49

50-64

65-69

80+

Occupation (7)

White collar labor

Work at home labor

Service labor

Health labor

Retail and food labor

Blue collar labor

Military labor

Group quarters residents are treated as a separate category of households. In the PUMS data, each group quarters resident has a record in the person format as well as a record in the household format representing a one-person pseudo-household containing only that individual. These fields are distinguished from the normal household records by the UNITTYPE field, which indicates if the record is a household record, a non-institutional group quarters record, or an institutional group quarters record. The UNITTYPE field is used to distinguish the type of household, and group quarters residents are otherwise treated just like any other household record. Institutional group quarters residents are generated so that the total population matches control totals. However, because institutional residents are not expected to travel, these records are not printed to the population output file used by the model system.

Combinations of the dimensions that are excluded or merged include:

- Illogical combinations of workers and household size are excluded.
- For group quarters, no distinctions are made by household income.
- For group quarters, no distinctions are made by household size.
- For group quarters, no distinctions are made by person dimensions.
- For group quarters, no distinction is made by the number of units in the structure.

Base-Year Control Totals

For the base-year application, the control totals are derived entirely from 2000 Census data tabulated at the block-group level and converted to a TAZ-level. The controls include:

- Households by Household Size (4 controls);
- Households by Household Size x Number of Workers (4x4=16 controls);
- Households by Household Income x Household Size (4x4=16 controls);
- Households by Household Income x Number of Workers (4x4=16 controls);
- Households By Household Income x Household Size x Number of Workers (3x4x4=48 controls);
- Households By Household Size x Number of Units (4x2=8 controls);
- Households By Number of Units (2 controls);
- Households By Group Quarters Type x Number of Workers (2x2=4 controls);
- Persons by age (9 controls); and
- Workers by occupation (7 controls).

Future-Year Control Totals

For the forecast years, a more limited set of control totals is available from PECAS. The forecast-year control totals from PECAS include:

- Housing type and quality (available at a TAZ level)
- Group Quarters (held constant except where known changes occur)
- Household income (available at an MGRA level, summarized to a TAZ level)
- Household size (will be available at a TAZ level)
- Workers per household (will be available at a TAZ level)
- Workers by occupation (available at a PECAS-zone level)
- Persons by age (county-level control)

This second IPF process results in a floating point future-year seed distribution for the 608 categories. That distribution is then converted to an integer seed distribution using a randomized rounding method. The randomized rounding works such that if a cell contains the value 0.14, it has an 86% chance of being rounded to 0, and a 14% chance of being rounded to 1. This randomized rounding is preferred because it avoids bias, but it does not guarantee that the total number of households in a TAZ exactly matches the targets. Households are drawn from the PUMS sample to fill this integer distribution and create the synthetic population. Any income values less than zero are set to zero prior to writing the population.

The forecast-year control totals are based on PECAS land-use model projections and other supplemental data (such as distributions of persons by age). PECAS operates at a 350 zone system, but also tracks certain data at the TAZ and parcel level. Housing type and quality, for example, are tracked at the TAZ level, while workers by occupation and place of residence are tracked at the PECAS-zone level. The distribution of persons by age is specified as a county-wide control.

The population synthesizer currently operates at the TAZ level. Every household is automatically assigned to a TAZ based on the marginal distributions generated for each TAZ. This model assigns an MGRA to each household as follows:

- The quantity of housing by type (single-family attached, single-family detached, multi-family, mobile-home, non-institutional group quarters, and military) will be summarized by MGRA (Q_h). This data is available at the parcel level.
- A probability for each housing type will be computed for each MGRA as the quantity of housing by type for the MGRA divided by the sum of housing by type across all MGRAs in the TAZ ($P_{i,h}=Q_{i,h}/\Sigma Q_h$).

A Monte-Carlo random number draw will be made for each synthetic household, and that household will select a residential MGRA based on its housing type and the probability distribution for that housing type across all MGRAs in the TAZ.

1.2 Accessibilities

All accessibility measures for the SANDAG ABM are calculated at the MGRA level. The auto travel times and cost are TAZ-based and the size variables are MGRA-based. This necessitates that auto accessibilities be calculated at the MGRA level. The SANDAG ABM 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 for the SANDAG ABM model is summarized in Table T.7.

Table T.7

Accessibility Measures for the SANDAG ABM

No.	Description	Model utilization	Attraction size variable S_j	Travel cost c_{ij}	Dispersion coefficient $-\gamma$
1	Access to non-mandatory attractions by SOV in off-peak	Car ownership	Total weighted employment for all purposes	Generalized SOV time including tolls	-0.05
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	-0.05
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)	-1.00
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 ipersons) segmented by 3 car-availability groups	+1.00
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	+1.00
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	+1.00
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	+1.00
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	+1.00
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	+1.00
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	+1.00
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	+1.00

Table T.7 Continued

Accessibility Measures for the SANDAG ABM

No.	Description	Model utilization	Attraction size variable S_j	Travel cost c_{ij}	Dispersion coefficient $-\gamma$
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	+1.00
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	+1.00
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	+1.00
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	+1.00
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	+1.00
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 graeter than workers)	+1.00
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	+1.00
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)	+1.00
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	+1.00

Size Variables by Travel Purpose

Table T.8

Correspondence of LU Variables to Travel Purposes and Relative Attraction Rate

Employment by PECAS Model categories of Industry and other variables		Non-mandatory travel purpose in the ABM							
		4=escort	5=shop	6=main	7=eat	8=visit	9=disc	At-work	All
12	Retail Activity		3.194	0.776	0.325		0.098	0.154	3.970
13	Professional and Business Services			0.243				0.029	0.087
19	Amusement Services				0.089		0.364		0.407
20	Hotels Activity (479, 480)						0.318		
21	Restaurants and Bars		3.081		2.103	0.253	0.769	0.367	8.123
22	Personal Services Retail Based			0.500				0.054	0.999
23	Religious Activity						5.154		7.786
25	State and Local Government Enterprises Activity								
27	Federal Non-Military Activity			1.025					1.313
29/30	State and Local Non-Education Activity								0.214
	Total number of households	1.0				0.105	0.156		0.489

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 (approximately 15,000 out of 33,334 MGRAs have non-zero values at least for some LU activity and/or observed trip ends).

The following 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; off-peak mode choice logsum. These travel cost functions are explained.

- Generalized SOV time, including tolls and parking cost; time equivalent of tolls and operation cost should be included (approximately $1 per 6 minutes, that is Value of Time (VOT)=$10/h).

- Generalized best path walk-to-transit time including fares; this includes total in-vehicle time (reset to 10,000 if no transit path), walk, weight, transfer penalty, and time equivalent of fare according to the average VOT. It is suggested to use the relative in-vehicle and out-vehicle coefficients in the current mode choice model. First wait = 1.5, transfer wait = 3.0, Short walk (less than 1/4 mile) = 1.5, long walk (1/4 + miles) = 2.5, and there are additional transfer penalties equal to 2 minutes for the first transfer for LRT or Commuter rail only, and 15 minutes for all ride modes for the second transfer. The current cost coefficient is $5.41/hour which is for the middle income category; but I think we ought to use 1/2 of the average annual salary in San Diego in 2005 (which was $43,824 according to BLS) divided by 2080 = $10.53.
- SOV off-peak distance (set to 999 if distance>3) for non-motorized travel.
- Off-peak mode choice logsum calculated over 3 modes in trinary multinomial logit (auto/SOV skims, walk to transit, and non-motorized) segmented by 4 individual car-availability groups; the utility specifications are found in Table T.9.
- Off-peak mode choice logsum calculated over 3 modes in trinary multinomial logit (auto/HOV skims, walk to transit, and non-motorized) segmented by 3 household car-availability groups; the specifications are founds in Table T.9. It should be noted that despite a large number of measures to be calculated (42), this set is not computationally intensive since the most detailed model portion (mode choice logsum) is calculated for only 7 different types (4 for individual activities and 3 for household joint activities). These 7 logsums are then combined with different size variables.

Table T.9

Mode Utility Components for Accessibility Calculations

Segment	Mode	Constant	Travel time		Cost, $	
			Variable	Coefficient	Variable	Coefficient
U16 Adult, 0 cars	SOV*	-999	SOV time / off-peak	From the 4-step model	SOV toll plus operating cost plus parking	From the 4-step model
Adult, cars fewer than adults		2.0				
Adult, cars equal or greater that adults		3.5				
0 cars	HOV*	0.5	HOV time / off-peak	From the 4-step model	HOV toll plus operating cost plus parking	From the 4-step model divided by 2 (if not scaled in the model)
Cars fewer than adults		1.5				
Cars equal or greater than adults		1.0				
U16 Adult, 0 cars Adult, cars fewer than adults Adult, cars equal or greater than adults	Transit (best path)	-0.5	Total in-vehicle time (10,000 if no transit path) plus weighted walk plus weighted wait plus transfer penalty as defined in the 4-setp model	From the 4-step model	Fare	From the 4-step model
U16 Adult, 0 cars Adult, cars fewer than adults Adult, cars equal or greater than adults	Non-motorized		SOV off-peak distance (set to 999 if distance>3)	-1.00		

*Only one utility (SOV or HOV) is used at a time depending on the accessibility type as specified in Table T.7.

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.4.

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.

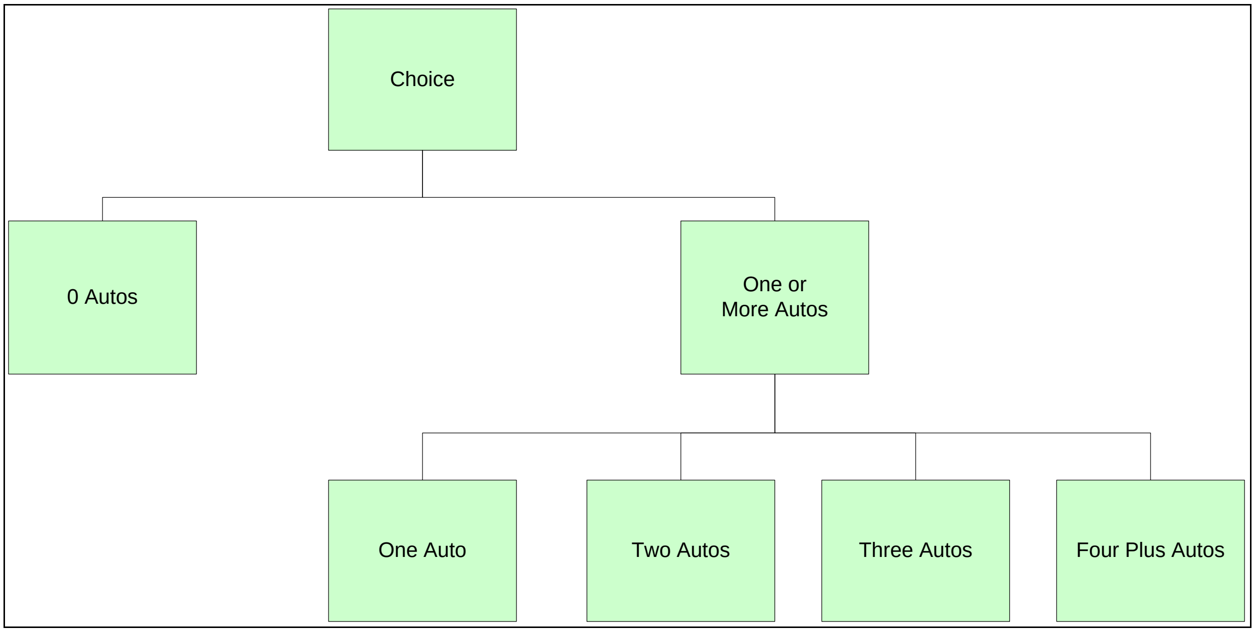
The model includes the following explanatory variables:

- 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 1.2, above.

Figure T.4

Auto Ownership Nesting Structure



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 1.2)

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.2. 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 the CT-RAMP system for SANDAG 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 each 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 application 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 prices 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: a pre-school model, a grade school model, a high school model, and a university model.

The pre-school mandatory 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: College enrollment, which measures enrollment at major colleges and universities; other college enrollment, which measures enrollment at community colleges, and 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

3.1 Employer Parking Provision Model

Number of Models: 1
Decision-Making Unit: Workers whose workplace is in CBD or other priced-parking area (parkarea1)
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 *parkarea1* 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.

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 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 model 3.1.

The explanatory variables in model 3.2 include the ones listed under 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. The auto dependency variable is calculated according to the following formula:

$Dependency_{auto} = min((Logsum_{auto} – Logsum_{transit})/3 , 1.0) * Factor_{non\text{-}motorized}$

Where:

$Factor_{non\text{-}motorized} = 0.5 * min((max(Distance_{home,work/school}, 1.0), 3.0)) – 0.5$

The non-motorized factor takes a value of 0 if the distance between home and work or school is less than one mile. If the distance between home and work/school is between one and three miles, the factor takes a value between 1.0 and 3.0. If the distance between home and work/school is greater than 3 miles (which serves as an upper cap on walkability), the non-motorized factor takes the maximum value of 1.0. The effect of this factor is to reduce the auto dependency variable if the work or school location is within walking distance of the residential MGRA.

The difference between auto and transit utility is divided by 3.0 to represent the resulting utility difference in units of hours (assuming an 'average' time coefficient of -0.05 multiplied by 60 minutes per hour). The difference is capped at 1.0, in effect representing the difference in scaled utility as a fraction between zero and one.

The household mandatory activity rail mode index is calculated using the ratio of the rail mode in-vehicle time over the total transit in-vehicle time for trips that used rail as part of their transit path, stratified by person type (worker versus student). The household rail mode index is obtained by aggregating individual rail indices of worker/student members in the household. All mandatory mode choice logsums and accessibilities are calculated using AM peak skims.

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). They are fully described under 1.2, above.

The average expected travel time savings provided by toll facilities to work is calculated using a simplified destination choice logsum. The expected travel time savings of households in a zone z is:

$$\frac{\sum_d (AutoTime_{zd} - TollTime_{zd}) \cdot Employment_d \cdot \exp(-0.01\ AutoTime_{zd})}{\sum_d Employment_d \cdot \exp(-0.01\ AutoTime_{zd})}$$

The times are calculated in minutes and include both the AM peak travel time to the destination and the PM peak time returning from the destination. The percent difference between the AM non-toll travel time to downtown zone 3781 and the AM non-toll travel time to downtown when the general purpose lanes parallel to all toll lanes requiring transponders were made unavailable in the path-finder. This variable is calculated as:

$$\frac{Non\ Toll\ Time\ Avoiding\ Facility - Non\ Toll\ Time}{Non\ Toll\ Time}.$$

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 (see Table T.10)

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 a number of 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.10. Note that the choices are available based on household size. There are also two facets of the model that reduce the complexity. First of all, mandatory DAP types are only available for appropriate person types (workers and students). Even 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.10

Number of Choices in CDAP Model

Household Size	Alternatives – no Joint Travel	Alternatives with Joint Travel	All Alternatives
1	3	0	3
2	3x3=9	3x3-(3x2-1)=4	13
3	3x3x3=27	3x3x3-(3x3-2)=20	47
4	3x3x3x3=81	3x3x3x3-(3x4-3)=72	153
5 or more	3x3x3x3x3=243	3x3x3x3x3-(3x5-4)=232	475
Total	363	328	691

The structure is shown graphically in Figure T.5 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).

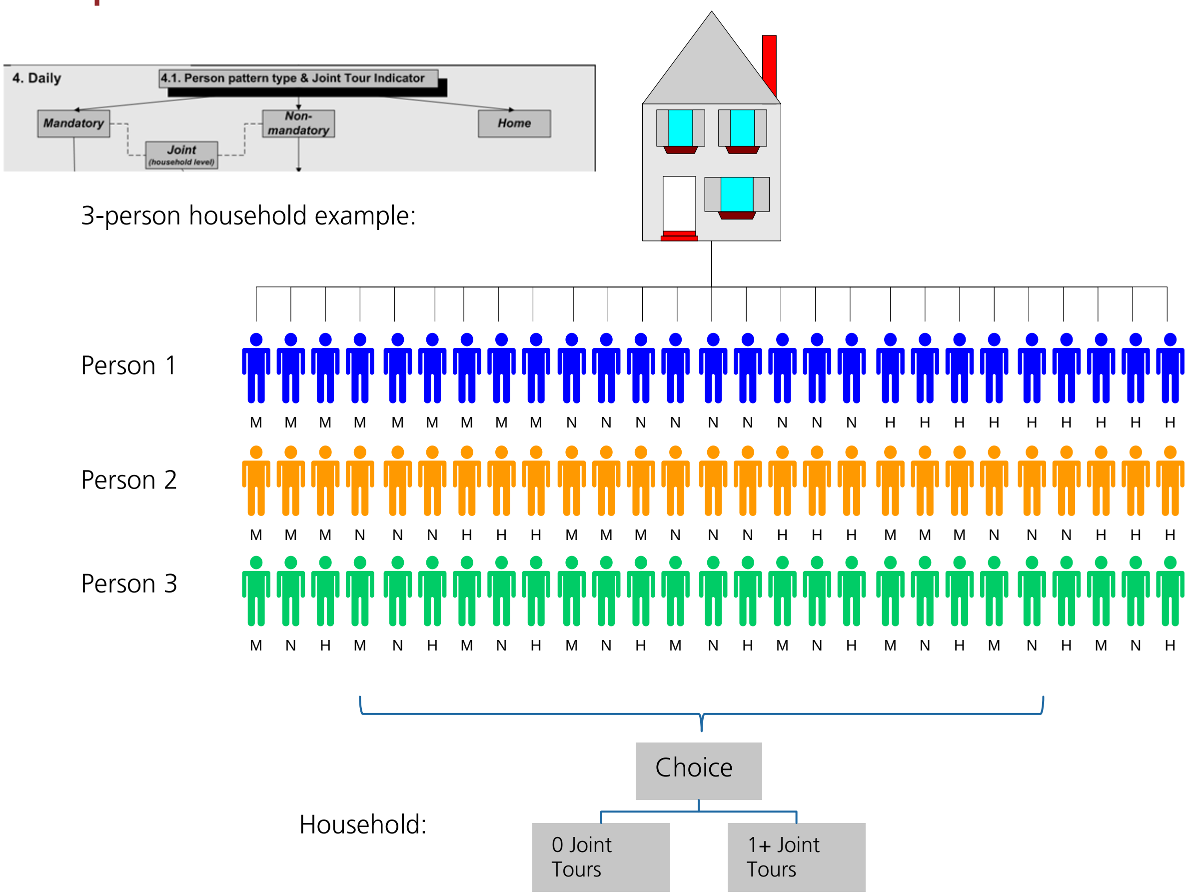
The CDAP model explanatory variables include:

- Household Size
- Number of Adults in household
- Number of children in household
- Auto Sufficiency
- 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 1.2)

Figure T.5

Example of DAP Model Alternatives for a 3-Person Household



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 Work Tour, 2 or more Work Tours, 1 School Tour, 2 or more School Tours, 1 Work/1 School Tour.

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

- Auto sufficiency
- Household income
- Non-family household 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 1.2)

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 Model 2.1. 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.

For model estimation, the following practical rules can be 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 × 42/2 = 861 choice alternatives.

The network simulations to obtain travel time and cost skims are implemented for five broad periods, early A.M., A.M. peak, midday, P.M. peak, and 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

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.6)

This model determines 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.6. 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 bicycle trips is significant.

Note that free and pay alternatives for each auto mode provide an opportunity for toll choice as a path choice within the nesting structure. This requires separate free and pay skims to be provided as inputs to the model (where free paths basically "turn off" all toll and HOT lanes). Transit skims are segmented by local versus premium (express bus, BRT, LRT, and commuter rail) modes, but as described, the mode used for the longest segment of in-vehicle time is used to define the actual premium ride mode in the creation of transit level-of-service. Transit ride modes are based on a modal hierarchy in which modes that are ranked lower in the hierarchy are used as feeder modes to modes ranked higher. Table T.11 describes skims used in tour mode choice. A number of mode codes have been reserved for future use.

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 also 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 estimation and application process 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 line-haul 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 same as the trip mode choice model alternatives) are:

- Drive-alone Free
- Drive-Alone Pay
- Shared-Ride 2 Free (General Purpose Lane)
- Shared-Ride 2 Free (HOV Lane)
- Shared-Ride 2 Pay
- Shared-Ride 3+ Free (General Purpose Lane)
- Shared-Ride 3+ Free (HOV Lane)
- Shared-Ride 3+ Pay
- Walk
- Bike
- Walk-Local Bus
- Walk-Express Bus
- Walk-Bus Rapid Transit
- Walk-Light Rail Transit

- Walk-Commuter Rail
- PNR-Local Bus
- PNR-Express Bus
- PNR-Bus Rapid Transit
- PNR-Light Rail Transit
- PNR-Commuter Rail
- KNR-Local Bus
- KNR-Express Bus
- KNR-Bus Rapid Transit
- KNR-Light Rail Transit
- KNR-Commuter Rail
- 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, are based on a selection of the path with the best overall utility for each of five transit ride modes (local bus, express bus, bus rapid-transit, light-rail, and heavy rail).

Figure T.6

Tour Mode Choice Model Structure

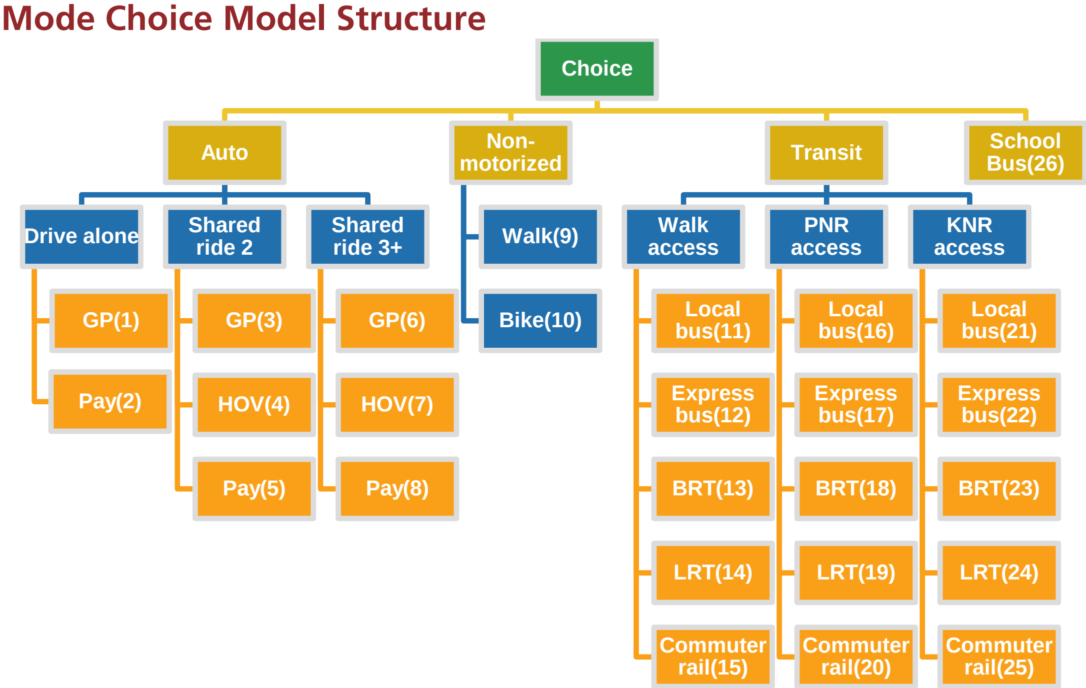


Table T.11

Skims Used in Tour Mode Choice

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	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, Non-HOV	All general purpose lanes available. HOV lanes, HOT lanes, and toll lanes unavailable. Toll bridges are available.
Shared-2 Non-Toll, HOV	All general purpose lanes available. 2+ occupancy HOV lanes available. Toll lanes unavailable. HOT lanes where 2+ occupant vehicles go free are available. Toll bridges are available.
Shared-2 Toll, HOV	All general purpose lanes available. 2+ occupancy HOV lanes and HOT lanes where 2+ occupant vehicles go free are available for free. Toll lanes and HOT lanes where 2-occupant vehicles are tolled at the 2-occupant toll rate. Toll bridges are available.
Shared-3+ Non-Toll, Non-HOV	All general purpose lanes available. HOV lanes, HOT lanes, and toll lanes unavailable. Toll bridges are available.
Shared-3+ Non-Toll, HOV	All general purpose lanes available. 2+ and 3+ occupancy HOV lanes available. Toll lanes unavailable. HOT lanes where 2+ or 3+ occupant vehicles go free are available. Toll bridges are available.
Shared-3+ Toll, HOV	All general purpose lanes available. 2+ and 3+ occupancy HOV lanes and HOT lanes where 2 or 3+ occupant vehicles go free are available for free. Toll lanes and HOT lanes where 3+ occupant vehicles are tolled at the 3+ occupant toll rate. Toll bridges are available.
Walk	Highway 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	Highway 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	Local Bus TAP-to-TAP skims, including in-vehicle time, first wait time, transfer wait time, and fare.
Transit-Premium	Premium TAP-to-TAP skims, including in-vehicle time, first wait time, transfer wait time, and fare. These include local bus as a feeder mode, as well as express bus, bus rapid transit, light rail, and commuter rail. A premium mode designator is also included in the skim for each interchange, to identify which of the 4 premium ride-modes is used, based on the mode for which the greatest distance was travelled.

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

4.3 Generation of Joint Household Tours

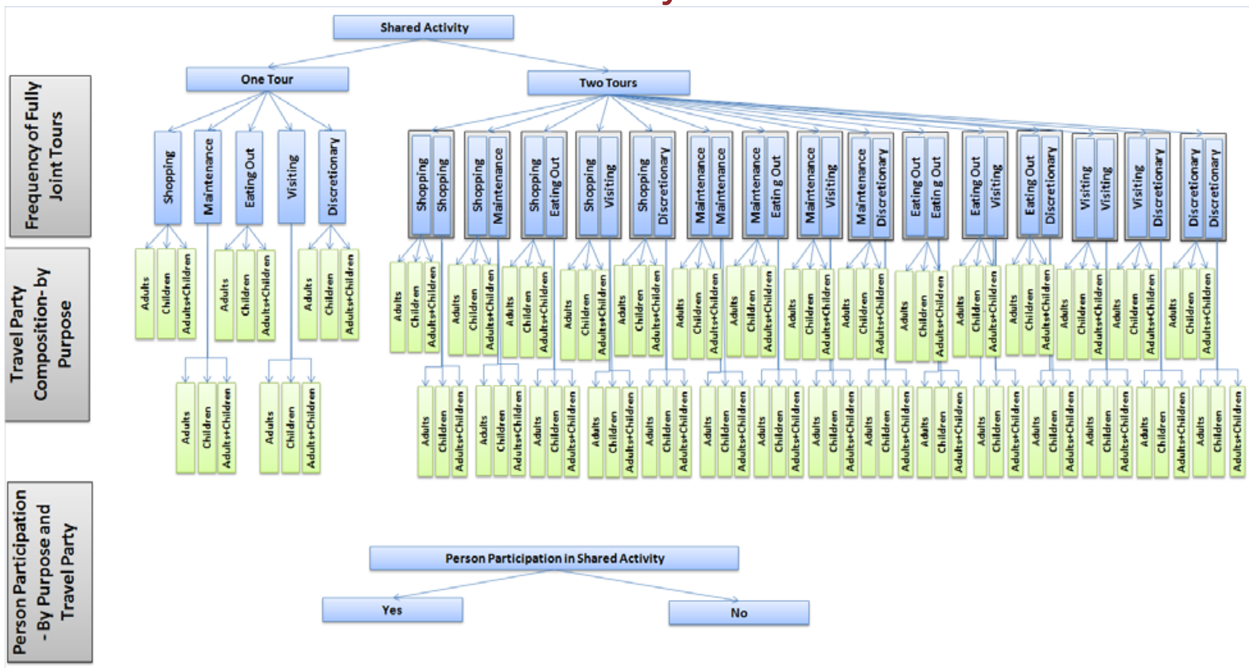
In the CT-RAMP structure, joint travel for non-mandatory activities is modeled explicitly in the form of fully joint tours (where all members of the travel party travel together from the beginning to the end and participate in the same activities). This accounts for more than 50 percent of joint travel.

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.7.

- 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.7
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.

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 1.2
- Maintenance HOV Accessibility from household MGRA to employment (accessibility terms #13, 14, 15 (by auto sufficiency) , see section 1.2
- Discretionary HOV Accessibility from household MGRA to employment (accessibility terms #22, 23, 24 (by auto sufficiency) , see section 1.2
- 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

4.3.2 Joint Tour Participation

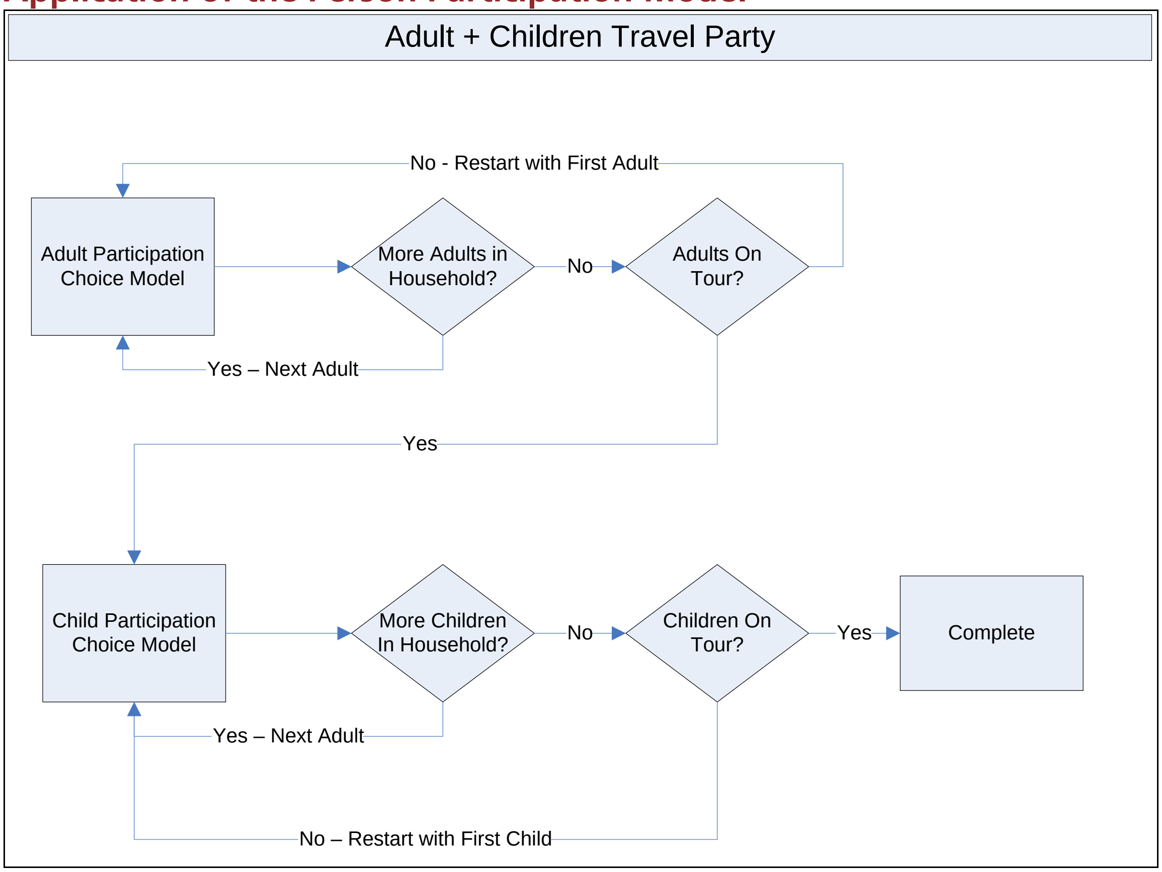
Number of Models:	1
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	2 (Yes or No)

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.8.

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.8
Application of the Person Participation Model



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 1.2)
- The size of each sampled MGRA by tour purpose (see section 1.2)

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 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

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.6 under the Individual Mandatory Tour Mode Choice Section)

Like the individual mandatory tour mode choice model, the joint tour model determines 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 Free (General Purpose Lane)
- Shared-Ride 2 Free (HOV Lane)
- Shared-Ride 2 Pay
- Shared-Ride 3+ Free (General Purpose Lane)
- Shared-Ride 3+ Free (HOV Lane)
- Shared-Ride 3+ Pay
- Walk
- Bike
- Walk-Local Bus
- Walk-Express Bus
- Walk-Bus Rapid Transit
- Walk-Light Rail Transit
- Walk-Commuter Rail
- PNR-Local Bus
- PNR-Express Bus
- PNR-Bus Rapid Transit
- PNR-Light Rail Transit
- PNR-Commuter Rail
- KNR-Local Bus
- KNR-Express Bus
- KNR-Bus Rapid Transit
- KNR-Light Rail Transit
- KNR-Commuter Rail

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

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

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 escorting, shopping, other maintenance, eating out, visiting, and other discretionary. The non-mandatory tour primary destination choice model determines the location of the tour primary destination for each of the 6 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 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

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 model is fully described under 4.1.2, above. 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

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.6 under the Individual Mandatory Tour Mode Choice Section)

Like the individual mandatory tour mode choice model, the individual non-mandatory tour model determines 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 Free
- Drive-Alone Pay
- Shared-Ride 2 Free (General Purpose Lane)
- Shared-Ride 2 Free (HOV Lane)
- Shared-Ride 2 Pay
- Shared-Ride 3+ Free (General Purpose Lane)
- Shared-Ride 3+ Free (HOV Lane)
- Shared-Ride 3+ Pay
- Walk
- Bike
- Walk-Local Bus
- Walk-Express Bus
- Walk-Bus Rapid Transit
- Walk-Light Rail Transit
- Walk-Commuter Rail
- PNR-Local Bus
- PNR-Express Bus
- PNR-Bus Rapid Transit
- PNR-Light Rail Transit
- PNR-Commuter Rail
- KNR-Local Bus
- KNR-Express Bus
- KNR-Bus Rapid Transit

- KNR-Light Rail Transit
- KNR-Commuter Rail

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

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 1.2

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 a 'representative' time period for individual non-mandatory tours, which is currently off-peak, since the actual time period is not chosen until model 3.6.3. 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

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 3.1.2, 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

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.6 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 tour mode" used to get from the origin to the primary destination and back is determined.

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

- Drive-alone Free
- Drive-Alone Pay
- Shared-Ride 2 Free (General Purpose Lane)
- Shared-Ride 2 Free (HOV Lane)
- Shared-Ride 2 Pay
- Shared-Ride 3+ Free (General Purpose Lane)
- Shared-Ride 3+ Free (HOV Lane)
- Shared-Ride 3+ Pay

- Walk
- Bike
- Walk-Local Bus
- Walk-Express Bus
- Walk-Bus Rapid Transit
- Walk-Light Rail Transit
- Walk-Commuter Rail
- PNR-Local Bus
- PNR-Express Bus
- PNR-Bus Rapid Transit
- PNR-Light Rail Transit
- PNR-Commuter Rail
- KNR-Local Bus
- KNR-Express Bus
- KNR-Bus Rapid Transit
- KNR-Light Rail Transit
- KNR-Commuter Rail

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

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 3) for a total of 8 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)

The observed stop frequency distributions are given in Table T.12 and Table T.13.

Table T.12

Observed Stop Frequency Distribution by Tour Purpose

		Primary Tour Purpose									
Inbound Stops	Outbound Stops	Work	University	School	Escorting	Shopping	Maintenance	Eating Out	Visiting	Discretionary	Total
0	0	2,061	174	1,162	1,038	726	869	336	318	968	7,652
1	0	511	22	203	151	141	165	26	35	118	1,372
2	0	124	6	40	36	34	66	2	3	26	337
3	0	85	2	31	18	18	27	0	11	10	202
0	1	294	23	84	84	216	95	17	41	64	918
1	1	154	8	73	25	62	43	11	19	30	425
2	1	47	3	19	5	20	13	0	5	15	127
3	1	32	1	7	2	14	10	0	0	2	68
0	2	78	5	6	23	56	22	3	12	15	220
1	2	27	0	7	11	22	18	4	1	9	99
2	2	22	0	3	0	14	5	2	1	8	55
3	2	15	0	0	2	2	2	0	1	2	24
0	3	17	0	3	10	20	11	3	7	6	77
1	3	13	1	0	6	11	8	0	2	2	43
2	3	9	0	0	1	1	5	0	0	7	23
3	3	5	0	0	1	5	1	0	0	1	13
Total		3,494	245	1,638	1,413	1,362	1,360	404	456	1,283	11,655

Table T.13
Observed Stop Frequency Distribution by At-work Sub Tour Purpose

Inbound Stops	Outbound Stops	At-Work Sub Tour EPurpose
0	0	441
1	0	25
2	0	2
3	0	1
0	1	26
1	1	8
2	1	2
3	1	0
0	2	1
1	2	0
2	2	0
3	2	0
0	3	1
1	3	0
2	3	0
3	3	0
Total		507

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 will be a lookup table of probabilities based upon tour purpose, stop direction, departure time, and person type.

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 3 stops in outbound and 3 stops in inbound direction are modeled for each tour. Since there are a large number (over 33,000) 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:

1. Household Income
2. Gender
3. Age
4. Mode choice logsum
5. Distance deviation or "out-of-the-way" distance for stop location when compared to the half-tour distance without detour for any stop
6. Distance of stop location from tour origin and destination is used to define closeness to tour origin or destination.
7. Stop purpose
8. Tour purpose
9. Tour mode
10. Stop Number
11. Direction of the half-tour

    Size variables:

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

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 will be a lookup table of probabilities based upon tour purpose, stop direction, tour departure time, and stop number.

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.6)

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. In particular, 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.14. Note that in the SANDAG trip mode choice model, the trip modes are exactly 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 are 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 with the exception of driving alone and biking, since these modes imply that the traveler is attached to the mode of transport (the auto or bicycle) 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 will break 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 sufficiency
- Age
- Gender
- Tour mode
- Individual or joint tour indicator
- Number of outbound and return stops
- First and last stop indicators
- 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

Table T.14

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 Free	A	A	A				A	
Drive-Alone Pay	A	A	A				A	
Shared-Ride 2 Free (GP Lane)		A	A			A	A	A
Shared-Ride 2 Free (HOV Lane)		A	A			A	A	A
Shared-Ride 2 Pay		A	A			A	A	A
Shared-Ride 3+ Free (GP Lane)			A			A	A	A
Shared-Ride 3+ Free (HOV Lane)			A			A	A	A
Shared-Ride 3+ Pay			A			A	A	A
Walk		A	A	A		A	A	A
Bike					A			
Walk-Local Bus						A	A	A
Walk-Express Bus						A	A	A
Walk-Bus Rapid Transit						A	A	A
Walk-Light Rail Transit						A	A	A
Walk-Commuter Rail						A	A	A
PNR-Local Bus							A	
PNR-Express Bus							A	
PNR-Bus Rapid Transit							A	
PNR-Light Rail Transit							A	
PNR-Commuter Rail							A	
KNR-Local Bus								A
KNR-Express Bus								A
KNR-Bus Rapid Transit								A
KNR-Light Rail Transit								A
KNR-Commuter Rail								A
School Bus	Available for school bus tour mode only, on school tours.							

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

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:	*In estimation,* lots sampled in the parking behavior survey *In application,* 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 *parkarea 1* (downtown San Diego area). For work trips, the model will subtract 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 will be 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

Special Market Models

Cross border model

In 2010, SANDAG collected data on Mexican resident border crossings into the United States and their travel patterns within the US. Data was collected at the three border crossing stations – San Ysidro, Otay Mesa, and Tecate. Based upon this data, PB is developing a travel demand model for Mexican residents. The purpose of this model is two-fold. The primary purpose of the model is to measure the impact of Mexican resident travel on the San Diego transport network. The model will account for Mexican resident demand (such as auto volume, transit boarding, and toll revenue) for transportation infrastructure in San Diego County. The other purpose of the model is to forecast border crossings at each current and potential future border crossing station.

The model flow and inputs are shown in Figure T.10, and described in detail in the following sections.

Cross Border Modeled Travel Dimensions

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 US.
- **School:** At least one trip on the tour is made for attending school in the US, 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 US, 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 US.
- **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 US.
- **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).

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 also 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 US Visa, Mexican passport, and contact number in the US. This typically means that in order to obtain a pass, Mexican residents must be lawfully employed in the US.

Trip Mode

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

Treatment of Time

Every trip will be allocated to a half-hourly period consistent with the resident travel demand model treatment of time. Travel skims will also be consistent with resident travel demand models; currently there are three sets of skims, for the AM peak, PM peak, and off-peak periods. Eventually the off-peak period will be represented as four time periods (early AM, early midday, late midday, and evening), for a total of six sets of skims.

Treatment of Space

Every trip end in San Diego County will be allocated to an MGRA. Within Tijuana, each border crossing origin will be 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 will be distributed to a *localidad*, or locality. These units are similar to the Census Designated Place in the US.

Figure T.9

Total Population of Áreas Geoestadísticas Básicas (AGEB) in Tijuana

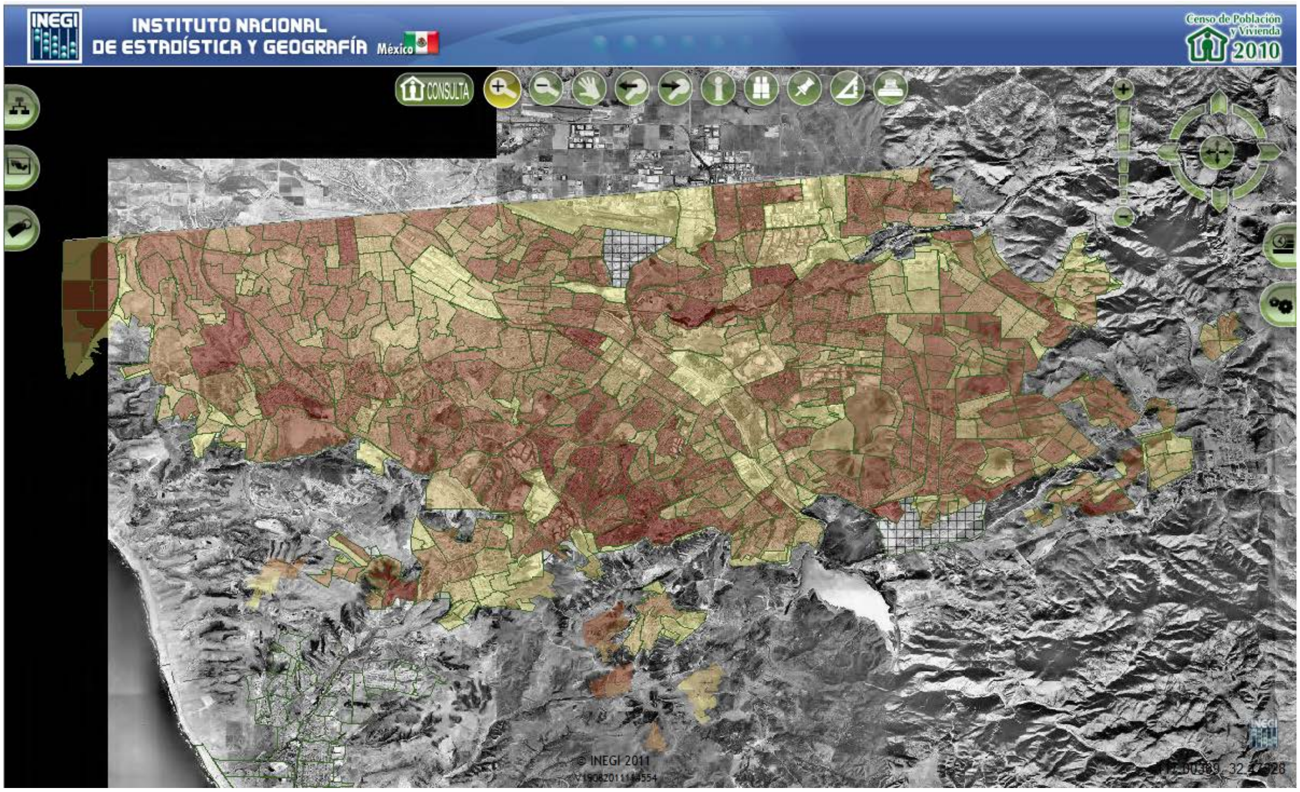
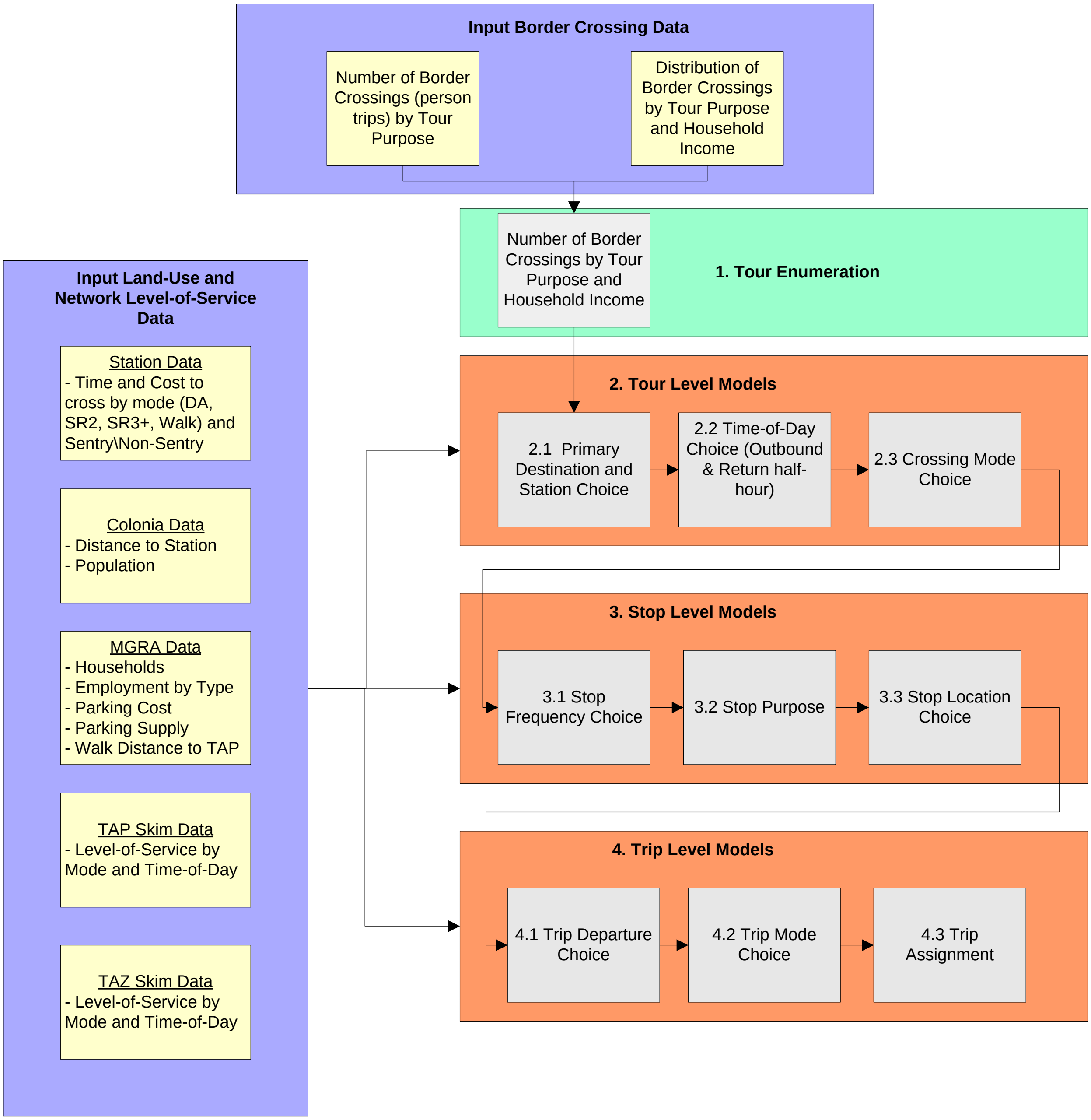


Figure T.10

Mexican Resident Travel Model



2.1 Border Crossing Primary Destination and Station Crossing Choice

Number of Models:	6 (Work, School, Cargo, Shop, Visit, Other)
Decision-Making Unit:	Person-tour
Model Form:	Multinomial Logit
Alternatives:	MGRAs and border crossing stations

The primary destination and border crossing choice model is a joint choice model of tour primary destination in the US and border crossing station. Due to the number of alternatives in the model, sampling will be used to select a sub-set (50) of primary destination MGRAs and border crossing pairs. The sampling procedure will be based upon a simplified destination choice model that takes into account:

- The weighted distance from the TAZ to all border crossing stations S
- The time and cost that it takes to cross each station S
- The accessibility of the border crossing station to persons in Mexico

The explanatory variables in the primary destination and station crossing choice model are:

- Distance
- Station index
- The tour mode choice logsum for the traveler from the residence MGRA to each sampled destination MGRA using a representative departure and arrival periods for each purpose.
- Station accessibility to population
- The size of each sampled MGRA

2.2 Border Crossing Tour Time-of-Day Choice

Number of Models:	1-6 (Work, School, Cargo, Shop, Visit, Other – depending on significance of purpose-specific parameters)
Decision-Making Unit:	Person-tour
Model Form:	Lookup table
Alternatives:	820 (combinations of border entry half-hour and return half-hour, with aggregation between 1 AM and 5 AM)

The border crossing tour time of day choice model will be a lookup table of probabilities based upon tour purpose, tour entry and tour return.

2.3 Border Crossing Tour Mode Choice

Number of Models:	1-6 (Work, School, Cargo, Shop, Visit, Other – depending on significance of purpose-specific parameters)
Decision-Making Unit:	Person-tour
Model Form:	Multinomial or Nested Logit
Alternatives:	Tour Mode (4: Drive Alone, Shared 2 person, Shared 3+ person, Walk)

This model chooses tour mode based on a known tour destination, border crossing station, and entry/return time-of-day. The mode choice will be based upon a simplified trip mode choice logsum representing the accessibility of relevant modes for each border crossing mode as well as the time and cost of crossing the station by border crossing mode.

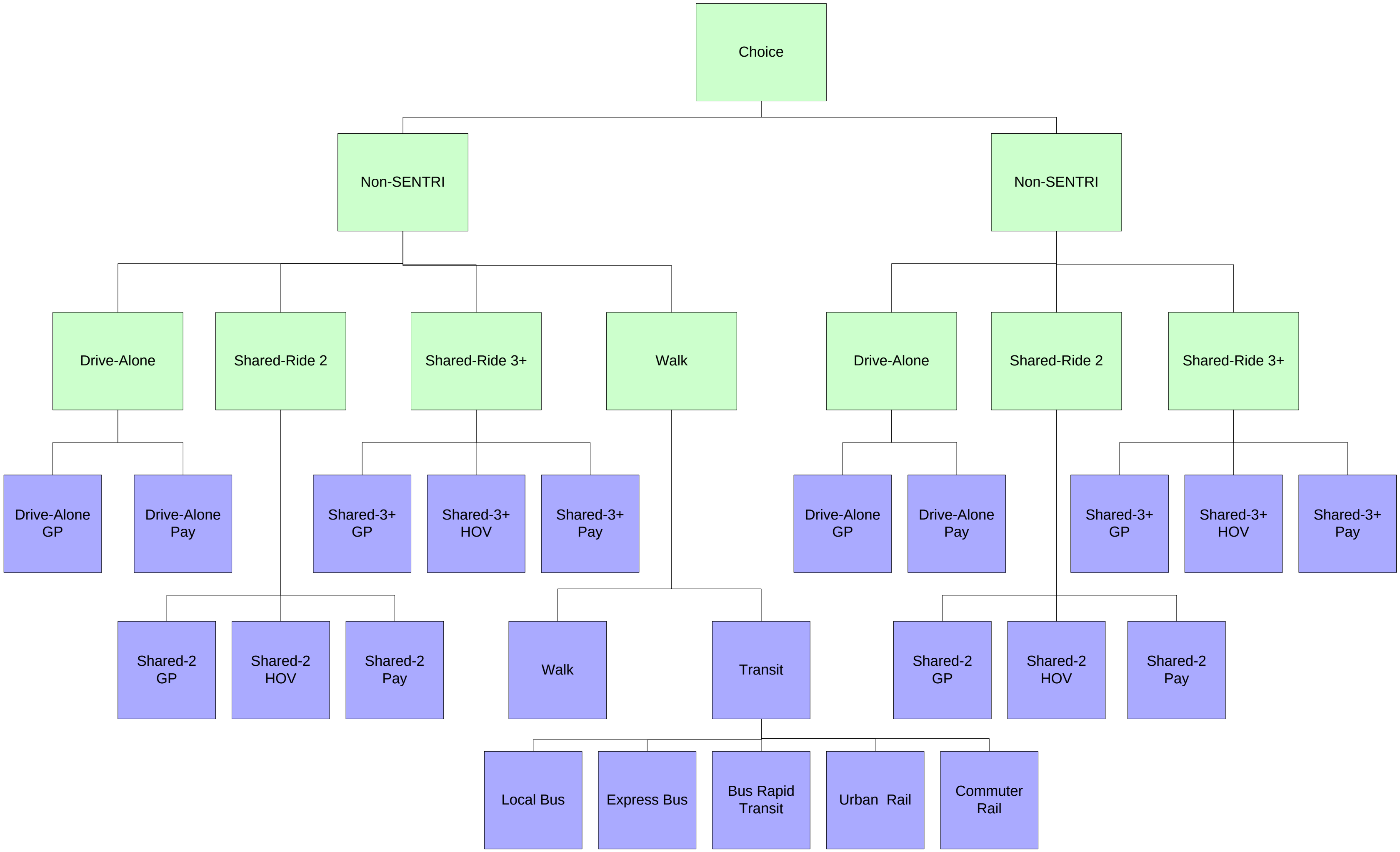
Figure T.11 shows a potential nesting structure of the border crossing mode choice model. In this figure, trip modes are shown in blue and border crossing modes are shown in green. The choice of mode will be made from one of the green (border crossing mode) alternatives, but the accessibility between the border crossing station and the tour primary destination by the trip modes shown in blue will influence the choice.

The border crossing tour mode choice model includes the following explanatory variables:

- Traveler has a SENTRI pass indicator
- Trip mode choice logsum by mode and stop direction
- Border wait time for automobiles
- Border wait time for travelers with a SENTRI pass
- Border wait time for pedestrians

Figure T.11

Potential Border Crossing Mode Choice Nesting Structure



3.1 Border Crossing Stop Frequency Choice

Number of Models: 1-6 (Work, School, Cargo, Shop, Visit, Other – depending on significance of purpose-specific parameters)
Decision-Making Unit: Person-tour
Model Form: Lookup table
Alternatives: 16 (0, 1, 2, 3 stops per half-tour)

The stop frequency choice model will be a lookup table of probabilities based upon tour purpose and duration.

3.2 Border Crossing Stop Purpose Choice

Number of Models: 1-6 (Work, School, Cargo, Shop, Visit, Other – depending on significance of purpose-specific parameters)
Decision-Making Unit: Stop
Model Form: Lookup table
Alternatives: 6 (Work, School, Cargo, Shop, Visit, Other)

The stop purpose choice model will be a lookup table of probabilities based upon tour purpose and number of stops on tour. The purpose-segmentation will be based on the tour purpose, if implemented.

3.3 Border Crossing Stop Location Choice

Number of Models: 1 (with stop-purpose-specific size terms)
Decision-Making Unit: Stop
Model Form: Multinomial Logit
Alternatives: MGRAs

The stop location choice model predicts the location of stops along the tour other than the primary destination. The stop-location model is structured as a multinomial logit model using MGRA attraction size variable and route deviation measure as impedance. The alternatives are sampled from the full set of MGRAs, based upon the out-of-direction distance to the stop and the size of the MGRA. The sampling mechanism is also subject to certain rules based on tour mode. All destinations are available for auto tour modes, so long as there is a positive size term for the MGRA. Intermediate stops on walk tours must be within 3 miles of both the tour origin and primary destination MGRAs. The sampling for intermediate stops on walk-transit tours is based upon the MGRAs that are within walking distance of the boarding or alighting stops at the tour origin and primary destination.

The intermediate stop location choice model works by cycling through stops on tours. The level-of-service variables (including mode choice logsums) are calculated as the additional utility between the last location and the next known location on the tour. For example, the LOS variable for the first stop on the outbound direction of the tour is based on additional impedance between the tour origin and the tour primary destination. The LOS variable for the next outbound stop is based on the additional impedance between the previous stop and the tour primary destination. Stops on return tour legs work similarly, except that the location of the first stop is a function of the additional impedance between the tour primary destination and the tour origin. The next stop location is based on the additional impedance between the first stop on the return leg and the tour origin, and so on.

The cross border stop location choice model explanatory variables included were:

- Mode choice logsum
- Tour duration
- Distance of stop location from tour origin and destination is used to define closeness to tour origin or destination
- Stop Number
- Direction of the half-tour
- Stop frequency
- The size of each sampled stop location MGRA

4.1 Border Crossing Trip Departure Choice

Number of Models: 1
Decision-Making Unit: Trips other than first trip and last trip on tour
Model Form: Lookup from Probabilities
Alternatives: Number of half-hour time after outbound period for outbound trips/number of half-hour time periods before return period for return trips

Each trip will be assigned to a trip departure time period. The first and last trips of the tour are set to the entry/return time periods from Model 2.2, respectively. Each intermediate trip departure time is calculated from a lookup table of probabilities that consider the number of remaining half-hour periods in the tour from the last scheduled trip and whether the stop is made on the outbound or return direction.

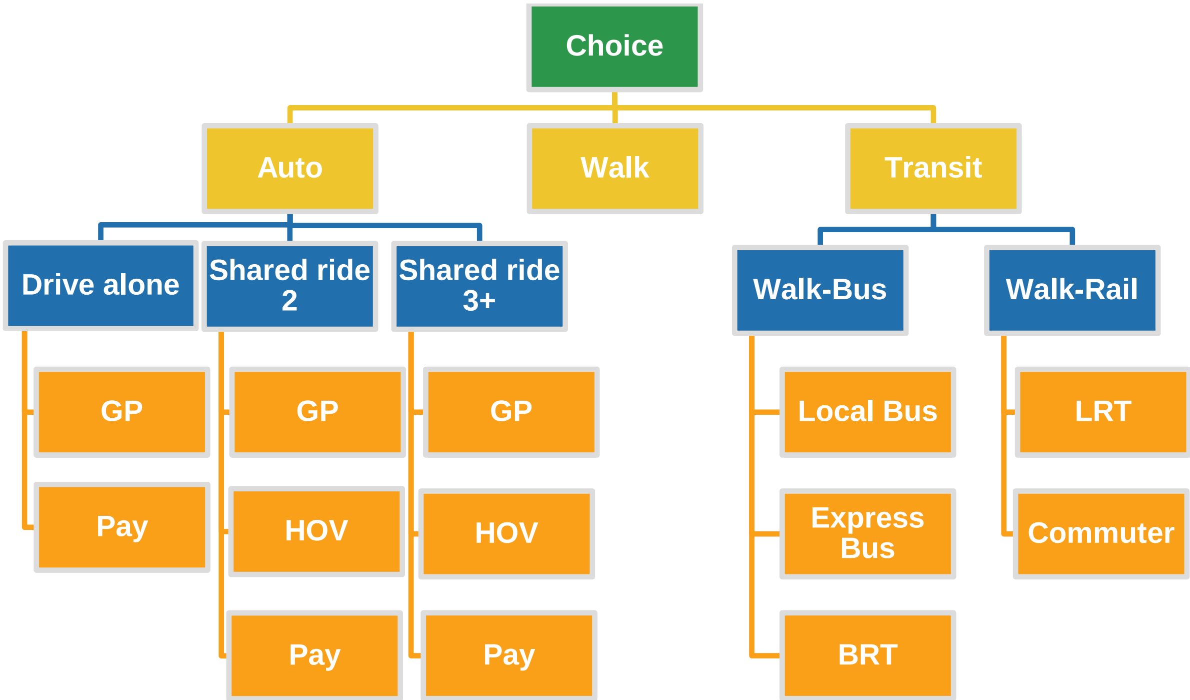
4.2 Border Crossing Trip Mode Choice

Number of Models: 1
Decision-Making Unit: Trip
Model Form: Nested Logit
Alternatives: 13 Trip Modes

A trip mode is chosen for each trip on the tour. Trip modes are consistent with the resident travel model, as shown in Figure T.12, though certain modes (bike, drive-transit, and school bus) are unavailable for Mexican residents. The utility of each mode is a function of the time and cost of the mode for the period that the trip occurs in, and is influenced by the mode used to cross the border.

Figure T.12

Mexican Resident Trip Mode Choice Model for Travel in US



The border crossing trip mode choice model includes the following explanatory variables:

- Tour mode
- Tour purpose
- Traveler has a SENTRI pass indicator
- 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

Airport ground access model

In 2008, San Diego International Airport (SDIA) conducted a survey of airport passengers in which data was collected on their travel to the airport prior to their departure. Based upon this data, PB is developing a model of travel to and from the airport for arriving and departing passengers. The purpose of this model is to capture the demand of airport travel on transport facilities in San Diego County. Additionally, the model will allow SANDAG to test the impacts of various parking price and supply scenarios at the airport.

The 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.13, and described in detail in the following sections.

Airport Model Travel Dimensions

Airport Model Trip Purposes

There are four trip purposes and these 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)

Airport Model Trip Mode

The model of airport ground access will be 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 will be 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. The number of survey respondents by trip mode is listed in Table T.15, and shares of respondents by trip mode are shown in Table T.16. Note that if private auto is used to access the airport, the choice of parking versus curbside pickup/dropoff is explicitly represented. For travelers that park, the chosen lot (terminal, airport remote lot, private remote lot) is explicit as well. Also note that auto occupancy is not a choice for airport ground access trips. Auto occupancy will be based upon travel party size, which will be simulated as part of the attribution of ground access trips.

Table T.15

Survey Respondents by Purpose and Trip Mode

Mode	Purpose*					Total
	Res-Bus	Res-Pers	Vis-Bus	Vis-Pers	External	
Unknown/Walk	1	7	7	5	2	22
Park-terminal	163	133	14	66	39	415
Park-SAN Offsite	61	74	3	4	12	154
Park-PVT Offsite	174	253	6	7	33	473
PUDO-Escort	39	100	18	53	27	237
PUDO-Curbside	627	1,538	310	1,096	205	3,776
Rental Car	9	9	695	761	123	1,597
Taxi/Limo/Towncar	155	227	520	288	15	1,205
Shuttle	66	143	301	259	21	790
Transit	13	32	10	38	8	101
Total	1,308	2,516	1,884	2,577	485	8,770

Table T.16

Frequency of Survey Respondents by Purpose and Trip Mode

Mode	Purpose					Total
	Res-Bus	Res-Pers	Vis-Bus	Vis-Pers	External	
Park-terminal	12%	5%	1%	3%	8%	5%
Park-SAN Offsite	5%	3%	0%	0%	2%	2%
Park-PVT Offsite	13%	10%	0%	0%	7%	5%
PUDO-Escort	3%	4%	1%	2%	6%	3%
PUDO-Curbside	48%	61%	16%	43%	42%	43%
Rental Car	1%	0%	37%	30%	25%	18%
Taxi/Limo/Towncar	12%	9%	28%	11%	3%	14%
Shuttle	5%	6%	16%	10%	4%	9%
Transit	1%	1%	1%	1%	2%	1%
Total	100%	100%	100%	100%	100%	100%

Airport Model Treatment of Time

Every trip will be allocated to a half-hour period consistent with the resident travel demand model treatment of time. Travel skims will also be consistent with resident travel demand models; currently there are three sets of skims, one each for the AM peak, PM peak, and off-peak periods. Eventually the off-peak period will be represented as four time periods (early AM, early midday, late midday, and evening), for a total of six sets of skims.

Airport Model Treatment of Space

Every trip end in San Diego County will be allocated to an MGRA. The trips that are external to the region will be modeled by the internal-external travel model.

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 would be given 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 (as per Table T.15)
  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.

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 will be divided by an average travel party size to convert passengers to travel parties. This will be converted into a list format that will then be 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 will be assumed that 50% of the daily enplanements are arriving passengers and 50% are departing passengers)
   - Departure time for airport

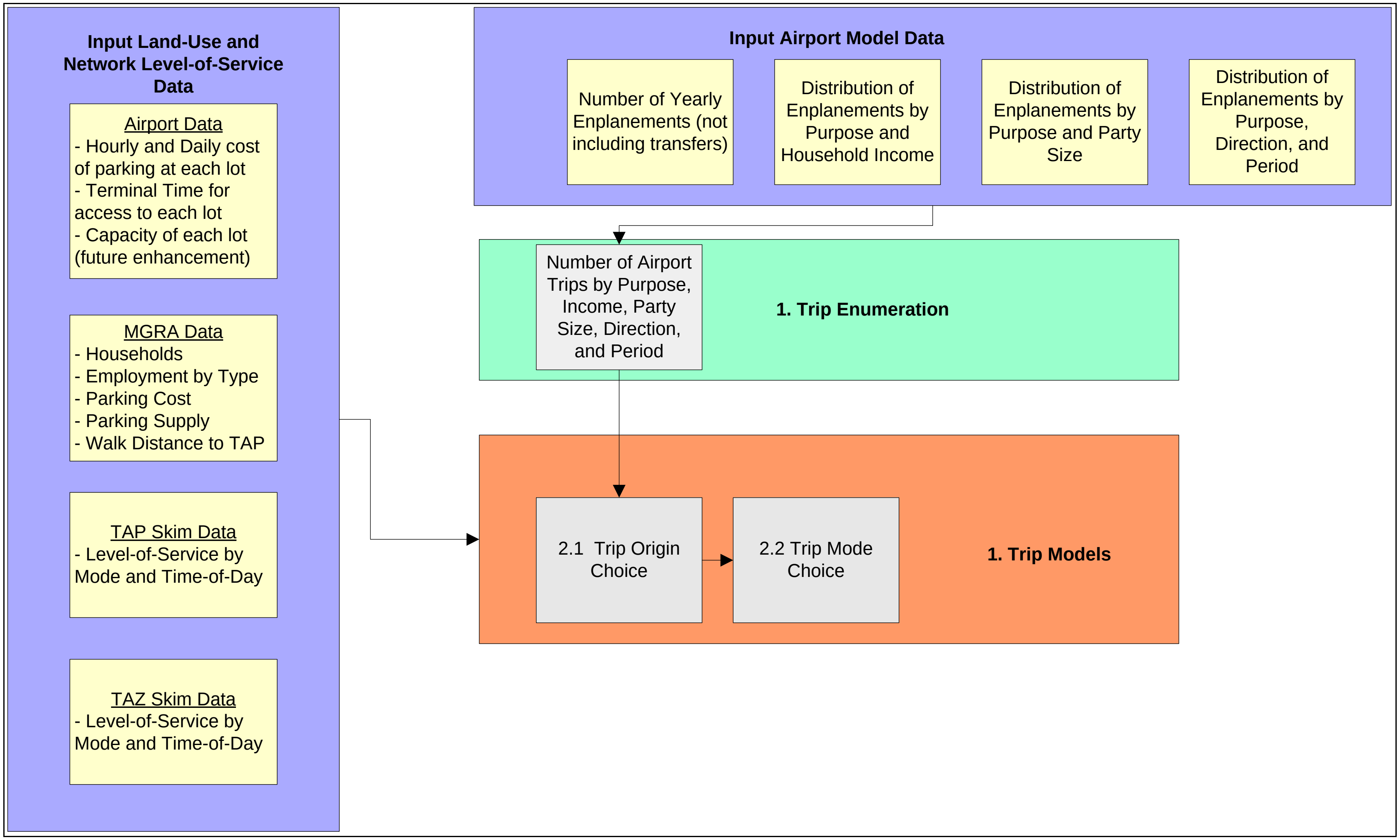
2. **Trip Models**

   2.1. Trip origin: Each travel party will be assigned an origin MGRA.

   2.2. Trip mode: Each travel party will be assigned a trip mode.

Figure T.13

SAN Airport Ground Access Travel Mode



2.1 Airport Destination Choice Model

Number of Models:	4 (Resident-Business, Resident- Personal, Visitor-Business, Visitor-Personal)
Decision-Making Unit:	Travel party
Model Form:	Multinomial Logit
Alternatives:	MGRAs

The airport destination choice model chooses the origin or destination MGRA, depending on whether the travel party is arriving or departing. The model is based upon the airport survey data, which collected the zip code of the origin location for trips made to the airport by departing passengers.

The airport destination choice model explanatory variables include:

- Trip Distance
- La Jolla destination indicator
- Size of sampled MGRA

To speed calculations, the TAZ will be sampled first since distance is the only measure of impedance used to represent accessibility of primary destination to station, and distance is represented at the TAZ level. Zone size in this case will be equal to the sum of the sizes of the MGRAs within the TAZ. Once the TAZ is sampled, an MGRA within the TAZ can be chosen based on the pre-calculated probability of the MGRA within the TAZ, which is based on the MGRA proportion of the TAZ size.

2.2 Airport Trip Mode Choice

Number of Models:	4 (Resident-Business, Resident-Personal, Visitor-Business, Visitor-Personal)
Decision-Making Unit:	Travel party
Model Form:	Nested Logit
Alternatives:	Trip Mode (see Table T.16)

Since the data in the ground access survey is too aggregate to estimate a mode choice model, trip mode was asserted based upon estimation work from applications of the similar models in other regions (for example, for Port of Portland).

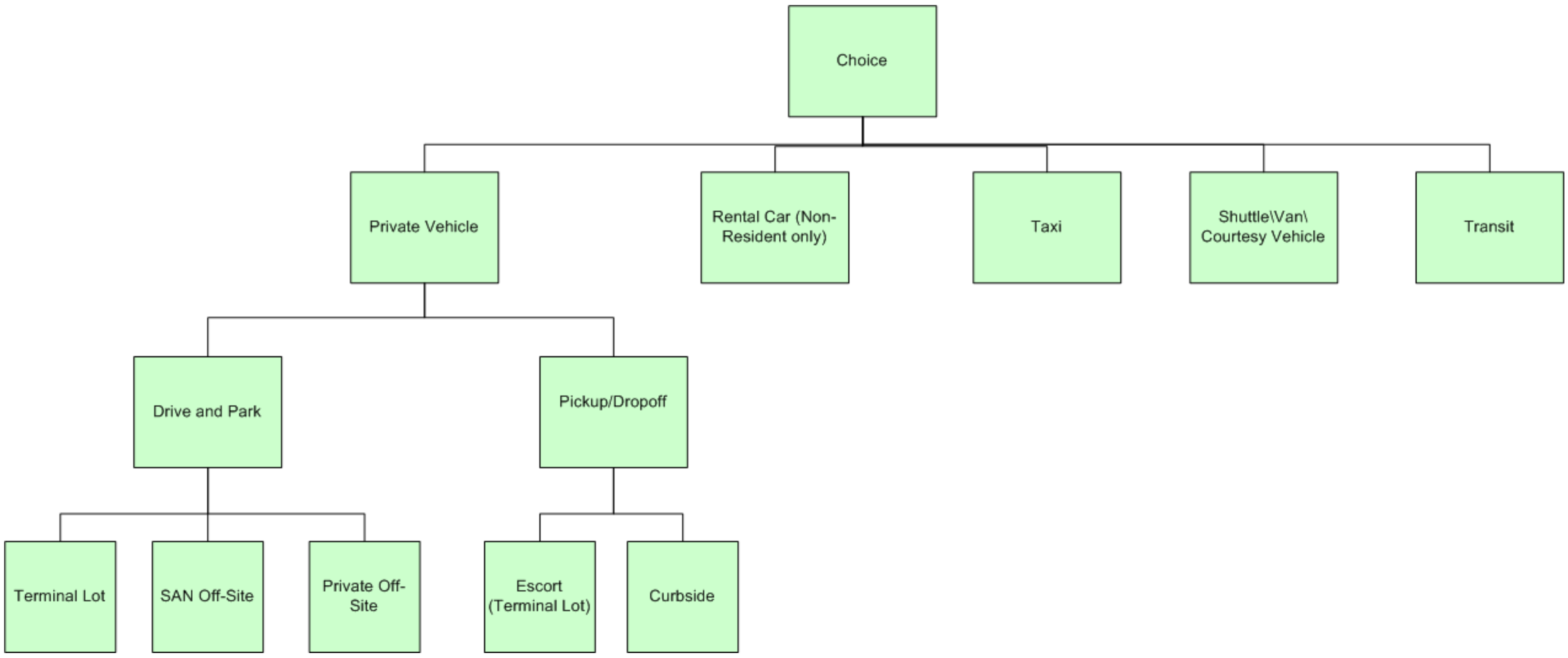
Figure T.14 shows the nesting structure of the mode choice model.

The model explicitly represents the options of parking versus pick-up/drop-off for private vehicle trips. All trips are assigned either curbside (for pick-up/drop-off, taxi, shuttle/van/courtesy vehicle, and transit) or parking lot (terminal, off-site SAN lot, or off-site private lot). The choice of transit access and line-haul mode is not shown but will be modeled explicitly, as will the path choice for HOV or pay options for auto trips.

The explanatory variables included in the airport trip mode choice model are:

- Household income
- Resident status
- Party size
- Number of nights stayed in San Diego
- Trip mode
- Trip purpose
- Trip departure time
- Mode choice logsums
- In-vehicle time (auto and transit)
- Walk time
- Auto operating 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
- Terminal parking walk time
- Terminal parking cost per day
- Terminal escorting cost per hour
- Off-site in-vehicle time
- Off-site walk time
- Off-site wait time
- Off-site parking cost per day
- Time to rental car center
- Walk time to rental car shuttle
- Wait time to rental car shuttle
- Rental car cost per day
- Taxi cost per trip

Figure T.14
SANDAG Airport Ground Access Mode Choice Nesting Structure



Visitor model

In 2011, the San Diego Association of Governments (SANDAG) conducted a survey of airport passengers and hotel guests in which data was collected on their travel while visiting San Diego. Based upon this data, a model of visitor travel was developed. The purpose of this model is to capture the demand of visitor travel on transport facilities in San Diego County.

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.15, and described in detail in the following sections.

1. 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.

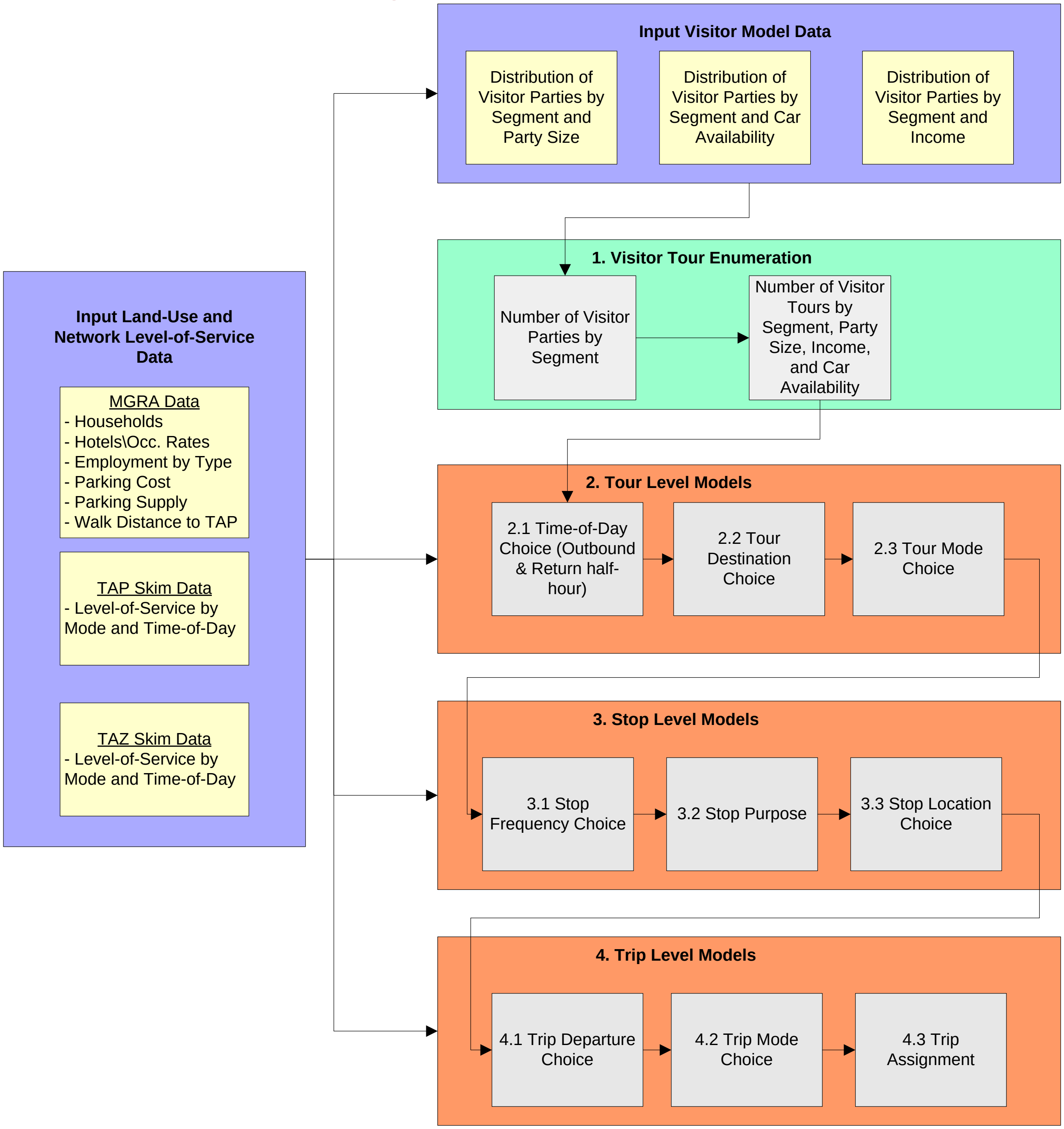
- **TAP skim data.** Transit network level-of-service between each transit access point (transit stop). This provides sensitivity to transit network supply and cost. These are the same data sets as are used in the resident activity-based model.
- **TAZ skim data.** Auto network level-of-services between 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.

2. Model Description

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

Figure T.15

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.

Visitor Travel Parties and Tour Generation

This section describes the generation of visitor travel parties, the generation of tours, and the attribution of each.

Visitor Travel Party Generation

The number of visitors to San Diego in 2009, according to the San Diego Convention and Visitor Bureau, and are summarized by visitor segment in Table T.17.

Table T.17
Number of Visitors

	Count	Frequency
Business	2.5M	17%
Personal	11.8M	83%
Total	14.3M	100%

Visitors are generated for two visitor segment types:

- **Business:** Self-identified as business traveler, or self-identified as 'Both Business and Personal' but took at least one 'business' purpose trip on travel day.
- **Personal:** Self-identified as personal traveler, or self-identified as 'Both Business and Personal' but took no business purpose trips on travel day. A few self-identified Personal travelers have reported Work tours.

The distributions of visitors by segment in the visitor survey are shown in Table T.18. We assume that the share of business travelers in the San Diego Convention and Visitor Bureau data (17%) is more accurate than the visitor survey (25%) since the visitor survey was a place-based survey and likely did not capture a proportional share of visitors staying in households. Therefore the visitor data was re-weighted to the split of business versus personal travelers from the Convention and Visitor Bureau data.

Table T.18
Survey Respondents by Visitor Segment

Segment	Visitor Respondent Count	% of Total
Business	259	25%
Personal	769	75%
Total	1,028	100%

The model generates visitor parties by segment by applying separate occupancy rates to hotels and households, which were obtained from the San Diego Convention and Visitor Bureau. The occupancy rate for hotels is 70%, while the occupancy rate for households is 1.8% (a bit less than 2 out of every 100 households in San Diego County have visitors, on average). The model then applies separate distributions of visitor parties by segment to hotel visitor parties and household visitor parties separately. The frequencies used are shown in Table T.19.

According to the visitor survey, only 2% of overnight visitors stayed in a location that was not identified as a hotel or private residence. Of those, 54% stayed at a military base and 38% stayed at a vacation rental. For the purposes of this model, vacation rentals are included in the estimate of households. A small number of visitors could be allocated to the military base in the future, but this is not done currently in the model.

Table T.19
Share of Visitor Parties by Segment and Overnight Accommodation

Segment	Hotel	Household
Business	30%	4%
Personal	70%	96%
Total	100%	100%

Visitor parties are attributed with household income based upon the distribution of parties by visitor segment and income, as shown in Table T.20. Note that party size and auto availability are attributed on a tour-by-tour basis, since these attributes can change depending on which tour is undertaken and which day it is taken on.

Table T.20
Visitor Parties by Visitor Segment and Household Income

Income	Business	Personal
< $30k	7%	34%
$30-$60k	29%	34%
$60-$100k	34%	20%
$100-$150k	16%	7%
$150k+	14%	5%
Total	100%	100%

Tour Generation

Next, tours are generated by visitor parties and attributed with party size, auto availability, and income attributes. There are three tour purposes, which were coded based on the reported trip purpose in the survey, as follows:

- **Work:** Business travel made by Business travelers
- **Recreational:** All other recreational purposes besides dining
- **Dining:** Travel to eating establishments

Tour purpose was coded according to a hierarchy of trip purposes, with work at the top and dining last. Tours by visitor segment are shown in Table T.21.

Table T.21
Tour Purpose by Visitor Segment

Person Type	Business	% of Total	Personal	% of Total
Work	154	59%	27	4%
Recreational	78	30%	691	90%
Dining	27	10%	51	7%
Total	259	100%	769	100%

Each travel party can generate one or more tours of each purpose on any given day. The tour generation rates are shown in Table T.22 (for the business segment) and Table T.23 (for the personal segment).

Table T.22
Tour Distribution, Business Parties

Work	Recreational	Dining	Total Tours	Frequency
1	0	0	1	40%
2	0	0	2	1%
0	1	0	1	29%
1	1	0	2	5%
0	2	0	2	1%
0	0	1	1	11%
1	0	1	2	10%
0	1	1	2	3%

Table T.23
Tour Distribution, Personal Parties

Work	Recreational	Dining	Total Tours	Frequency
1	0	0	1	3%
0	1	0	1	82%
1	1	0	2	0%
0	2	0	2	5%
0	0	1	1	6%
0	1	1	2	4%
0	2	1	3	0%
0	1	2	3	0%

The average size of the travel parties was obtained from both the San Diego Convention and Visitor Bureau numbers and the visitor survey. The visitor survey averages are slightly smaller.

Table T.24
Average Party Size

	Business	Personal
Convention and Visitor Bureau	1.3	2.4
Visitor Survey	1.04	2.2

Ultimately, the average party size observed in the survey is used in the model. The distribution of visitor tours by party size and tour purpose is shown in Table T.25.

Table T.25

Tours by Party Size and Tour Purpose

Party Size	Work	Recreate	Dining
1	31%	4%	10%
2	12%	12%	13%
3	18%	29%	33%
4	15%	23%	17%
5	3%	17%	6%
6	0%	5%	6%
7	20%	9%	14%
8	0%	0%	0%
9	0%	0%	0%
10	1%	0%	0%
Total	100%	100%	100%

Most visitors in the visitor survey did not have access to an automobile. Table T.26 shows the number and percentage of visitors who made complete tours by auto accessibility. If a person drove into San Diego, either in a personal or rental vehicle, they were assumed to have access to a car during their stay. If a person flew into San Diego and rented a car, they were also assumed to have access to a car. Persons who do not fit into either of those categories were assumed to have no vehicle. The model uses the distribution of tours by auto availability to attribute each tour with whether an auto is available, as shown in Table T.27.

Table T.26

Auto Availability by Segment

	Business	% of Total	Personal	% of Total
Drove into San Diego	18	8%	82	12%
Flew into SD, rented car	67	31%	173	25%
No Vehicle	197	60%	617	64%
Total	215	100%	699	100%

Table T.27

Auto Availability by Tour Purpose

Auto Available	Work	Recreate	Dining
Yes	38%	58%	53%
No	62%	42%	47%
Total	100%	100%	100%

2.1 Visitor Time of Day

Number of Models: 3 (Work, Recreational, Dining)
Decision-Making Unit: Tour
Model Form: Look up table
Alternatives: 40 half-hour time-of-day periods by purpose

This model selects an outbound and return half-hour period, based on a probability distribution created using the visitor survey observed tour arrival and departure data, by tour purpose. Model input is the observed percent of tours by purpose with each combination of departure and arrival time period.

2.2 Visitor Destination Choice

Number of Models: 3 (Work, Recreational, Dining)
Decision-Making Unit: Tour
Model Form: Multinomial logit
Alternatives: MGRAs

The tour destination choice model predicts the 'preferred' destination for the tour at the level of the Master Geographic Reference Area (MGRA). There are two stages involved in the estimation and application of the model. In the first phase, a list of sampled MGRAs is created. In the second phase, a multinomial logit form is applied to each sampled alternative and a destination MGRA is selected. The two-stage procedure is necessary in order to minimize the computational burden associated with computing mode choice logsums for each tour to 21633 MGRAs. In both estimation and application, 30 destination MGRAs were sampled.

Mode choice logsums used in this model were based upon an asserted mode choice model that was derived from the resident discretionary tour mode choice model.

The visitor survey contains information about the trips for each visitor during one day in San Diego. A handful of MGRAs, containing popular attractions like the Convention Center, Sea World, and the San Diego Zoo attracted a large number of the visitor trips, although destinations did occur throughout the model area.

Table T.28
Special Attractors

Location	Trips	Percent of Total
Convention Center	120	4%
Sea World	120	4%
San Diego Zoo	92	3%
Balboa Park	75	3%
Coronado Beach	62	2%
Legoland	32	1%
San Diego Zoo Safari Park	16	1%
Total trips in data frame	2,914	100%

The visitor destination choice model explanatory variables are:

- Mode choice logsum
- Distance
- Size of the sampled MGRA

2.3 Visitor Tour Mode Choice

Number of Models: 5 (Business-Work, Business-Recreational, Business-Dining, Personal-Recreational, Personal-Dining)
Decision-Making Unit: Tour
Model Form: Nested Logit
Alternatives: 15 Tour Modes (all the residential tour modes plus taxi except bike, park and ride, kiss and ride, and school bus)

This model chooses a tour mode based on a known trip origin and destination MGRAs, and travel party characteristics including purpose, party size, and income. Since the data in the visitor survey is too aggregate to estimate a mode choice model, the model was asserted based on the resident tour mode choice model. Figure T.16 shows a nesting structure of the mode choice model. Note that the modes are the same as are used in the resident model, with the addition of the taxi mode, which utilizes the same coefficients as auto modes (in-vehicle time and cost), though cost is based on an initial fare (meter-drop) and a cost-per-mile.

The visitor tour model explanatory variables include:

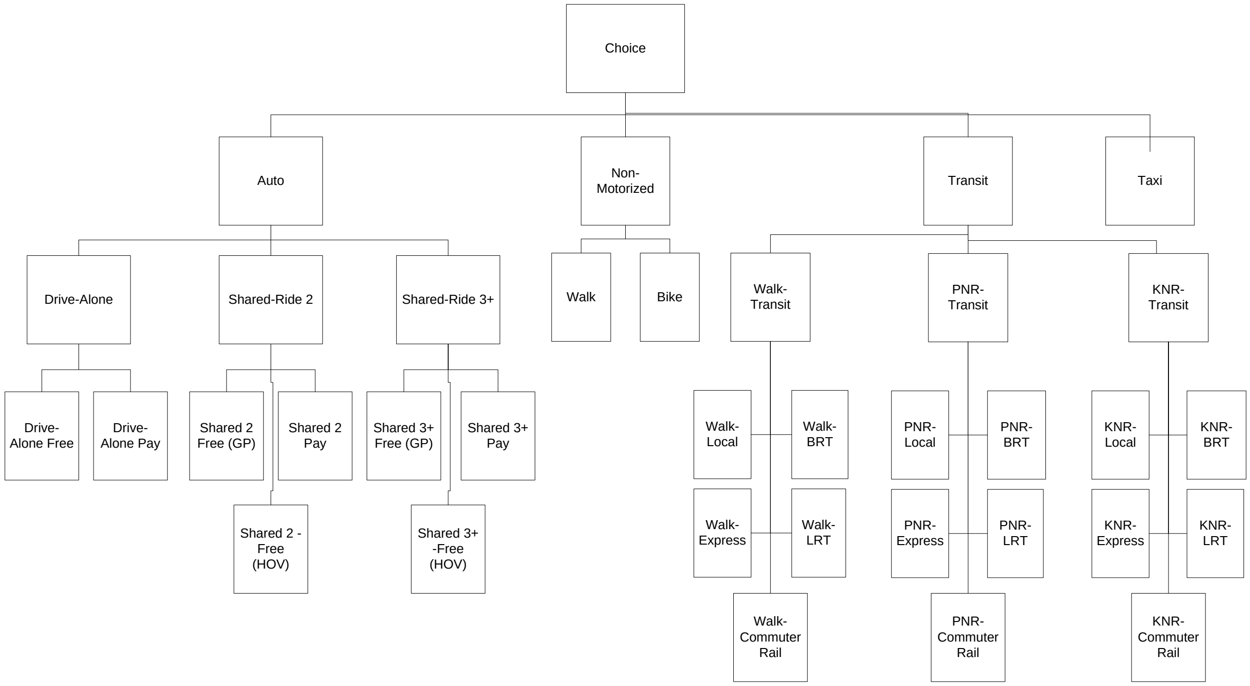
- Auto availability indicator
- In-vehicle time (auto and transit)
- Walk time
- Auto operating cost
- Auto parking cost
- Auto terminal time
- Auto toll value
- Transit first wait time
- Transit Transfer time
- Number of transit transfers
- Transit walk access time
- Transit walk egress time
- Transit walk auxiliary time
- Transit Fare

Table T.29

Survey Respondents by Purpose and Trip Mode

Mode	Tours				Trips on Tours			
	Business	% of Total	Personal	% of Total	Business	% of Total	Personal	% of Total
Personal Vehicle	49	19%	279	36%	75	11%	633	34%
Rental Car	75	29%	233	30%	160	24%	528	29%
Taxi	29	11%	184	24%	93	14%	458	25%
Walk/Bike	104	40%	68	9%	330	49%	201	11%
Bus	1	0%	4	1%	5	1%	18	1%
Trolley	1	0%	0	0%	5	1%	2	0%
Coaster	0	0%	0	0%	1	0%	4	0%
Other Mode	0	0%	1	0%	1	0%	5	0%
Total	259	100%	769	100%	670	100%	1849	100%

Figure T.16
SANDAG Nested Tour Mode Choice model structure



3.1 Visitor Stop Frequency

Number of Models: 1
Decision-Making Unit: Tour
Model Form: Probability Distribution Lookup table
Alternatives: 0-1 outbound stops by 0-3 inbound stops

Number of stops per tour is determined by sampling from the observed distribution of number of stops per tour. The model input is the percentage of observed number of stops (both inbound and outbound) by purpose and tour duration. The input frequency table is too large for documentation, but the frequency of stops by tour purpose and segment is shown in Table T.30. For simplicity's sake, intermediate stops are not allowed on non-motorized or transit tours (which speeds up and simplifies the intermediate stop sampling procedure).

Table T.30
Frequency of Stops on Tour

Number of Stops	Business Respondents			Personal Respondents	
	Work	Shop\Recreate	Eat Out	Shop\Recreate	Eat Out
0	31%	47%	100%	52%	94%
1	41%	44%	0%	42%	6%
2	28%	9%	0%	6%	0%
Total	100%	100%	100%	100%	100%

3.2 Visitor Stop Purpose

Number of Models: 1
Decision-Making Unit: Stop
Model Form: Probability Distribution Lookup Table
Alternatives: Work, Other Recreational, Dining

Purpose of stops is determined by the observed purpose of stops in the visitor survey. The model input is the percentage of observed stops by purpose, stop number, number of stops on tour, and stop direction (inbound or outbound). The actual table used is too large to include in documentation, but the frequency of stops by tour purpose and segment is shown in Table T.31.

Table T.31
Stops by Purpose

Stop Purpose	Business Respondent			Personal Respondent	
	Work	Shop\Recreate	Eat Out	Shop\Recreate	Eat Out
Work	100%	63%	76%	5%	5%
Shop\Recreate	0%	37%	24%	95%	93%
Eat Out	0%	0%	0%	0%	2%

3.3 Visitor Stop Location

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

The stop location model was asserted, based on the discretionary purpose of the resident stop location choice model. See Section 5.3.

4.1 Visitor Trip Time of Day

Number of Models: 1
Decision-Making Unit: Travel party
Model Form: Lookup table
Alternatives: Half-hour offsets

The stop time of day is chosen based on a distribution of observed stop durations from the survey. Distributions were prepared for stop duration for outbound and inbound stops, by purpose, and overall tour duration.

4.2 Visitor Trip Mode Choice

Number of Models: 5 (Business-Work, Business-Recreational, Business-Dining, Personal-Recreational, Personal-Dining)
Model Form: Nested Logit
Alternatives: 15 Tour Modes (all the residential tour modes plus taxi except bike, park and ride, kiss and ride, and school bus)

As with tour mode choice, this model is asserted. It is based on the resident trip mode choice model, with the addition of a taxi mode.

The visitor trip mode selection is based on the following explanatory variables:

- Auto availability indicator
- In-vehicle time (auto and transit)
- Walk 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

Special event model

A special event survey was conducted in San Diego in 2011, collecting information on trips to and from a number of sporting and cultural events throughout San Diego County. This data has been used to implement a special event model component for the San Diego region. The model shares similar features with the event model originally developed for Phoenix, including an origin choice and mode choice component. However, in keeping with the other model components developed as part of the activity-based model development project, the SANDAG special event model is a simulation-based framework. Travel parties to and from the special event are generated from input event attendance, and key characteristics (party size and income) are selected from observed distributions. Then each travel party chooses an explicit origin micro-zone (Master Geographic Reference Area) and an explicit mode. The model produces a list of trips to and from the event, with a number of records equal to twice the number of event attendees (one trip to the event and one trip from the event).

Survey Data

Table T.32 shows the special event data used to develop the model. There were six different events surveyed, including concerts, sporting events, the Gaslamp Mardi Gras festival, and the San Diego County Fair.

Table T.32

Special Events Surveyed, Location, Samples and Annual Attendance

Event Name	Type	MGRA	Number of Samples	Average Attendance Per Event-Day
Gaslamp Mardi Gras	Other	2351	219	40,000
Viejas Arena (SDSU)	Concert\Sporting	955	266 (186\80)	12,000
Petco Park (Baseball)	Sporting	2436	586	23,000
San Diego County Fair (Fairgrounds)	Other	12395	369	50,000
Cricket Wireless Amphitheater (Chula Vista)	Concert	6468	245	11,000
Qualcomm Stadium (Football)	Sporting	5855	183	65,000

Characteristics of the respondents at each event were analyzed to determine appropriate groupings of events. Figure T.17 shows survey respondents by age range. The chart shows that Gaslamp Mardi Gras attendees and attendees at Viejas Arena tend to be younger, while attendees at the County Fair tend to be older.

Figure T.17

Survey Respondents by Age Range and Event

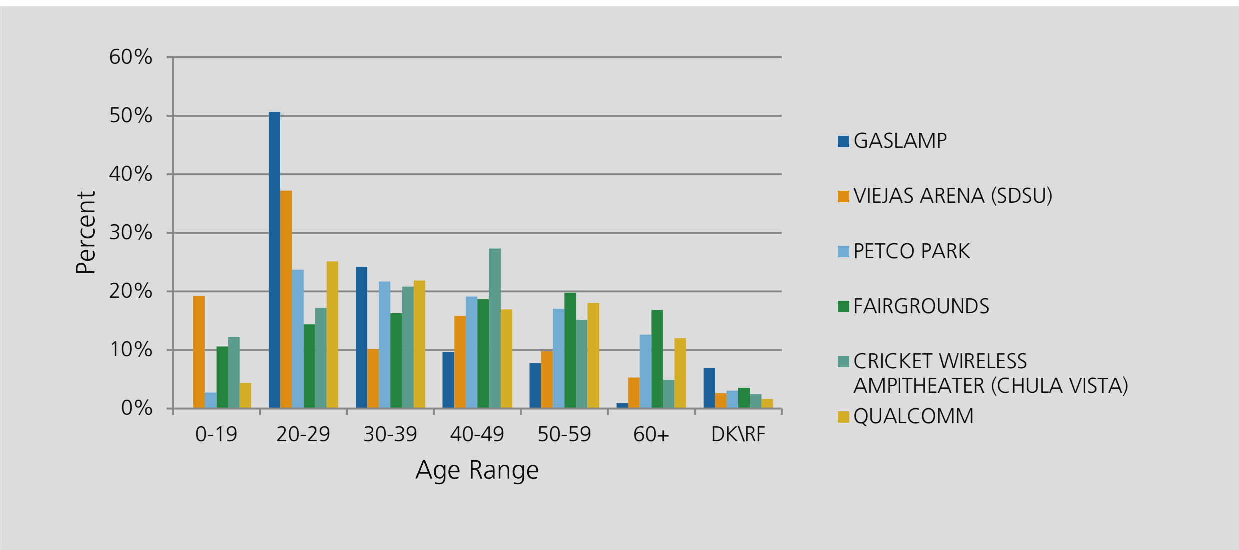


Figure T.18

Respondents by Party Size and Event

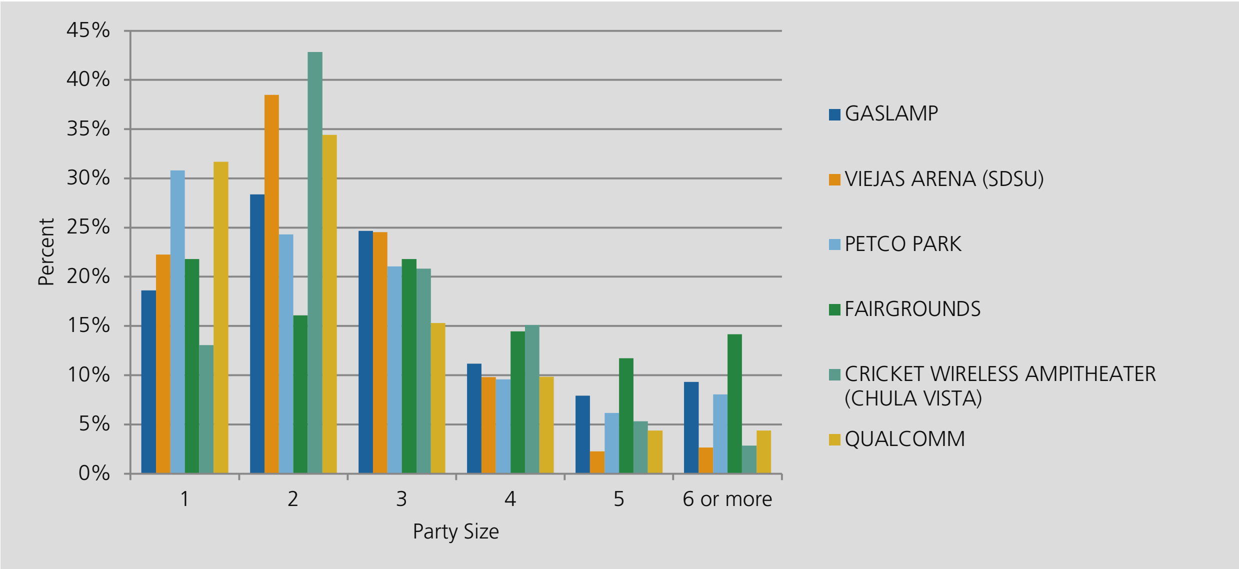


Figure T.18 shows survey respondents by party size and event. Party sizes at Petco Park tend to be smaller than other events, while party sizes at the Fairgrounds tend to be larger. The fairgrounds may attract school classes, resulting in a larger average party size than other events. Events at the Cricket Wireless Amphitheater and at Viejas Arena tend to attract a greater share of two-person parties.

Figure T.19

Survey Respondents by Household Income Range and Event

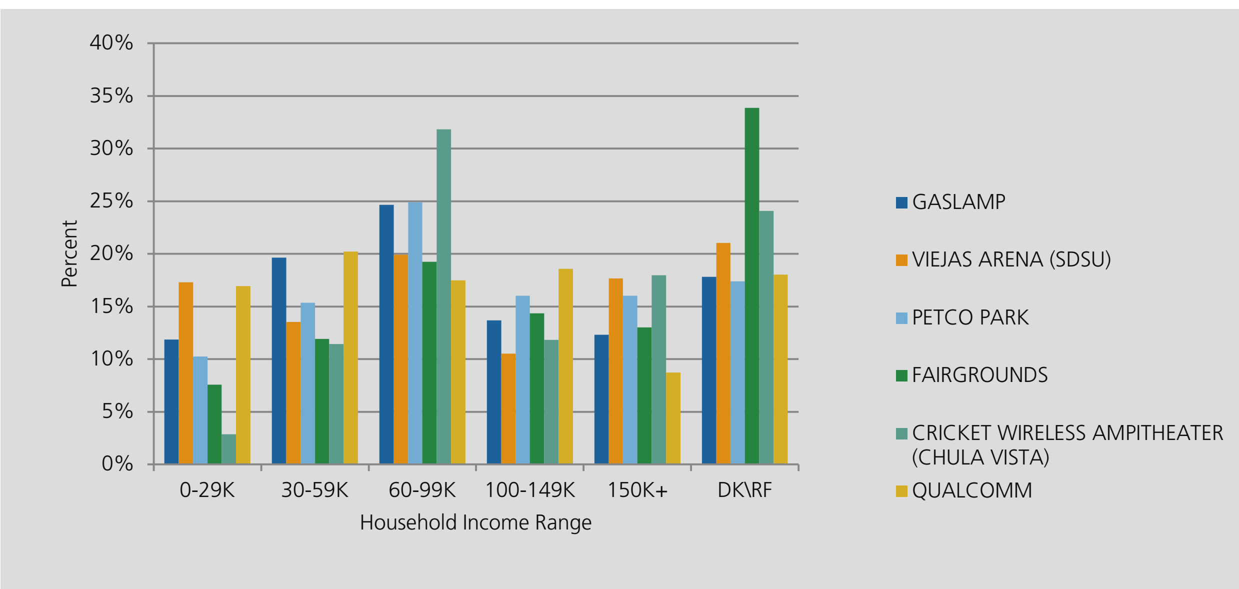


Figure T.19 shows survey respondents by household income and event. The most noticeable difference among events is that Chula Vista appears to attract a larger proportion of attendees in the medium ($60k-99k) income range than other events, while events at Viejas Arena tend to attract relatively lower income attendees (as might be expected given that the venue is at a major university and is likely attended by a greater proportion of college students with limited income).

Figure T.20

Survey Respondents by Origin Place Type and Event

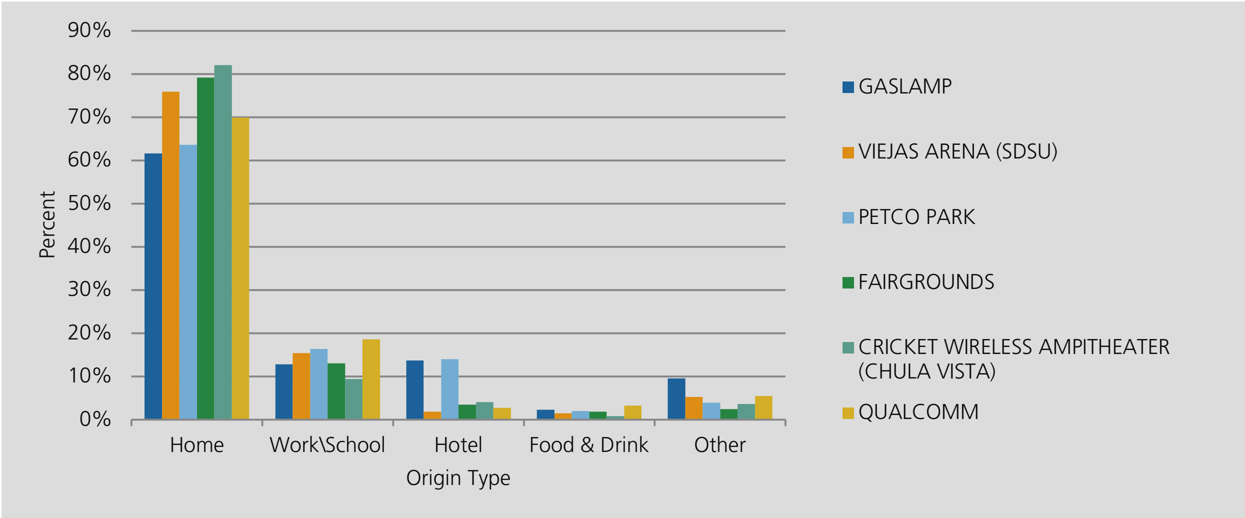


Figure T.20 shows survey respondents by origin place type and event. The chart shows that between 60% and 80% of attendees travel to the special event directly from home. Special events with a relatively lower share of attendees from home tend to have a higher share of attendees from hotel – including Gaslamp Mardi Gras and Petco Park. This is reasonable given that both of these venues are in the Gaslamp area, which has a high concentration of hotels. The special event survey also collected information on destination location after the event. As can be seen in Figure T.21, between 80% and 90% of respondents return to the same location after the event. The special events with lower shares of respondents who return to the same location after the event correspond to events with lower shares of respondents whose origin is home, such as Gaslamp Mardi Gras and Petco Park. Again, given the high concentration of restaurants and bars around these venues, it is not surprising that a greater portion of attendees are not going directly home after these events.

Figure T.21

Respondents by Destination Location

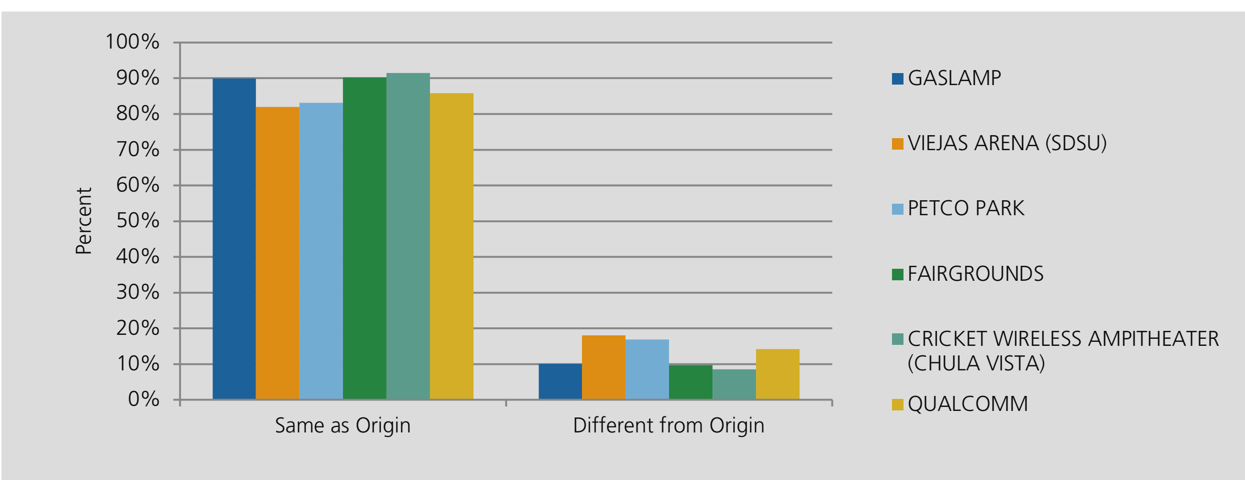


Figure T.22

Respondents by Distance to Special Event

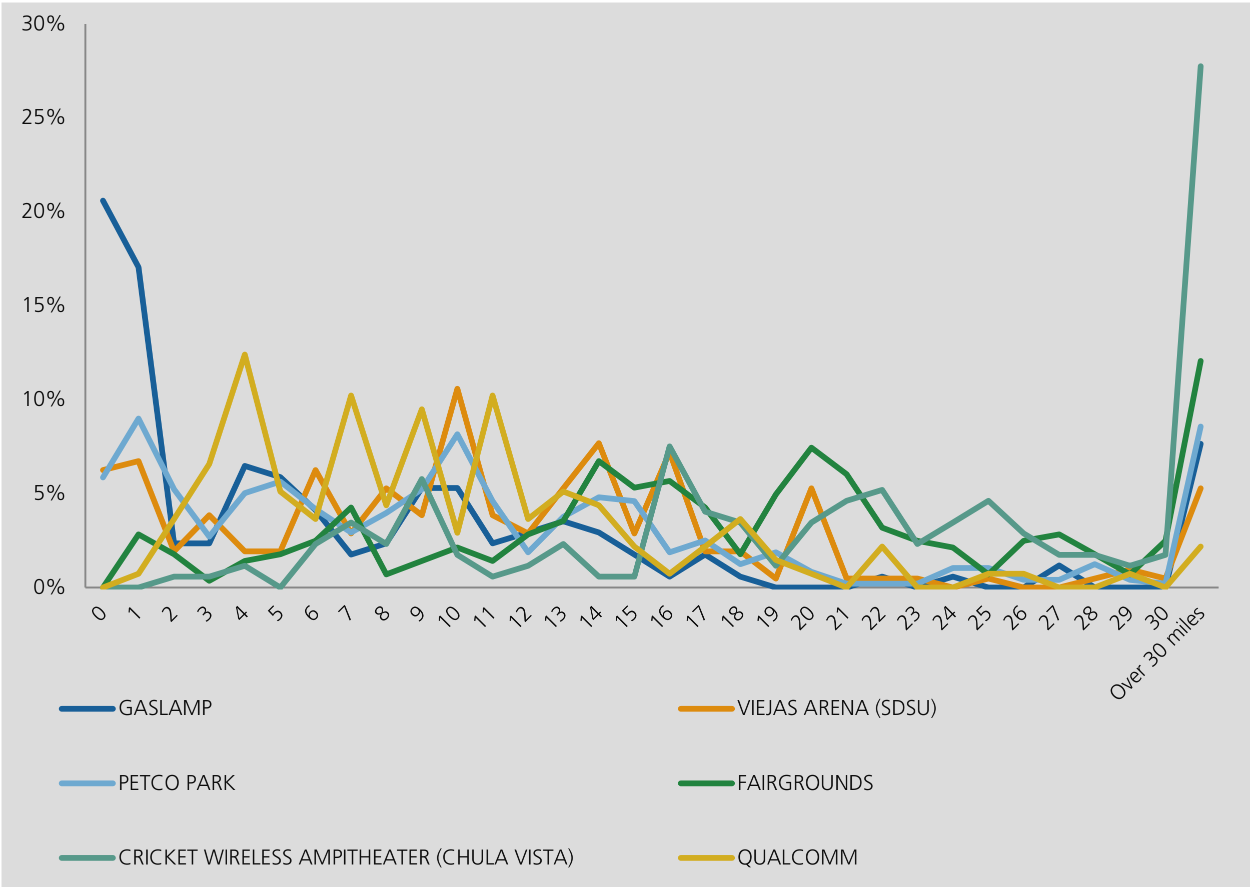


Table T.33

Average Distance by Special Event

Special Event	Average Distance
Gaslamp Mardi Gras	8.8
Viejas Arena (SDSU)	12.0
Petco Park (Baseball)	12.1
San Diego County Fair (Fairgrounds)	19.1
Cricket Wireless Amphitheater (Chula Vista)	24.6
Qualcomm Stadium (Football)	10.7
Total	14.4

Trip length frequency distributions to each event are shown in Figure T.22, and average distance to event is shown in Table T.33.

Trip length distributions are lumpy due to the relatively low number of observations at each event and the relatively high rate of non-geocodable observations (between 20% and 30% at each event). However, it is clear that certain events, such as the San Diego County Fair and the Cricket Wireless Amphitheater in Chula Vista, tend to draw from a much larger area than other, more centrally located events such as Gaslamp Mardi Gras and football games held at Qualcomm Stadium.

Figure T.23 shows survey respondents by mode to special events. Although carpool tends to be the dominant travel mode, there is considerable variation in mode usage across events. Qualcomm has the highest share of trips by transit, with the vast majority of transit trips on the trolley mode. Note that Qualcomm Stadium is well-served by a stop on the trolley Green Line, and MTS provides extra service on football game-days. Events at Petco Park, SDSU, and Gaslamp also have relatively higher shares of transit patronage than other events. In all cases in which transit shares are significant, trolley carries a much higher share of attendees than local bus.

Figure T.24 shows transit trips by mode of access and event. Transit trips to Gaslamp Mardi Gras, SDSU, and Petco Park tend to be more walk-access (45% to 55%), while transit trips to Qualcomm and the Fairgrounds tend to be more drive-access (50% to 55%). It appears that the transfer rate is low (only 5% to 10% of respondents report bus as their mode of access) as is kiss-and-ride (1% to 5% of transit trips). Note that there was only one observed transit trip to Cricket Wireless Amphitheater, which reported walk as the access mode, resulting in a 100% walk-transit share for that venue.

Table T.34 shows parking costs by venue, including the highest parking cost paid across all respondents, the average parking cost paid across all respondents and the average parking costs paid among respondents who paid for parking (not including respondents who walked, took transit, or were dropped off at the event). Not surprisingly, the events with higher parking costs also have relatively higher shares of transit use.

Figure T.23

Respondents by Mode to Event

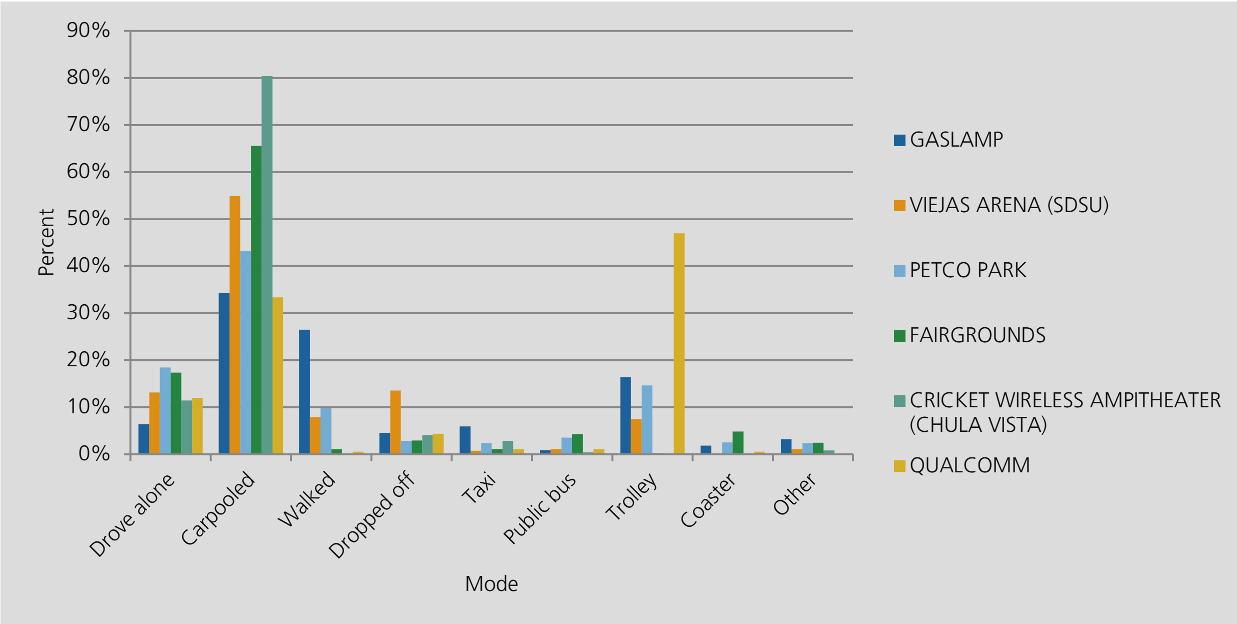


Figure T.24

Transit Trips by Mode of Access to Transit

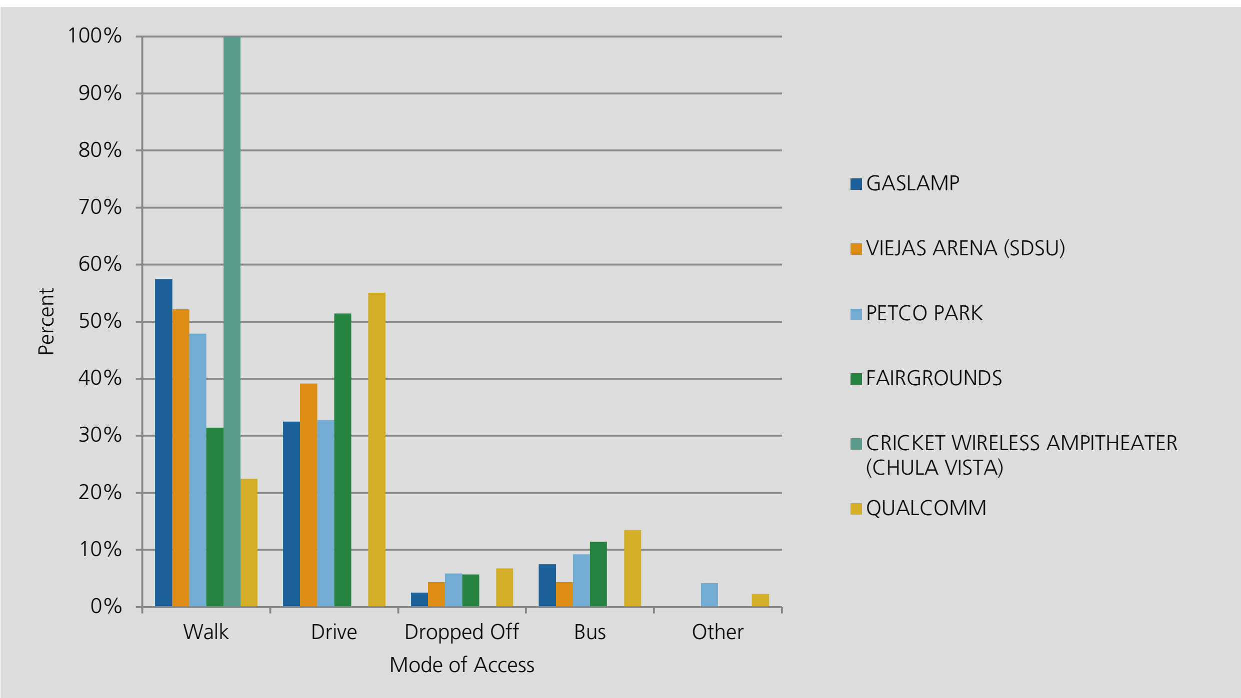


Table T.34

Parking Costs by Venue

Special Event	Average Parking Paid	Maximum Parking Cost	Average Parking Paid, of people who paid
Gaslamp Mardi Gras	$4.07	$36.00	$15.29
Viejas Arena (SDSU)	$3.94	$16.00	$9.04
Petco Park (Baseball)	$6.26	$32.00	$12.62
San Diego County Fair (Fairgrounds)	$7.13	$20.00	$10.73
Cricket Wireless Amphitheater (Chula Vista)	$1.76	$35.00	$21.50
Qualcomm Stadium (Football)	$7.23	$40.00	$24.35
Average	$5.75	$40.00	$12.73

Model Form

The special event model is formulated as an origin and mode choice model, as shown in Figure T.25. The model reads a special event input file (see Table T.35) and generates special event travel parties based upon the input attendance at each special event. Given that there is a fairly low share of trips to special events that do not return to the same location, an origin is chosen for every Special Event person tour. Trips are generated to and from the event for each tour, and the mode of each trip is modeled independently.

The following section describes each model.

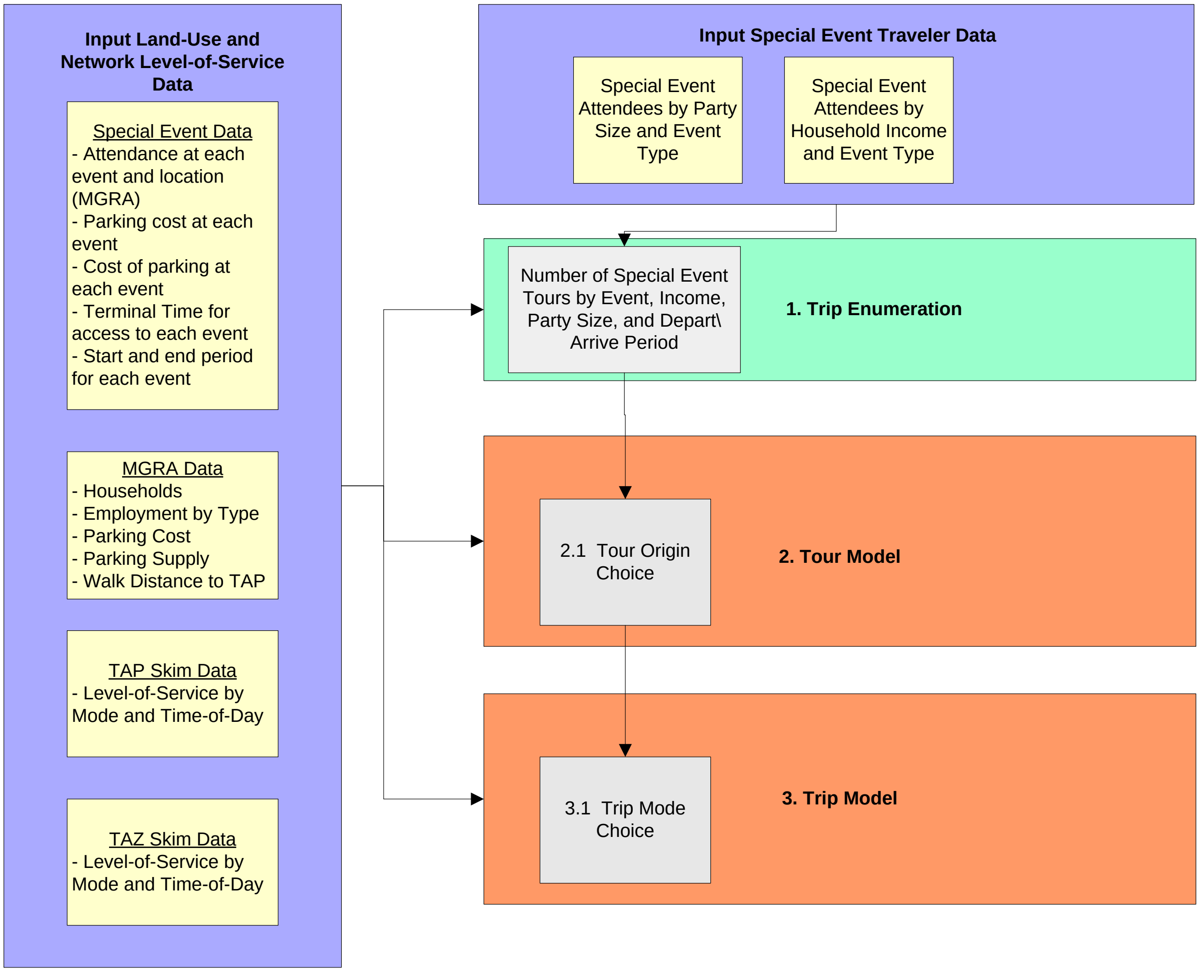
Table T.35

Example Special Event Input File

Event Number	MGRA	Attendance	Event Type	Start Period	End Period	Parking Cost	Parking Time
1	2436	23,000	Sporting	28	37	1262	5
2	955	12,000	Sporting	28	37	904	10
3	18721	12,000	Cultural	26	35	904	10

Figure T.25

Special Event Model Form



Trip Enumeration

Special event tours are generated based on total attendance. Tours are attributed with party size (number of participants) and household income based upon input distributions which vary by event type (see Table T.35). The event types are flexibly defined in the input event table, but at a minimum, based upon observed data, we recommend Sporting and Cultural events as two distinct categories of events. Alternatively, one could input specific party size and income distributions for each event based upon the data shown in the above tables and charts. For purposes of calibration, we used data for Petco Park.

Tour Model

There is only one tour model, in which the origin is chosen.

Tour Origin Choice

Number of Models:	1 per event type (size terms estimated for each venue)
Decision-Making Unit:	Person-tour
Model Form:	Multinomial logit
Alternatives:	21,633 MGRAs

The tour origin choice model predicts the origin for the Special Event tour at the level of the Master Geographic Reference Area (MGRA). There are two stages used for destination choice. In the first stage, a

TAZ is chosen based upon distance to the venue and size term. In the second stage, an MGRA within the chosen TAZ is selected based upon the relative size of the MGRA compared to the size of the TAZ. Note that mode choice logsums are not used in the origin choice model.

Origin choice model size terms were estimated for each venue. They are shown in Table T.36.

The size term variables are defined as follows:

- Low income households: $0-$30k
- Medium income households: $30k- $150k
- High income households: $150k+
- Retail employment: Retail activity
- Service employment: Professional and Business Services, Personal Services Office-Based, and Personal Services Retail-Based
- Hotel Employment: Hotels and Models
- Restaurant Employment: Restaurants and Bars

A distance term was not estimated. However, an asserted term (-0.05) was compared to observed data and found to match trip length very well for Petco Park. The term may need to be adjusted somewhat for venues with longer trip lengths.

Table T.36

Estimated Size Terms (Exponentiated Coefficients)

Variable	All Venues	Gaslamp Mardi Gras	Viejas Arena	Petco Park	Fair-grounds	Cricket Amphitheater	Qualcomm
Low Income HH	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Med Income HH	1.60	2.17	0.77	0.50	3.46	5.05	43.82
High Income HH	2.80	0.00	2.01	1.68	1.49	4.22	0.28
Retail Employment	0.27	0.05	0.01	0.08	0.13	0.63	0.00
Service Employment	0.72	0.67	0.89	3.42	0.90	4.57	10.70
Hotel Employment	0.52	0.70	1.22	0.11	0.98	0.88	1.22
Restaurant Employment	0.86	0.34	0.13	0.34	0.44	1.16	4.81

Trip Mode Choice

Number of Models: 1
Decision-Making Unit: Person-trip
Model Form: Nested logit

An asserted nested logit mode choice model is used to model trip mode choice for trips to and from special events. The model utilizes the same functional form as the resident mode choice models, though many of the person and household specific variables are not available in the special event model and are therefore not used. The asserted mode choice parameters are shown in Table T.37.

Table T.37
Special Event Trip Mode Choice Model Asserted Parameters

Coefficient	Value	Ratio to IVT ($/hr)
In-vehicle time coefficient	-0.0300	1.0
First wait time coefficient	-0.0457	1.5
Transfer wait time coefficient	-0.0457	1.5
Walk access time coefficient	-0.0457	1.5
Walk egress time coefficient	-0.0457	1.5
Walk auxiliary time coefficient	-0.0457	1.5
Transfer penalty (above one)	-0.7200	24
Walk mode time coefficient	-0.0536	1.8
Transfer penalty - PNR	c_ivt*15	24
Cost coefficient for income < $30k	-0.0075	($2.40)
Cost coefficient for income $30k-$60k	-0.0033	($5.45)
Cost coefficient for income $60k - $100k	-0.0021	($8.57)
Cost coefficient for income > $100k	-0.0009	($20.00)
Express bus IVT factor	0.9000	0.9000
BRT IVT factor	0.9000	0.9000
LRT IVT factor	0.8500	0.8500
Commuter rail IVT factor	0.7500	0.7500

External model

The external travel models predict characteristics of all vehicle trips and selected transit trips crossing the San Diego County border.

External Model Definition of Trip Type

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 microsimulation 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

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 will be 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.

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 travel has been developed in a separate task.
- **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.

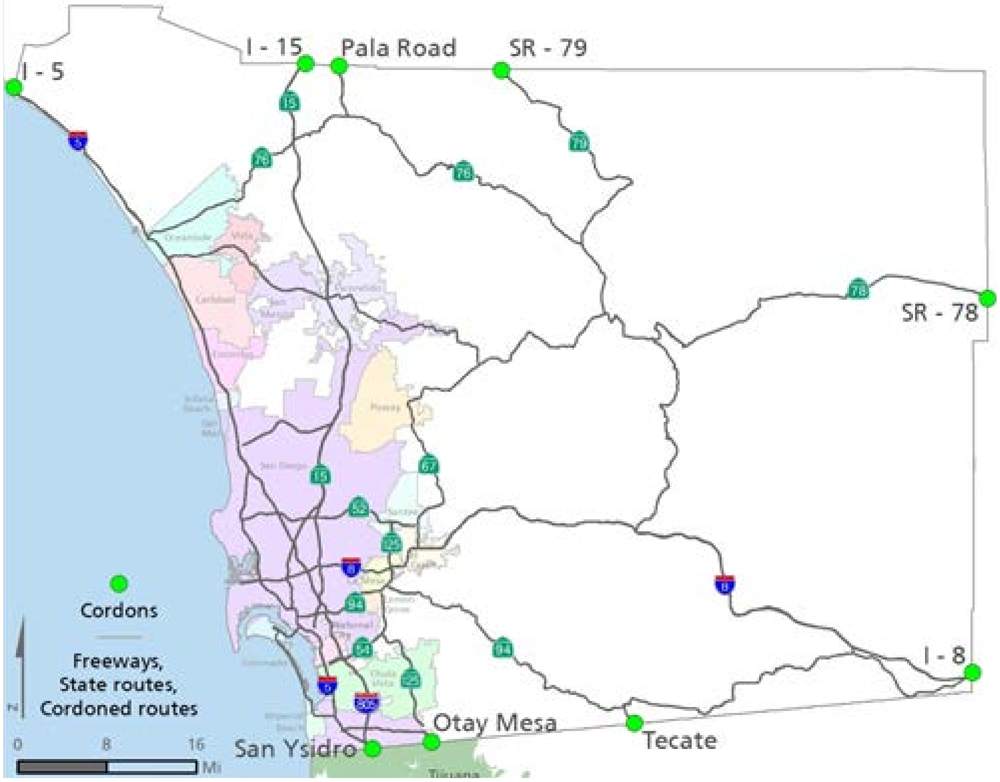
External-External (EE) Trips
Number of Models: 1
Model Form: Fixed Trip table

The EE trip matrix (covering US-US and US-MX trips) is estimated as described in the previous sections appears in Table T.38.

Table T.38
External-External Trip Matrix

Origin	Destination									
	San Ysidro	Otay Mesa	Tecate	I-8	CA-78	CA-79	Pala Road	I-15	I-5	Total
San Ysidro	-	-	-	167	17	25	37	1,563	1,527	3,336
Otay Mesa	-	-	-	42	4	6	9	396	387	844
Tecate	-	-	-	13	1	2	3	124	121	264
I-8	167	42	13	-	-	-	-	-	22	244
CA-78	17	4	1	-	-	-	-	-	-	22
CA-79	25	6	2	-	-	-	-	-	-	33
Pala Road	37	9	3	-	-	-	-	-	-	49
I-15	1,563	396	124	-	-	-	-	-	1,086	3,169
I-5	1,527	387	121	22	-	-	-	1,086	-	3,143
Total	3,336	844	264	244	22	33	49	3,169	3,143	11,104

Figure T.26
San Diego County Cordons



US-SD External-Internal (EI) Trips

The US-SD External-Internal trip model covers vehicle trips with destinations in San Diego made by persons residing in other areas of the United States. Intermediate stops and transit trips are not modeled in this segment due to the small contribution of these events to the total demand in the segment.

The US-SD model accepts as an input the total number of work and non-work vehicle trips from the SCAG cordon survey at each external station (Table T.39).

Table T.39
US-SD Trips by Production Location

Production	Trips
I-5	28,820
I-15	33,661
Pala Rd	813
CA-79	543
I-8	3,413
CA-78	344
Total	67,593

External-Internal Destination Choice Model

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

The external-internal destination choice model distributes the EI trips to destinations within San Diego County.

The EI destination choice model explanatory variables are:

- Distance
- The size of each sampled MGRA

Diurnal and vehicle occupancy factors (Table T.40 and Table T.41) are then applied to the total daily trip tables to distribute the trips among shared ride modes and different times of day.

Table T.40

US-SD Vehicle Occupancy Factors

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

Table T.41

US-SD Diurnal Factors

	Work Percent		Non-Work Percent	
Time Period	P to A	A to P	P to A	A to P
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%

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

Internal-External (IE) Trips

IE Trip Generation Model

Number of Models: 2 (Work, Non-work)
Decision-Making Unit: Person
Model Form: Binary logit
Alternatives: 2 (Made a 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 which is defined by:

$$Access_h = \sum_z IePct_z \times \exp(-0.047 \times Dist_{h,z})$$

where h is the home zone, z ranges over external zones, $IePct_z$ is the percent of base-year IE trips that used the external station at zone z, and $Dist_{h,z}$ is the distance between the home and the external zone in miles.

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

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

Endnotes

[1] Note that although it is possible to include race/ethnicity as an explanatory variable in the model system, it has been decided to not include such variables in the San Diego implementation.

[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] Destination Lindbergh: The Ultimate Build-Out Aviation Activity Forecast, Jacobs Consultancy Team, February 2009, page 5-39 (Table 5.4-1).