Appendix M: Travel Demand Modeling Tools

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Executive Summary

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

The SANDAG ABM includes a number of methodological strengths. It predicts the travel decisions of San Diego residents at a detailed level, taking into account the way people schedule their day, their behavioral patterns, and the need to cooperate with other household members. When simulating a person's travel patterns, the ABM takes into consideration a multitude of personal and household attributes like age, income, gender, and employment status. The model's fine temporal and spatial resolution ensures that it is able to capture subtle aspects of travel behavior. In addition to resident travel, SANDAG ABM also simulates several other market segments such as crossborder, airport, visitor, commercial travel etc., to assess the full impact of policies and projects on San Diego's transportation system.

The SANDAG ABM strives to be as behaviorally realistic as possible and is based on empirical data collected by SANDAG, Caltrans, and the federal government. Travel behavior was significantly impacted due to COVID-19. In the current update, several survey datasets were collected in 2022, and the model base year was updated (also to 2022) so that the forecasts are reflective of post-pandemic changes and effects. The model development has been regularly peer-reviewed by the ABM Technical Advisory Committee, a panel of national experts in the travel demand forecasting field.

This Regional Plan documentation is a synthesis of the detailed model code, design, and documentation publicly available at SANDAG's GitHub repository (**SANDAG/ABM: Sandag ABM**) and documentation website (**https://sandag.github.io/ABM**).

SANDAG Travel Demand Model Documentation and Methodology

This document describes the SANDAG updated third-generation activity-based model system (ABM3) used in the 2025 Regional Plan. SANDAG ABM development started in 2009, and the first SANDAG ABM was applied in San Diego Forward: The 2015 Regional Plan (2015 Regional Plan). Subsequently, SANDAG applied the ABM2 for the 2019 Federal RTP in 2019. The next version, called ABM2+, was applied to both 2021 Regional Plan and 2021 Regional Plan Amendment. SANDAG has been continuously updating the ABM system to ensure that the regional transportation planning process can rely on forecasting tools that are adequate for new socioeconomic environments and emerging transportation planning challenges. To support the 2025 Regional Plan, SANDAG developed a significantly updated activity-based model called ABM3. The most noteworthy change for ABM3 when compared to ABM2+ is the movement away from the Java-based CT-RAMP platform to the Python-based ActivitySim platform (**ActivitySim/activitysim: An Open Platform for Activity-Based Travel Modeling**) for demand generation. ActivitySim has been developed by a consortium of several MPOs and other government agencies, of which SANDAG is a founding member. The following are key improvements made over ABM2+:

- Transition from a 3-zone (Transit Access Points or TAPs, Master Geography Reference Areas or MGRAs, and Travel Analysis Zones or TAZs) modeling system to a 2-zone system (MGRAs and TAZs).
- Addition of new model components, including disaggregate accessibility calculation, transit pass ownership and subsidy, vehicle type choice, and external trip identification and destination choice.
- Inclusion of shared e-bike and e-scooter in mode choice models.
- Addition of a wait time model to the cross-border model.
- Updated internal-external travel component to be a part of the resident model using latest data.
- Updated tour-based commercial vehicle model that takes into account demand for last-mile delivery services such Amazon Flex, Uber Eats, DoorDash, etc.

The ABM3 accounts for a variety of different weekday travel markets in the region, including San Diego region resident travel, travel by Mexico residents and other travelers crossing San Diego County's borders, overnight visitor travel, airport passengers at both the San Diego International Airport (SDIA) and the Cross Border Xpress (CBX) bridge to the Tijuana International Airport, and commercial travel. Many of the models used to represent demand are simulation-based models, such as activity-based or tour-based approaches, while others use aggregate three- or four-step representations of travel. Table M.1 lists the SANDAG travel markets along with several key dimensions.

There are two broad categories of models – disaggregate and aggregate. Disaggregate models refer to models whose demand is generated via a stochastic simulation. They rely upon a synthetic population to generate travel and stochastic processes to choose alternatives. The models output disaggregate demand in the form of tour and trip lists.

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

Aggregate models generate trips at the zonal level. They rely upon probability accumulation processes to produce travel demand and output trip tables. The external heavy-duty truck model and certain external travel models are aggregated.

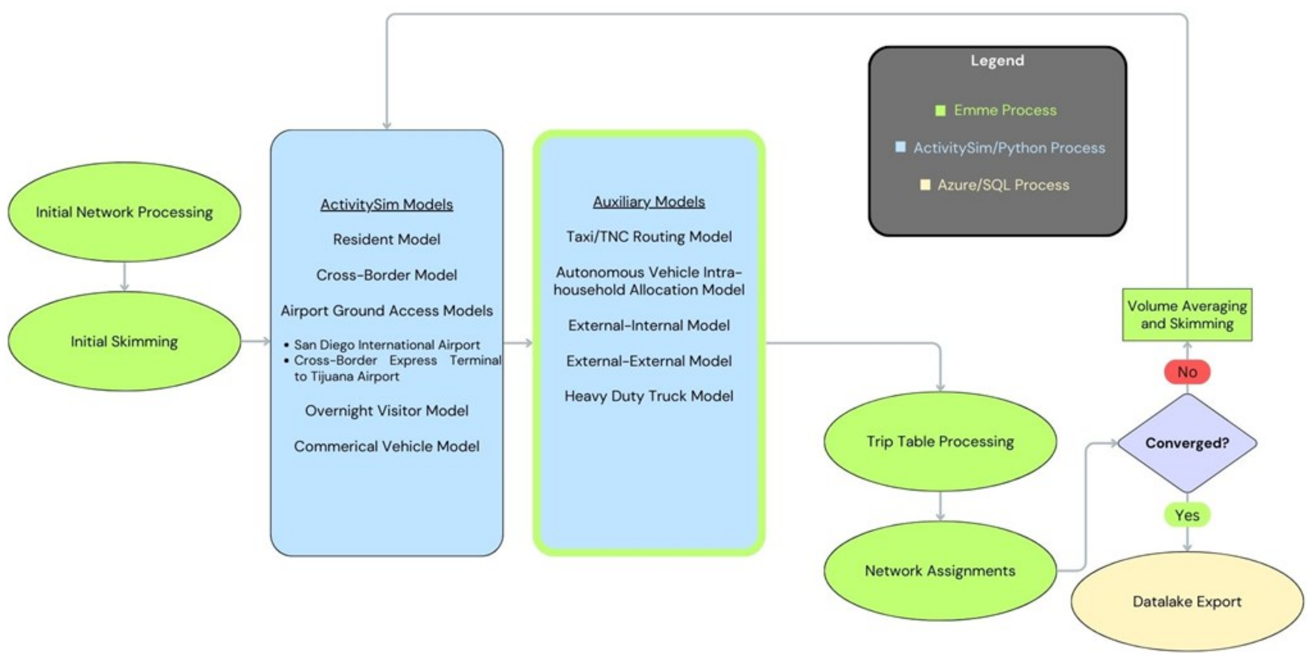
Table M.1: SANDAG ABM3 Travel Markets

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

Notes: MGRA = Master Geographic Reference Area; there are 24,321 MGRAs in the region
All travel is average weekday.

The flow of these models is represented in Figure M.1. The SANDAG ABM3 starts with importing and processing various networks – Active Transportation (AT), Highway, and Transit. AT network is an all-streets-based network that is used in conjunction with Master Geographic Reference Areas or MGRAs to determine walk, bike, and transit stop distances. Highway and Transit networks are used by Emme (traffic modeling software licensed from Bentley) in the "Initial Skimming" step to route an existing set of trips (also called warm start trip tables) to produce congested highway and transit travel times across the region. Next, the resident travel model is executed, followed by the other disaggregate models (visitor, SDIA, CBX terminal, crossborder, and commercial vehicle) and aggregate models (external heavy truck, external–external and external–internal). The trip tables from all the models are summed up by vehicle classes, time of day (TOD), and value of time (VOT) and are used by traffic assignment. The skims after the traffic assignment are used for the subsequent iteration in a three-feedback-loop model run. The final traffic and transit assignment and data export conclude the ABM3 modeling procedure. The outputs from the final step are used to generate input for Emission Factors emissions modeling.

Figure M.1: SANDAG ABM3 Flow Chart



Source: SANDAG

Spatial and Temporal Resolutions

As indicated in Table M.1, different travel markets are operated in different model types with different spatial and temporal resolutions. The following section describes the treatment of space and time in the SANDAG ABM3.

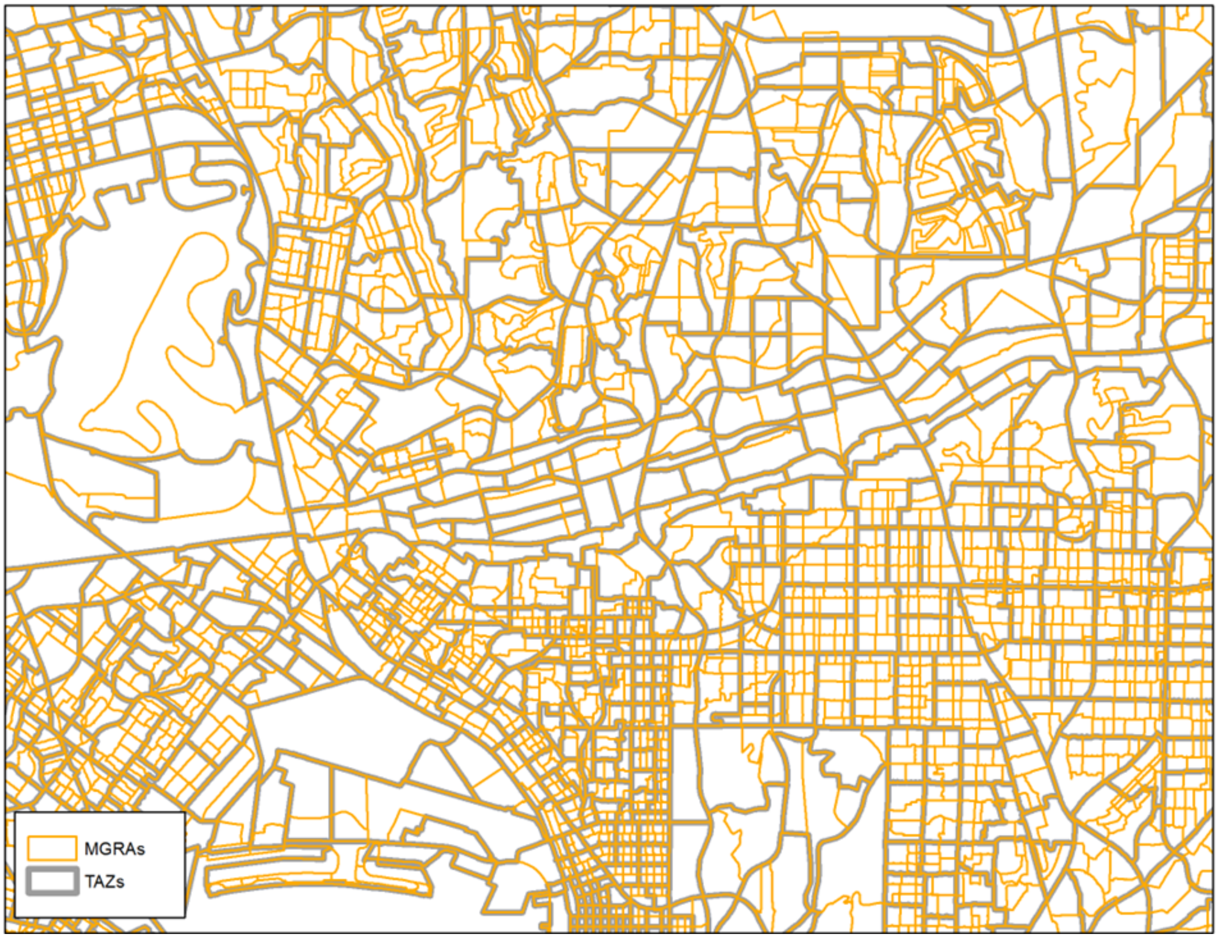
Treatment of Space

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

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

SANDAG ABM3 uses the SANDAG MGRA zone system, which is one of the most disaggregate zonal systems used in travel demand models in the United States. The SANDAG MGRA system used in ABM3 consists of 24,321 zones, which are roughly equivalent to Census blocks (Figure M.2). To avoid computational burden, SANDAG relies on a 4,947 Transportation Analysis Zone (TAZ) system for roadway and transit skims and assignment. Emme modeling software to generate TAZ–TAZ level-of-service highway and transit 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 TAZ–Destination TAZ patterns, are computed within custom-built software. These calculations rely upon detailed geographic information regarding MGRA–Transit stop distances.

Figure M.2: Treatment of Space - TAZs and MGRAs



Source: SANDAG

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

Treatment of Time

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

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

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

Table M.2: Time Periods for Level-of-Service Skims and Assignment

Number	Description	Begin Time	End Time
1.	Early	3 a.m.	5:59 a.m.
2.	a.m. Peak	6 a.m.	8:59 a.m.
3.	Midday	9 a.m.	3:29 p.m.
4.	p.m. Peak	3:30 p.m.	6:59 p.m.
5.	Evening	7 p.m.	2:59 a.m.

Network Inputs

There are three major network inputs: (1) highway networks used to describe existing and planned roadway facilities, (2) transit networks used to describe existing and planned public transit service, and (3) an AT network used to describe non-motorized bicycle and pedestrian facilities.

Highway Networks

The regional highway networks in the 2025 Regional Plan include all roads classified by local jurisdictions in their general plan circulation elements and Caltrans state facilities. SANDAG uses geographic information system (GIS) software to maintain feature classes of segments and nodes in an enterprise geodatabase. The highway segment feature class includes existing and planned freeways, toll lanes, high-occupancy vehicle (HOV) lanes, Managed Lanes, ramps, surface streets classified on general plan circulation elements, and some local roads needed for network connectivity. Traffic control devices are included on segments for traffic signals, stop signs, ramp meters, and rail crossings. The zone connectors are used to schematically represent how traffic from zones accesses the street system.

Highway Facilities

SANDAG uses several sources to maintain the GIS roadway networks, such as high-resolution digital aerial photography, signal data from the Regional Arterial Management System, and ramp meter data from Caltrans. Alignments for planned roads are derived from several different sources, including Caltrans route location studies, local general plan circulation elements, environmental impact reports, and corridor studies.

Highway Attributes

Each highway segment and node contain attribute information that describes that feature. A number of attributes are informational, such as street name, node numbers, link ID numbers, and functional classification. Other attributes, used to calculate travel time, include segment length, posted speed, one/two-way operation, and type of intersection control. Another set of attributes used to calculate capacity includes number of lanes; median condition; number of freeway auxiliary lanes; type of operation (mixed flow or HOV only); type of intersection control; and the number of through, left turn, and right turn lanes at intersection approaches. The phasing of new roads, improvements to existing roads, and in some cases, the deletion of existing roads are identified using another set of attributes.

Many base-year physical attributes can be obtained from high-resolution digital photography. These include one/two-way operation; location and type of intersection controls; median condition; and the number of main lanes, auxiliary lanes, and through, right turn, and left turn intersection approach lanes. Planned roadway improvements are obtained from local circulation elements, Regional Transportation Improvement Programs, and local Capital Improvement Programs.

Highway Capacities

Roadway network for specific model years and alternatives are selected from the master transportation segments. Computer programs covert these feature classes to Emme highway networks by reformatting data items and computing additional attributes needed in the modeling process, such as capacities, travel times, distances, and costs from attributes.

Two capacities are calculated for each direction of a highway link: (1) mid-link capacity, which is the amount of traffic a link could accommodate without intersection controls; and (2) intersection capacity, which is the amount of traffic that can be accommodated by an intersection approach at the end of a link.

Mid-Link Capacity

Mid-link capacity calculations vary for four different types of facilities: freeways, freeway HOV/Managed Lanes, urban streets, and rural highways. Hourly directional freeway capacities are calculated by multiplying the number of main lanes by a per-lane carrying capacity supplied by Caltrans that varies between 1,900 and 2,100 vehicles per hour per lane. Auxiliary lane capacity, assumed to be 1,200 vehicles per hour per lane, is added to main lane capacity.

Mid-link capacities for arterial streets and two-lane rural highways typically can accommodate much less traffic, and a lower capacity of 950 vehicles per hour per direction is assumed for these facilities.

Intersection Approach Capacity

Because the most significant traffic congestion on urban streets often occurs at traffic signals, procedures have been developed to represent individual signal approach capacity within the model. While actual signalized operation is very complex, this approach captures the primary factors that determine capacity. A through lane capacity of 1,800 is multiplied by the number of approach lanes. The green-to-cycle time (GC) ratio is a traffic engineering term that quantifies the fraction of total cycle time that is in the green phase for each intersection approach. Within the model, GC ratios vary between 0.09 and 0.84 depending on the functional classification of intersecting streets and number of approaches. For example, a prime arterial that intersects with another prime arterial would have a lower capacity than one with the same approach lane configuration that intersects with a local street. Similarly, two- and three-legged intersections have higher capacities than four-legged intersections because total cycle time is apportioned to fewer phases.

A turn lane capacity that varies between 100 and 250 vehicles per lane per hour depending on the functional classification of the street is multiplied by the number of coded right and left turn lanes and added to through lane capacity.

A ramp meter is a special type of signal that controls the number of vehicles that can get on a freeway during peak periods. Metering rates are determined by Caltrans and vary from ramp to ramp depending on the location of the ramp and the severity of upstream freeway congestion. An average capacity of 1,000 vehicles per ramp meter is assumed unless location specific metering rates are available.

Stop signs also impose significant reductions in the capacity of surface streets. The model computes capacities of two-way and all-way stop sign–controlled approaches using techniques similar to the signalized intersection method shown above.

Intersection capacity considerations are turned off for freeways and other links that have no intersection controls by setting the capacity to a maximum value.

Highway Travel Times

As with capacities, separate link times and intersection times are computed for each highway segment. Travel times represent the free-flow link time (link length divided by the posted speed). During the calibration process, posted speeds may be varied by up to plus or minus 10 miles per hour to better match model-estimated traffic volumes with traffic counts. Adjusted speeds replace posted speeds where coded.

Intersection times represent the delay encountered at traffic signals and other intersection controls under uncongested conditions. An intersection delay time of ten seconds per signal or stop sign accounts for idling time, acceleration/deceleration time, and the likelihood of being stopped at a signal. Baseline ramp meter times of one minute are assumed for peak period networks. Ramp meters are assumed to be turned off during off-peak hours, so no off-peak ramp meter delays are added.

These input link and intersection travel times reflect free-flow conditions without congestion. Individual link and intersection congestion delays are computed later in the highway assignment step based on forecasted, link-specific traffic volumes.

Transit Network Inputs

Transit modeling requires coded transit networks that represent existing and planned conditions. Like roadway networks, transit networks are maintained in the master route feature class in the enterprise geodatabase. However, transit network coding is more complicated than highway coding because of the need to describe how individual transit routes operate over the transit system. Transit routes with similar operating characteristics are grouped into transit mode categories.

Transit Modes and Facilities

Table M.3: Transit Mode Definitions describes the seven transit modes and gives examples of existing routes in each category. Rapid Bus service would be provided by advanced design buses operating largely on Managed Lanes or arterials with priority transit treatments. This table is only representative of fixed-route transit services. Other nascent services, such as microtransit and other on-demand transportation concepts, are addressed in other components of ABM and are not explicitly coded in the transit network.

Table M.3: Transit Mode Definitions

Mode Number	Description	Examples
4	Commuter Rail	COASTER
5	Light Rail	Trolley, SPRINTER
5	Streetcar	Proposed New Service
6 and 7	Rapid Bus	Metropolitan Transit System Routes 215 and 235
9	Express Bus	San Diego Transit Corporation (SDTC) Routes 20, 50, 150
10	Local Bus	SDTC Routes 1–9

Most transit routes run over the same streets, freeways, HOV lanes, and ramps used in the highway networks. As a result, the only additional facilities that are added to the transportation network for transit modeling purposes are:

- Transit rail lines
- Streets used by buses that are not part of local general plan circulation elements
- Transit exclusive right of way (transitways) that have been proposed as part of the future transportation system

Nodes are located at each transit stop. Existing routes and stops are modified up to several times a year as new timetables are published. A transit scheduling system (HASTUS) and General Transit Feed Specification data provide accurate existing bus transit stop information. Near-term transit route changes are drawn from short-range plans produced by transit agencies. Longer-range improvements are proposed as a part of the Regional Plan and Sustainable Communities Strategy (SCS) and other transit corridor studies.

Transit Attributes

Transit stops and routes both have specific attribute data. Transit node attributes describe stop type and Park & Ride availability at each node. Transit route attributes include transit operator, mode, and most importantly, frequency of service by time period (a.m. peak period, p.m. peak period, midday, and night). Initial wait time and transfer time are significant factors that affect transit use and are computed from service frequencies. Existing frequencies are calculated based on published time schedules. Planned service frequencies may be policy-based, such as establishing a minimum 15–minute frequency.

Travel Times

Transit networks for different years and alternatives are selected from the master transportation feature class. Transit travel times on links between rail stations and bus stops are computed. Bus travel times are assumed to be a function of the number of bus stops on a link and roadway travel time. Since roadway times include congestion effects from the highway assignment step, bus travel times are recomputed at different stages of the modeling process. Roadway travel times are modified for the following special conditions before computing bus times:

- Ramp meter delays at meters with HOV bypass ramps are assumed to be one-third of single-occupancy vehicle (SOV) times.
- The maximum legal speed limit is used for the free-flow bus speed on freeways, whereas highway free-flow freeway speeds are set at 5 mph above the speed limit to reflect observed speeds from survey data.

Stop delay times of 30 seconds for Rapid and Express Bus service and 18 seconds for local bus routes are assumed. Express and local bus stop delays were calculated from observed data and include the effects of acceleration/deceleration, dwell time for boarding passengers, and likelihood of stopping at an individual stop. Rapid Bus stop delays were assumed to be similar to those of express buses based on existing systems in other regions.

Travel time procedures for rail service differ from the bus procedures described above. Where COASTER and Trolley routes already exist, speeds are obtained from published time schedules. Since rail service is normally not affected by highway congestion, base-year station-to-station travel times are assumed to remain unchanged over the forecast period with the exception of the COASTER, where rail straightening, complete double-tracking, and new technologies are thought to increase travel speeds up to a top speed of 110 mph by 2035. Average speeds are then calculated that attempt to factor in acceleration, deceleration, and dwell times for these high-speed rail services. Streetcar routes are assumed to operate at an average speed of 12 mph.

Fares

In addition to transit travel times, transit fares are required as input to the mode choice model. Emme procedures have been augmented to replicate the San Diego region's complicated fare policies, which differ as follows:

- Buses collect a flat fare of between $2.50 and $5 depending on the type of service
- Trolleys and SPRINTER charge a flat fare of $2.50

- Commuter rail has a zone-based fare of between $5 and $6.50

When transfers occur, the overall fare for the trip is set to the highest fare encountered. These fares represent cash fares and are factored later in the mode choice model to account for pass usage based on an analysis of survey data. Fares are converted to 2022 dollars for consistency with income data in the model and are assumed to remain constant over the forecast period unless fare policies are implemented that reduce the fares charged to transit riders.

Active Transportation Network Input

SANDAG maintains an all-street AT network including existing and planned bike projects to support bike project evaluation and impact analysis. Based on the proposed bike projects in the regional bikeway system, (see Appendices A and K) SANDAG generates year-specific AT networks and uses these networks to create accessibility measures from MGRA to MGRA for walking and short-distance biking and from TAZ to TAZ for longer-distance biking modes, including e-bikes. These accessibility measures are also used for micromobility. AT accessibility measures are inputs to the SANDAG ABM3 to simulate people's choice of travel mode and choice of bike routes.

The street geometry for the final Bike Network was developed from the SanGIS "Roads_all" shapefile, which is an All-Streets centerline network. In addition to the Roads_all shapefile, the spatial dispersal of San Diego's bike-exclusive infrastructure was captured from the SanGIS maintained "Bike" shapefile. The AT network has more features and a higher fidelity due to AT trips being shorter in distance compared to roadway segment feature class. Similar to the roadway network, evaluation of planned AT projects is possible. Future projects are manually added to the AT network.

Resident Travel Model

The AT network has unique characteristics that account for facility type, bike treatments, and elevation change. The AT networks include five classification types for bike facilities in the regional bikeway system: class I: bike paths, class II: bike lanes, class III: bike routes, class IV: cycle tracks, and "class V": bike boulevards. "Class V" is an internal designation and not a California vehicle code facility type.

The resident travel model is based on ActivitySim which is a Python platform for developing activity-based models. This model system is an advanced, but operational ABM that fits the needs and planning processes of SANDAG. The model adheres to the following principles:

- Corresponds to the most advanced principles of modeling individual travel choices with maximum behavioral realism. Addresses both household-level and person-level travel choices, including intrahousehold interactions (interactions between household members).
- Operates at a detailed temporal (half-hourly) level and considers congestion and pricing effects on travel time-of-day and peak spreading of traffic volume.

- Reflects and responds to detailed demographic information, including household structure, aging, changes in wealth, and other key attributes.[1]
- Offers sensitivity to demographic and socioeconomic changes observed or expected in the dynamic San Diego metropolitan region. This is ensured by the synthetic population as well as by the fine level of model segmentation. In particular, the resident travel model incorporates different household, family, and housing types, including a detailed analysis of different household compositions in their relation to activity-travel patterns.

The resident travel model has its roots in a wide array of analytical developments. They include discrete choice forms (multinomial and nested logit), activity duration models, time-use models, models of individual microsimulation with constraints, entropy-maximization models, etc. These advanced modeling tools are combined to ensure maximum behavioral realism, replication of the observed activity-travel patterns, and model sensitivity to key projects and policies. The model is implemented in a microsimulation framework. Microsimulation 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.

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 socioeconomic 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

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

A total of eight segments of person types (Table M.4) are used for the resident travel model. The person types are mutually exclusive with respect to age, work status, and school status. Reflects and responds to detailed demographic information, including household structure, aging, changes in wealth, and other key attributes.

[1] Please refer to the SANDAG ABM3 website for additional documentation - https://sandag.github.io/ABM/.

Table M.4: Person Types

Number	Person Type	Age	Work Status	School Status
1.	Full-time worker	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

Notes: Full-time employment is defined in the SANDAG 2022 household survey as at least 30 hours/week. Part-time is less than 30 hours/week but on a regular basis.

Further, workers are stratified by their occupation shown in Table M.5. These are used to segment destination choice size terms for work location choice based on the occupation of the worker.

Table M.5: Occupation Types

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

Activity Type Segmentation

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

The activity types are as shown in Table M.6. 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 and 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 duration.

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

Table M.6: Activity Types

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

Trip Modes

Table M.7 lists the trip modes defined in the resident travel model.

Table M.7: Trip Modes for Mode Choice

Number	Mode
1.	Drive-Alone
2.	Share Ride 2 Person
3.	Share Ride 3+ Person
4.	Walk
5.	Bike
6.	Shared E-bike (Micromobility)
7.	Shared E-scooter (Micromobility)
8.	Walk to Transit – Local Bus Only
9.	Walk to Transit – Premium Transit Only
10.	Walk to Transit – Local and Premium Transit
11.	Park & Ride to Transit – Local Bus Only
12.	Park & Ride to Transit – Premium Transit Only
13.	Park & Ride to Transit – Local and Premium Transit
14.	Kiss & Ride to Transit – Local Bus Only
15.	Kiss & Ride to Transit – Premium Transit Only
16.	Kiss & Ride to Transit – Local and Premium Transit
17.	TNC to Transit – Local Bus Only
18.	TNC to Transit – Premium Transit Only
19.	TNC to Transit – Local and Premium Transit
20.	Taxi
21.	TNC Single
22.	TNC Pooled
23.	School Bus (only available for school purpose)

Travel Time Reliability and Pricing Enhancements

Travel time and reliability enhancements are based upon recent federal research conducted under the Strategic Highway Research Program 2 C04[2] track to improve understanding of how highway congestion and pricing affect travel demand. The implemented travel time reliability and pricing features include:

- **Implementation of travel time heterogeneity** in which traveler's sensitivity to time is drawn from a log-normal distribution with a mean equal to the previously estimated travel time coefficient and a standard deviation that generally matches stated preference estimates of travel time distributions in a number of studies across the United States.
- **Continuous cost coefficients** that are based on household income, auto occupancy, and tour/trip purpose. They replace the previous version cost coefficients that were based on household income group (not continuous).
- **Value of Time (VOT)** bins used in assignment in which trips written by ABM3 demand models are grouped into three VOT bins and assigned using a relevant cost coefficient for each bin to reflect different cost sensitivities in skimming and assignment.
- **Implementation of a link-level measure of travel time reliability** based on an analysis of INRIX data. The reliability measure is based on link characteristics including volume/capacity ratio, link speed, and proximity of the link to major interchanges (to account for unreliability due to weaving conflicts), among other variables. The reliability measure is incorporated into the mode choice model utilities and therefore also affects upstream model components such as time-of-day choice and destination choice.
- **Implementation of a previously estimated toll transponder ownership model** in ABM3. In ABM2+, is-of-fit for forecasting demand on I-15 Managed Lanes.

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

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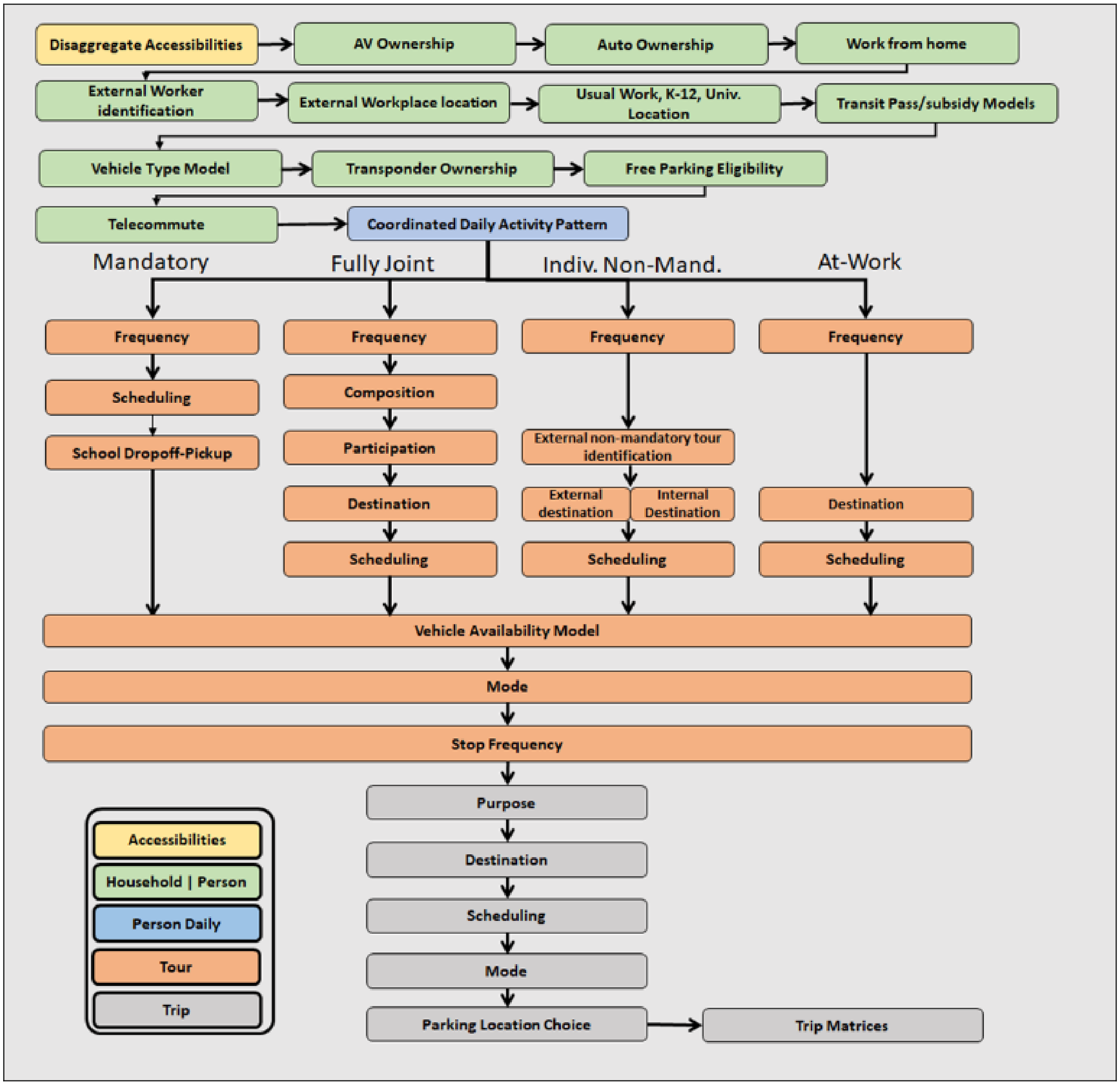
[2] https://nap.nationalacademies.org/catalog/22689/improving-our-understanding-of-how-highway-congestion-and-pricing-affect-travel-demand

Basic Structure and Flow

The resident travel model consists of a series of interdependent sub-models to simulate person and household travel. Figure M.3 illustrates the basic structure and flow.

Figure M.3: Resident Travel Model Design and Linkage Between Sub-Models



Source: SANDAG

The first model in the sequence is disaggregate accessibilities. This is a recent addition to ActivitySim in which the tour destination choice model is run for a prototypical sample population covering key market segments and destination choice logsums from the model are written for each tour in the population. These destination choice logsums are then merged with the actual synthetic population and used as accessibility variables in downstream models such as auto ownership, coordinated daily activity patterns, tour frequency, and mandatory location choice. This model is run for all workers and students regardless of whether they attend work or school on the simulated day.

Next, a set of long-term and mobility models are run. The first model in the sequence predicts whether an autonomous vehicle is owned by the household. This model conditions the next model, which predicts the number of autos owned. If an autonomous vehicle is owned, multiple cars are less likely. Next, the mandatory (work and school) location choice models are run. The work location choice models include a model to predict whether the worker has a usual out-of-home work location or exclusively works from home. If the worker chooses to work from home, they will not generate a work tour. An external worker identification model determines whether each worker with an out-of-home workplace location works within the region or external to the region. If they work externally to the region, the external station is identified. Any primary destination of any work tours generated by the worker will be the external station chosen by this model. A work location choice model predicts the internal work location of each internal worker, and a school location choice model predicts the school location of each student.

Next, a set of models predicts whether workers and students have subsidized transit fares and if so, the percent of transit fare that is subsidized, and whether each person in the household owns a transit pass. A vehicle type choice model then runs, which predicts the body type, fuel type, and age of each vehicle owned by the household; this model was extended to predict whether each vehicle is autonomous, conditioned by the autonomous vehicle ownership model. Next, we predict whether each household has access to a vehicle transponder which can be used for managed lane use. We assume that all vehicles built after a certain year (configurable by the user) are equipped with transponders. Next, we predict whether each worker has subsidized parking available at work. Finally, we predict the telecommute frequency of each worker, which affects downstream models including the daily activity pattern model, the non-mandatory tour frequency model, and stop frequency models.

Next, the daily and tour level models are run. The first daily model is the daily activity pattern model, which predicts the general activity pattern type for every household member. 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. Because household members often travel together and to prevent situations such as young children being left alone, the pattern that one household member has can influence the patterns of other household members.

Then, mandatory tours are generated for workers and students, the tours are scheduled (their location is already predicted by the work/school location choice model), a vehicle availability model is run that predicts which household vehicle would be used for the tour, and the tour mode is chosen. After mandatory tours are generated, a school pick up/drop-off model forms half-tours where children are dropped off and/or picked up at school. The model assigns chaperones to drive or ride with children, groups children together into “bundles” for ride-sharing and assigns the chaperone task to either a generated work tour or generates a new tour for the purpose of ridesharing. Fully joint tours – tours where two or more household members travel together for the entire tour - are generated at a household level, their composition is predicted (adults, children or both), the participants are determined, the vehicle availability model is run, and a tour mode is chosen. The primary destination of fully joint tours is predicted, the tours are scheduled, the vehicle availability model is run, and a tour mode is chosen. Next, non-mandatory tours are generated, their primary destination is chosen, they are scheduled, the vehicle availability model is run, and a tour mode is chosen for each. At-work subtours are tours that start and end at the workplace. These are generated, scheduled (with constraints that the start and end times must nest within the start and end time of the parent work tour), a primary destination is selected, the vehicle availability model is run, and a tour mode is chosen.

At this point, all tours are generated, scheduled, have a primary destination, and a selected tour mode. The next set of models fills in details about the tours - number of intermediate stops, location of each stop, the departure time of each stop, and the mode of each trip on the tour. Finally, the parking location of each auto trip to the central business district (CBD) is determined.

Main Sub-Models and Procedures

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

Sub-Model (SM) 1.1: Disaggregate Accessibilities

In ABM3, a new disaggregate accessibilities component was added to the model system. These new disaggregate accessibilities consistent with the actual ActivitySim destination and mode choice models and are used by ActivitySim model components requiring destination choice logsums. In order to create a set of disaggregate accessibilities using ActivitySim destination and mode choice models, a 'prototypical' synthetic population must be created covering all market segments of interest, and a set of tours must be defined for each household and person covering all tour purposes of interest.

Household income and household vehicles are systematically varied in the synthetic population, with three levels of income and three levels of auto ownership (0 autos, autos<workers, autos>=workers) so there is a total of 3x3 or nine total household segments in the synthetic population. Each household in the 'prototypical' synthetic population has two persons; a full-time working female age 35 and a non-working male age 55. The full-time worker has a Mandatory activity pattern (one work tour) and the non-working adult has a Non-mandatory activity pattern (two non-mandatory tours). The default values for tour start and end times and auto operating costs are used in the mode choice logsum calculations.

SM 2.1: Autonomous Vehicle (AV) Ownership

Number of Models:	1
Decision-Making Unit:	Households
Model Form:	Binary Logit
Alternatives:	Two (households owns an AV; households do not own an AV)

This model predicts whether a household owns an AV. The model uses household income as an explanatory variable.

SM 2.2: Auto Ownership

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

The model predicts 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 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
- 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

SM 2.3: Work from Home

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

The 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
- Whether the worker is full time or part time
- Workplace location accessibility
- Worker industry

SM 2.4: External Worker Identification

Number of Models: 1
Decision-Making Unit: Workers
Model Form: Binary Logit
Alternatives: Two (regular workplace is external to the region; regular
workplace is internal to the region)

The model predicts which workers have a usual out-of-home workplace that is out of the region. If these workers generate a work tour, the primary destination of the tour would be an external station, predicted by the external worker location choice model. The model uses the following explanatory variables:

- Distance to nearest external station
- Total demand at external station
- Part-time worker status
- Household income

SM 2.5: External Workplace Location

Number of Models: 1
Decision-Making Unit: Workers with an external work location
Model Form: Multinomial Logit
Alternatives: 12 (External cordons)

The model predicts which external station is the primary destination for the work tours generated by external workers. The alternatives in the model are each external station. The model uses the following explanatory variables:

- Distance to the external station
- Mode choice logsum to the external station
- Size of external station

SM 2.6: Usual Workplace Location

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 model assigns a workplace MGRA for every employed person in the synthetic population who does not choose "works at home" from Model 2.3. 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 seven occupation categories used in the segmentation of size terms, as shown in Table M.5. Each occupation category uses 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 time versus part time)
- Gender
- Distance
- The tour mode choice logsum for the worker from the residence MGRA to each sampled workplace MGRA using peak level-of-service
- The size of each sampled MGRA

Since mode choice logsums are required for each destination, a two-stage procedure is used for all destination choice models in order to reduce computational time (it would be computationally prohibitive to compute a mode choice logsum for over 20,000 MGRAs and every tour). In the first stage, a simplified destination choice model is applied in which all TAZs are alternatives. The only variables in this model are the size term (accumulated from all MGRAs in the TAZ) and distance. This model creates a probability distribution for all possible alternative TAZs (TAZs with no employment are not sampled). A set of alternatives are sampled from the probability distribution and, for each TAZ, an MGRA is chosen according to its size relative to the sum of all MGRAs within the TAZ. These sampled alternatives constitute the choice set in the full destination choice model. Mode choice logsums are computed for these alternatives and the destination choice model is applied. A discrete choice of MGRA is made for each worker from this more limited set of alternatives. In the case of the work location choice model, a set of 30 alternatives is sampled.

The applied procedure uses an iterative shadow pricing mechanism to match workers to input employment totals. The shadow pricing process compares the share of workers who choose each MGRA by occupation to the relative size of the MGRA compared to all MGRAs. A shadow price is computed which scales the size of the MGRA based on the ratio of the observed share to the estimated share. The model is rerun 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 preschool model, a grade school model, a high school model, and a university model. Each of these uses distance and destination choice size terms as explanatory variables, with university including both worker status and high enrollment interacting with distance and preschool including both age and income interacting with distance. The size terms for each model are based on the appropriate enrollment number except for preschool, as those enrollment numbers aren't included. The size term for preschool is instead a combination of population and employment from the education, government, healthcare, military, and other sectors. As is the case with workplace location, school location uses the tour mode choice logsum as an explanatory variable for accessibility.

SM 2.7: Transit Pass Ownership

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

The model predicts which person owns a pass. Explanatory variables for this model include:

- Age
- Household income
- Number of children in household
- Auto sufficiency
- Transit pass cost
- Parking cost at work
- University student status

SM 2.8: Transit Pass Subsidy

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

The model predicts which workers have transit subsidized by their employer. Explanatory variables for this model include:

- Household income
- Industry
- Student status
- Parking cost at work
- Part-time worker status
- Transit accessibility

SM 2.9: Vehicle Type

Number of Models: 1
Decision-Making Unit: Vehicles
Model Form: Multinomial Logit
Alternatives: 1620 (9 × 20 × 5) 9 body types (Car, Car-AV, Van, Van-AV, SUV, SUV-AV, Pick up, Pick up-AV, Motorcycle) 20 ages (1-19, 20+) 5 fuel types (Gas, Diesel, Hybrid, PEV, BEV)

This model predicts the body type, fuel type, and age of each vehicle owned by each household. This model was estimated as part of work funded by the ActivitySim consortium using a national dataset, adapted for use in ABM3, and calibrated to data that SANDAG obtained from the California Department of Motor Vehicles. Explanatory variables for this model include:

- Number of makes and models available
- Miles per gallon/battery range
- Number of public chargers per capita
- New purchase price
- Household income
- Household density
- Household auto sufficiency
- Number of children in household

If a household was determined to own an AV in the AV ownership model, then that household must select an AV.

SM 2.10: Transponder Ownership

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:

- Number of autos owned by the household
- Number of workers in the household
- Household income
- The straight-line distance from the MGRA to the nearest toll facility in miles

SM 2.11: Free Parking Eligibility

Number of Models:	1
Decision-Making Unit:	Workers whose workplace is in a parking-constrained area (park area 1)
Model Form:	Binomial Logit
Alternatives:	Two (free on-site parking, and no parking provision)

The model predicts which persons have on-site parking provided to them at their workplaces and who receive reimbursement for off-site parking costs. The provision model takes the form of a multinomial logit discrete choice between free on-site parking and no parking provision.

Persons with workplaces outside of park area one are assumed to receive free parking at their workplaces. Explanatory variables in the provision model include household income and household auto sufficiency.

SM 2.12: Telecommute Frequency

Number of Models:	1
Decision-Making Unit:	Workers
Model Form:	Multinomial Logit
Alternatives:	Four (never or less than four days per month, one day per week, two to three days per week, and four or more days per week)

This model predicts telework frequency based on household and person variables for workers who telework occasionally. It was estimated using data from the 2016 and 2022 Household Travel Surveys and implemented in the resident travel demand models. The outcome of the telework model are reflected in adjustments made to the coordinated daily activity pattern (CDAP) model; the mandatory tour generation model; and the non-mandatory tour frequency model, tour, and trip mode choice models. The explanatory variables in the model include:

- Occupation
- Household size
- Household with kids
- Household income
- Work and student status
- Number of vehicles
- Distance to work

The number of significant explanatory variables decreases as telework frequency increases. This may be due in part to the limited number of observations for which more frequent teleworking is observed but may also be caused by limits in available explanatory variables. For example, some workers in the technology sector may be more able to telework than others, due to their job responsibilities. This unobserved variation in the factors that lead to teleworking suggests that future model predictions should be treated with care.

SM 3.1: Telecommute Frequency

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

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

- **Mandatory pattern (M)**, which means that the worker or student has at least one work or school activity. If a worker is not a student and works from home, they are not allowed to have an M DAP. People with an M pattern are also allowed to take non-mandatory tours.
- **Non-mandatory pattern (N)**, which indicates that the individual has at least one joint or individual non-mandatory activity. This alternative is available to all people.
- **At-home pattern (H)**, which includes only in-home activities. At-home patterns are not distinguished by any specific activity (e.g., working at home, taking care of a child, being sick, etc.). Cases where someone is not in town (e.g., business travel) are also combined with this category.

The CDAP model as implemented for SANDAG includes an additional joint indicator to determine which people participate in joint tours. Only the individual M, N, and H patterns were re-estimated in this work and the joint utility will be addressed in calibration.

It is important to only include data where the whole household has completed the survey for that day. In practice, this means that only data with non-zero person-day weights are included. In the survey processing procedures, many incomplete households are included because some members might have reported travel during that day, which we would like to keep, but it may not have been reported for all people. For example, child travel is only reported on one day for the 2022 data. Since CDAP is a coordinated decision by all household members, all members of the household must have completed the survey.

Interaction between household members is what the "coordinated" part of the CDAP model represents. There is an added utility component that is added for members of the household having the same M, N, or H pattern. Since the CDAP model must account for interactions between members across the household, the output is really a household level-decision where the alternatives are the specification for each person's daily activity pattern.

The choice structure includes 363 alternatives with no joint travel and 328 alternatives with joint travel, totaling to 691 alternatives as shown in Table M.8. Note that the choices are available based on household size. There are also two facets of the model that reduce the complexity. First, mandatory DAP types are only available for appropriate person types (workers and students). Second, and more importantly, intrahousehold 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.

To demonstrate, let's look at a couple of household sizes. First of all, a single person household has just the individual component and contains three alternatives: M, N, and H. For a two-person household, each individual can have any of the three alternatives which totals to six possible choices: MM, MN, MH, NM, NN, NH, HM, HN, HH (in implementation, the joint component extends the alternatives with non-home components to produce an additional four alternatives: MMJ, MNJ, NMJ, NNJ). In this two-person household example, interaction coefficients would be applied to all cases where both household members are performing the same activity. If both people in the household are full-time workers, then the added utility for the MM alternative would include the coef_M_11 where the two one's indicate the person types of the first and second person. Interaction coefficients only apply to alternatives where members of the household are performing the same DAP and represent the added utility of people performing activities together. Interaction coefficients are therefore generally positive due to this added utility of coordinating your activities across other members of the household. The number of alternatives grows combinatorically with additional household members up to a household size of five. For households with six or more people, the first five members of the household (ranked by worker status, student status, and age) are assigned a CDAP through the described process. The remaining household members have their CDAP assigned based on a probability lookup table segmented by person type. Probabilities were not adjusted as part of the estimation process.

Table M.8: Number of Choices in CDAP Model

Household Size	Alternatives – No Joint Travel	Alternatives with Joint Travel	All Alternatives
1	3	0	3
2	3×3=9	3×3−(3×2−1)=4	13
3	3×3×3=27	3×3×3−(3×3−2)=20	47
4	3×3×3×3=81	3×3×3×3−(3×4−3)=72	153
5 or more	3×3×3×3×3=243	3×3×3×3×3−(3×5−4)=232	475
Total	**363**	**328**	**691**

The structure is shown graphically in Figure M.4 for a three-person household. Each of the 27 DAP 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 one mandatory (M), person two non-mandatory (N), and person three 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 intrahousehold 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.

Some observations in the individual component from estimation results include:

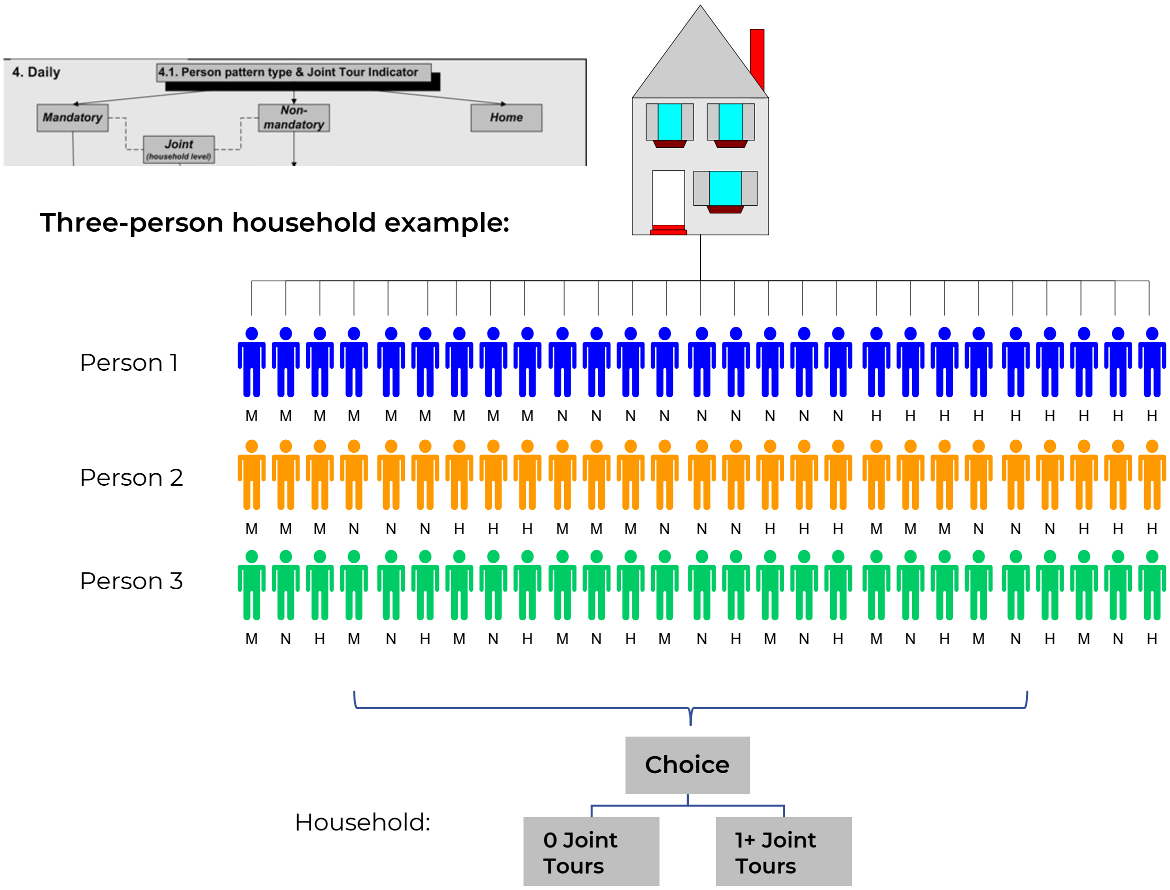
- People who work from home make more N travel.
- As telecommuting increases, the amount of M travel decreases.

- Younger people tend to have fewer at home days compared to older people. People over the age of 80 are especially more likely to stay at home.
- An increase in auto sufficiency generally showed a decrease in the H pattern, but this was not significant for all person types.
- Low income full-time and part-time workers are more likely to stay at home.

The CDAP model explanatory variables include:

- Household size
- Number of adults in household
- Number of children in household
- Auto sufficiency (see SM 2.2 auto ownership model for details)
- Household income
- Person type
- Age
- Gender
- Usual work location
- Telecommute frequency
- Accessibility across all modes of transport from household MGRA to non-mandatory locations

Figure M.4: Example of DAP Model Alternatives for a Three-Person Household



Source: SANDAG

SM 3.2.1: 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)

The CDAP model is used to assign each person a pattern of activities for whether there will be travel for mandatory activities, non-mandatory activities, or no travel/ external travel. Following this model, the mandatory tour frequency model assigns each worker and student an exact number of mandatory tours. Mandatory tour frequency model predicts exact number of mandatory tours by purpose of primary activity (work or school). It is important to note that it is impossible for non-working adults and retired adults to have mandatory tours, as the mandatory tour category consists of work and school trips. The model has the following five alternatives: 1 Work Tour, 2 or more Work Tours, 1 School Tour, 2 or more School Tours, and 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

SM 3.2.2: Individual Mandatory Tour Scheduling

Number of Models:	3 (Work, University, and School)
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	1176

After individual mandatory tours have been generated, the tour departure time from home and arrival time back at home is chosen simultaneously. The mandatory tour scheduling model assigns each work and school tour a start and end period simultaneously. It predicts the departure period (leaving home) and arrival period (returning home) simultaneously, Includes time for travel and all activities on tour. There are 48 half-hour periods in the model, starting and ending at 3 A.M. 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 1128 half-hour departure/arrival time alternatives. Every possible combination of the 48 departure half-hours with the 48 arrival half-hours (where the arrival half-hour is the same or later than the departure hour) is an alternative. This gives 48×49/2=1176 choice alternatives. The model uses 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 ActivitySim model structure, the tour-scheduling model is placed after destination choice and before mode choice. Thus, the destination of the tour and all related destination and origin-destination attributes are known and can be used as variables in the model estimation. The 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

SM 3.2.3: Individual Mandatory School Drop off-Pick up

The model identifies which student's school tours are candidates for ridesharing/joint travel, and which adults are chaperones for that travel. It either links an adult's work tour with one or more child's school tours where the drop off/pick up activities occur as stops on the adult's tour ("rideshare" tours) or generates a new tour for the adult specifically for the purpose of dropping off or picking up the child or children ("pure escort" tours). The model is applied by direction; for cases where the adult chaperones the child as part of their work tour, drop-offs at school are assumed to be outbound stops, while pick up at school are assumed to occur in the inbound direction.

This model was not calibrated due to lack of reliable data in the household travel survey, as nearly 100% of the observations were tours with no escort. We know that this is not the case in reality as evidenced by the long line of cars at schools in the morning and afternoon to drop-off and pick up kids. Therefore, we assume that the results of the model estimated using data from Maricopa Association of Governments is a more accurate source of observed data than the household travel survey for this behavior.

The model is run after work and school locations have been chosen for all household members and after work and school tours have been generated and scheduled. The model labels household members of driving age as potential "chauffeurs" and children with school tours as potential "escortees." The model then attempts to match potential chauffeurs with potential escortees in a choice model whose alternatives consist of "bundles" of escortees with chauffeurs for each half tour. A half tour is a sequence of trips between the tour origin (home) and the tour primary destination. For the chauffeur, the primary destination is the furthest drop-off or pick-up activity from home. For the child being escorted, the primary destination is school.

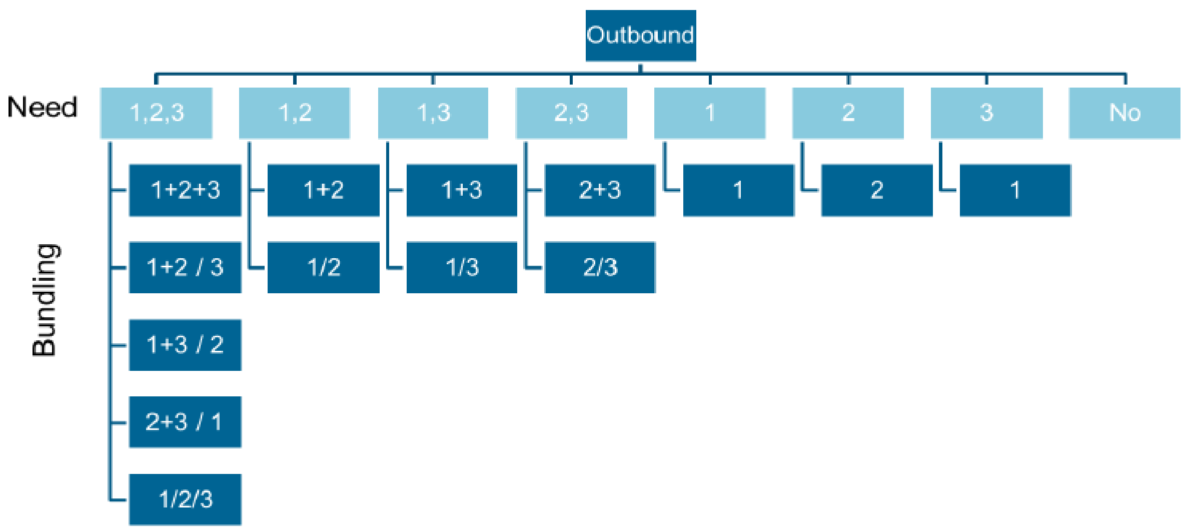
The model classifies each child's school tour into three types:

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

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

In summary, the model bundles which children are escorted by which drivers and by what type of school escort type. Figure M.5 shows an example of bundling children by chauffeur for a household with three children attending school and two eligible drivers. The first row of the alternatives shows different combinations of children being escorted. For example, in the left-most alternative, all three children are escorted, whereas in the right-most alternative, no children are escorted. The dark blue boxes under each of the first-row alternatives show different combinations of bundling children by tour; in the first box underneath the left-most alternative, both children are escorted on one half tour (one task). In the next alternative, child one and two are escorted on one tour, whereas child three is escorted on another tour (two tasks). Each task is matched with a chauffeur by tour type (pure escort versus rideshare). In this example, there are 15 alternatives and 22 potential tasks, and each task has a potential of four different options for chauffeur type and tour, yielding 189 alternatives.

Figure M.5: School Escort Model Example of Bundling Children by Half Tour



Source: SANDAG

The explanatory variables in the model include the following:

- Chauffeur disutility for ridesharing—out-of-direction distance and time
- Escortee utility for ridesharing, which considers age
- Escortee utility for non-rideshare (non-motorized time to school)
- Bundling utilities (the utility of driving each child separately versus taking children together)

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

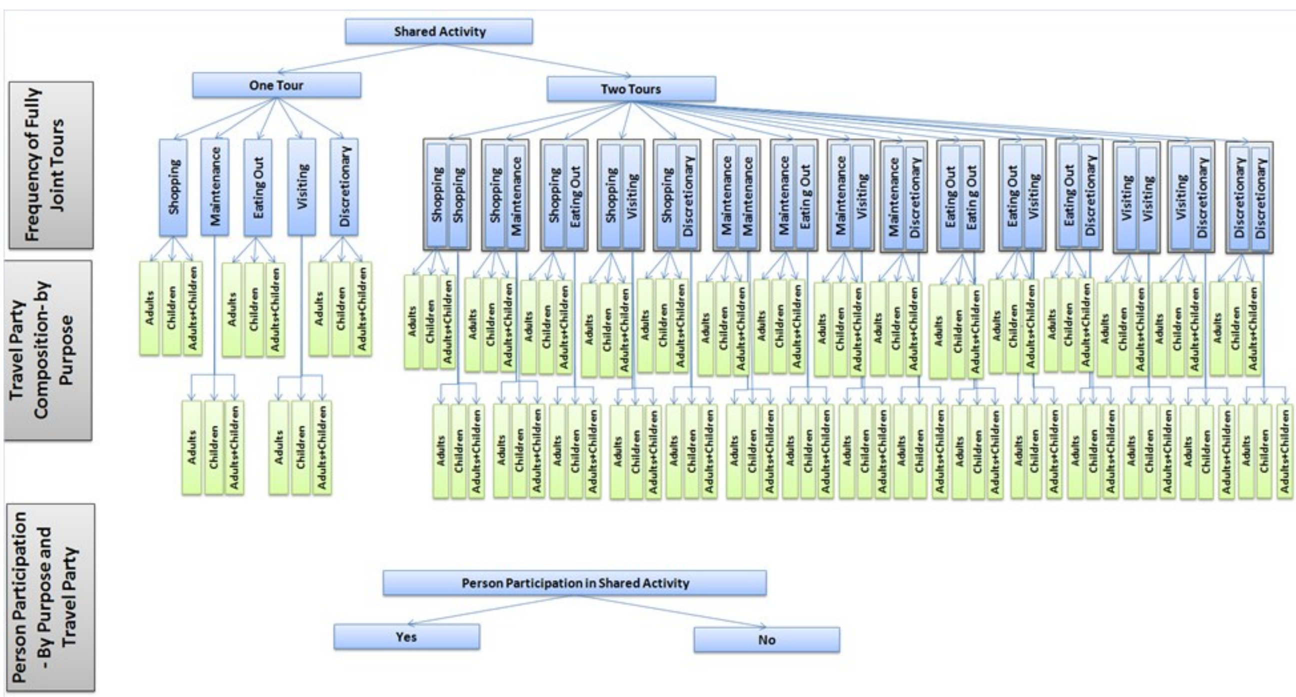
SM 3.3: Generation of Joint Household Tours

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).

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 stop. Modeling joint activities involves two linked stages (see Figure M.6).

- 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 & Composition 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 M.6: Model Structure for Joint Non-Mandatory Tours



Source: SANDAG

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

SM 3.3.1: 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)

The model simultaneously predicts the number of fully joint tours by purpose that will be made by each household, along with the composition of the tour. Fully joint tours are tours in which at least two household members travel together for the entire tour (no drop-offs or pick-ups of household members). Each alternative is a combination of the number of tours by purpose (up to two maximum) and the composition (adult only, children only, or mixed) of each tour. Joint tours are generated for only non-mandatory purposes whose activities include eating out, shopping, visiting, maintenance and other discretionary. The CDAP model predicts whether there are zero or at least one fully joint tour generated by the household, so this model is only run in the case that at least one fully joint tour is identified by the CDAP model. Thus, there is no zero joint tour alternative in the model. This mode was calibrated to reduce the predicted shares of 2+ joint tours, and better match the tour composition.

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
- Maintenance HOV accessibility from household MGRA to employment
- Discretionary HOV accessibility from household MGRA to employment
- Presence and size of overlapping time windows, which represent the availability of household members to travel together after mandatory tours have been generated and scheduled

SM 3.3.2: Joint Tour Participation

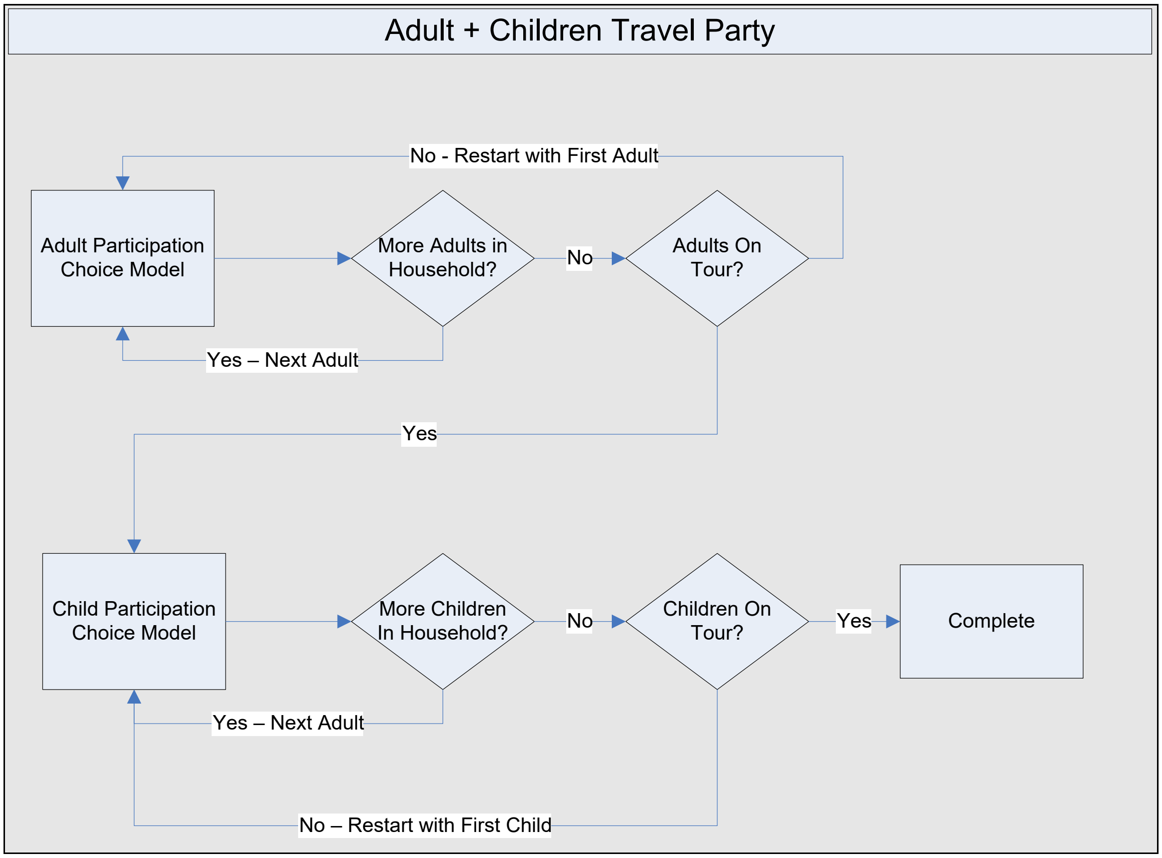
Number of Models:	1
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	2 (Yes or No)

The model predicts who participates in tour. It 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 DAP 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 M.7.

The explanatory variables in the participation model include:

- Auto sufficiency
- Household income
- Frequency of joint tours in the household
- Number of adults in household
- Number of children 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 M.7: Application of the Person Participation Mode



Source: SANDAG

SM 3.3.3: Joint Tour II & IE Destination Choice

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

The model predicts the primary destination for fully joint tours. This is a two-stage model; first, a sample of alternatives is selected using a simple utility that does not include a mode choice logsum term. Then, the mode choice model is run for sampled alternatives and a final selection is made using the full utility with the mode choice model logsum added to the utility of each sampled alternative. The fully joint tour destination choice models were not estimated nor calibrated; instead the models were transferred directly from ABM2+ and used in ABM3.

The joint tour IE tour identification model predicts whether primary activity is external to region. If so, the zone is selected from external stations. 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 to reduce computation time. The explanatory variables for the joint tour primary destination choice model include:

- Household income

- Gender and 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
- The size of each sampled MGRA by tour purpose

SM 3.3.4: Joint Tour Scheduling

Number of Models:	1
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	1176 (combinations of tour departure half-hour and arrival half-hour back at home)

After joint tours have been generated and assigned a primary location, the tour departure time from home and arrival time back at home is chosen simultaneously. The model is fully described under sub-model 3.2.2 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.

SM 3.4.1: 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, 2, 2+, 3+tours of each type of maintenance activity (Escort, Shop, Other Maintenance, Eat Out, Social, and Other Discretionary)

The model predicts the number of non-mandatory tours by purpose of primary activity that are taken by each individual. There are separate tour frequency models by person type. Each model predicts the number of non-mandatory tours by tour purpose. Each alternative is therefore a combination of the number of tours (0,1, 2, or 3+) tours by tour purpose. Any case where an individual selects 2+ or 3+ tours (there are different caps in total tours for each purpose based on observed data) requires an additional model in which a fixed set of probabilities is used in a Monte Carlo simulation to determine the exact number of tours. The six non-mandatory purposes are: escorting, shopping, social, eat out, other discretionary (such as gym, religious services and other activities), and other maintenance (medical, auto repair, etc.). This model was re-estimated for ABM3. 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
- School accessibility from household MGRA to employment (
- Escorting HOV accessibility from household MGRA to employment
- Shopping SOV/HOV accessibility from household MGRA to employment
- Maintenance SOV/HOV accessibility from household MGRA to employment
- Eating out SOV/HOV accessibility from household MGRA to employment
- Walk accessibility from household MGRA to non-mandatory activities

SM 3.4.2: External Non-Mandatory Tour Identification Choice

Number of Models:	1
Decision-Making Unit:	Tour
Model Form:	Binary Logit
Alternatives:	2 (External tour or Non-external tour)

The model identifies non-mandatory tours that have a destination outside of the region. If so, the zone is selected from external stations. This model was estimated for ABM3. If the tour is external, the external location choice model chooses external station used to access workplace; if the tour is not external, regular non-mandatory tour is inside region. The explanatory variables include:

- Worker status (full time/ part-time)
- Occupation
- Age
- Income
- Logsum to nearest external station
- Total IE demand at external station

SM 3.4.3: Individual Non-Mandatory Tour II & IE Destination Choice

Number of Models:	6 (Escort, Shop, Other Maintenance, Eat Out, Social, 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, social, and other discretionary. The individual non-mandatory tour destination choice model predicts the destination zone of primary activity for each of the six non-mandatory tour purposes.

The model works at an MGRA level, and sampling of destination alternatives is implemented to reduce computation time. Note that the mode choice logsum used is based on a “representative” time period for individual non-mandatory tours, which is currently off-peak, since the actual time period is not chosen until sub-model 3.4.3. The explanatory variables in non-mandatory tour location choice models include:

- Household income
- Age of the traveler
- Gender
- Distance
- Size of each sampled MGRA
- 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

SM 3.4.4: Individual Non-Mandatory Tour Scheduling

Number of Models:	6 (Escort, Shop, Other Maintenance, Eat Out, Social, and Other Discretionary)
Decision-Making Unit:	Person
Model Form:	Multinomial Logit
Alternatives:	1176(combinations of tour departure half-hour and arrival half-hour back at home)

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

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

SM 3.5.1: At-Work Sub-Tour Frequency

Number of Models:	1
Decision-Making Unit:	Workers
Model Form:	Multinomial Logit
Alternatives:	7 (none; 1 eating out tour; 1 work tour; 1 other tour; 2 work tours; 2 other; and a combination of eating out, work, and other tours)

The model predicts the exact number of at-work subtours. 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 workplace
- Mixed-use category at the workplace
- Non-motorized eating out accessibility from work MGRA to destination MGRA

SM 3.5.2: At-Work Sub-Tour II Destination Choice

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

The model determines the location of the tour primary destination. The model works at an MGRA level, and sampling of destination alternatives is implemented in order to reduce computation time. Note that the mode choice logsum used is based on a “representative” time period for individual non-mandatory tours, which is currently off-peak, since the actual time period is not chosen until model SM 3.5.3. The model is constrained such that only destinations within a reasonable time horizon from the workplace are chosen, such that the tour can be completed within the total available time window for the sub-tour. The explanatory variables in the at-work sub-tour choice models include:

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

SM 3.5.3: At-Work Sub-Tour Scheduling

Number of Models:	1
Decision-Making Unit:	Workers
Model Form:	Multinomial Logit
Alternatives:	1176 (combinations of tour departure half-hour and arrival half-hour back at home.)

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 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
- The tour mode choice logsum from the work MGRA to each sampled MGRA location

SM 3.6: Vehicle Availability Model

Number of Models:	1
Decision-Making Unit:	Tour
Model Form:	Multinomial Logit
Alternatives:	4 (vehicles that the household owns, plus one non-household vehicle)

The model predicts which vehicle would be used for the tour if a household vehicle is chosen. This influences the auto operating costs used in mode choice, and autonomous vehicle parameters if an AV is chosen. It can be used to post-process results to calculate greenhouse gas emissions, energy consumption, fuel consumption, and household travel expenditures. There are no hard constraints in the model. The same vehicle can be chosen for overlapping tours in the current version.

SM 3.7: Tour Mode Choice Model

Number of Models:	6 (Work, University, K–12, Maintenance, Discretionary, and At-Work Sub-Tours)
Decision-Making Unit:	Persons
Model Form:	Nested Logit
Alternatives:	23 (see M.8)

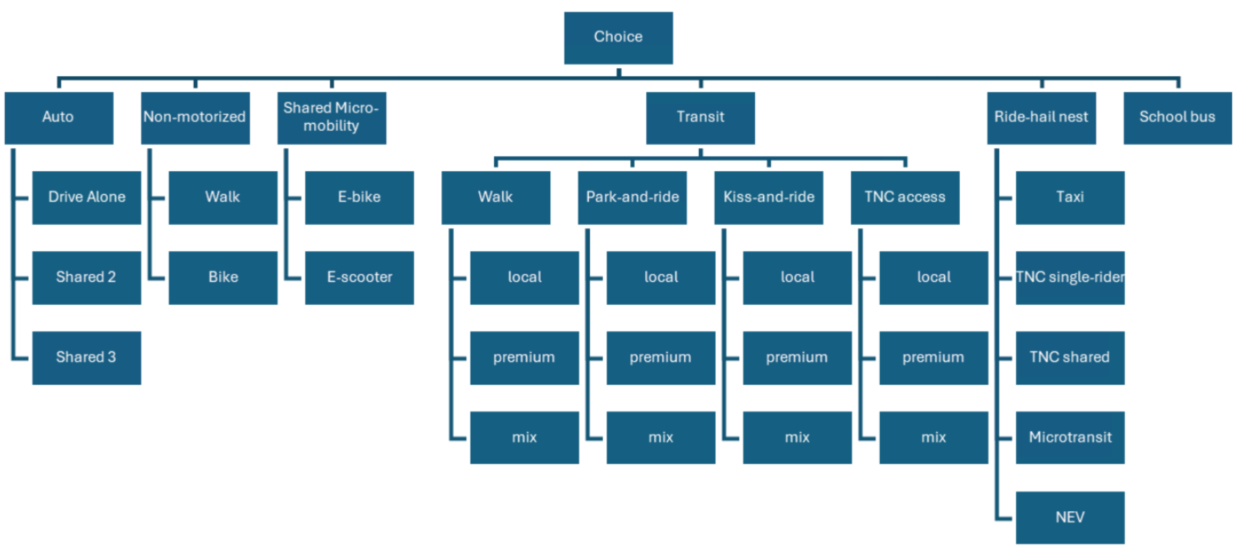
The model in ABM3 was revised and enhanced in several ways. New micromobility modes were added to the model, including e-scooter and e-bikes. The new model uses TAZs for transit skims (ABM2+ used Transit Access Points) and overrides skimmed walk time to transit with the time from the MAZ to the nearest transit stop by type of transit service (local versus premium). This section describes the new models.

There are two mode choice models used to predict mode in ActivitySim:

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

The tour mode level can be thought of as a mode preference model, while the trip mode choice model can be thought of as a mode switching model. Tour mode choice is used to constrain stop location choice as well as trip mode choice. The modes for both models are the same, but the higher level of the nesting structure constrains lower-level decisions. Figure M.8 shows the revised nesting structure for both tour and trip mode choice.

Figure M.8: Revised Mode Choice Nesting Structure



Source: SANDAG

Tour modes are defined based on a set of rules pertaining to the combination of modes reported for each trip on the tour. The following set of rules are proposed, subject to modification and finalization based on observed combinations of trip modes on tours. Note that micromobility and ride-hail modes are constrained at that level, rather than the lower level trip modes.

1. If any mode is PNR-transit, the tour mode is PNR-transit
2. If any mode is KNR-transit, the tour mode is KNR-transit
3. If any mode is TNC-transit, the tour mode is TNC-transit
4. If any mode is walk-transit, the tour mode is walk-transit
5. If any mode is ride-hail (taxi, single pay TNC, shared TNC), the tour mode is ride-hail
6. If any mode is micromobility (e-scooter or e-bike), the tour mode is micromobility
7. If any mode is school bus, the tour mode is school bus.
8. If any mode is shared 3+, the tour mode is shared 3+
9. If any mode is shared 2+, the tour mode is shared 2+
10. If any mode is drive alone, the tour mode is drive alone
11. If any mode is bike, the tour mode is bike
12. If any mode is walk, the tour mode is walk

Note that although there are options in the nesting structure for transit sub-mode (local-only, premium-only, and mix), we do not calibrate the model for these modes specifically in mode choice. Instead we apply terms in mode choice that reflect lower disutility for using bus to access premium transit, and apply technology-specific constants in premium and mix modes to reflect preferences for bus rapid transit, light-rail, and commuter rail, all else being equal. A potential refinement of this approach would be to allow all modes to compete in transit path building and attempt to address transit user preferences in path parameters as well as in mode choice instead of forcing the path-finder to find separate paths for each transit technology. However, we felt that this was beyond our current scope of work.

The tour mode choice model is based on the round-trip 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 is chosen based on LOS variables for both directions according to the time periods for the tour departure from the anchor and the arrival back at the anchor. This is one of the fundamental advantages of the tour-based approach. For example, a commuter can have very attractive transit service in the a.m. peak period in the outbound direction, but if the return home time is in the midday or later at night, the commuter may prefer private auto due to lower off-peak transit service. The appropriate skim values for the tour mode choice are a function of the TAZ/MAZ of the tour origin and TAZ/MAZ of the tour primary destination. The mode choice model alternatives and skims are shown Table M.9.

Table M.9: Mode Choice Alternatives and Network Level of Services Variables

Alternative	Network Level-of-Service (Skims)
Drive-Alone	Auto time, distance by drive-alone (no HOV lanes) by three value of time bins
Shared 2	Auto time, distance, and cost by shared-ride 2 (no HOV 3+ lanes) by three value of time bins
Shared 3+	Auto time, distance, and cost by shared-ride 3+ by three value of time bins.
Walk	Walk distance and time calculated across an all-streets network between MAZs within a certain distance threshold
Bike	Bike logsums calculated across an all-streets network between MAZs and TAZs within certain distance thresholds
e-scooter	e-scooter distance and time calculated across an all-streets network between MAZs within a certain distance threshold
e-bike	e-bike distances and logsums calculated across an all-streets network between MAZs and TAZs within certain distance thresholds
Walk-local	Walk local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, walk access time, walk egress time
Walk-premium	Walk premium skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, walk access time, walk egress time
Walk-mix	Walk mix skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, walk access time, walk egress time
PNR-local	PNR local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, PNR access (or egress) time, walk egress (or access) time
PNR-premium	PNR local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, PNR access (or egress) time, walk egress (or access) time
PNR-mix	PNR mix skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, PNR access (or egress) time, walk egress (or access) time
KNR-local	KNR local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, KNR access (or egress) time, walk egress (or access) time
KNR-premium	KNR local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, KNR access (or egress) time, walk egress (or access) time
KNR-mix	KNR mix skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, KNR access (or egress) time, walk egress (or access) time

Table M.9: Mode Choice Alternatives and Network Level of Services Variables Continued

Alternative	Network Level-of-Service (Skims)
TNC-local	KNR local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, KNR access (or egress) time, walk egress (or access) time
TNC-premium	KNR local skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, KNR access (or egress) time, walk egress (or access) time
TNC-mix	KNR mix skims: in-vehicle by transit technology, total in-vehicle time, first wait, transfer wait, auxiliary walk time, transit fare, KNR access (or egress) time, walk egress (or access) time
Taxi	Auto time, distance, and cost by shared-ride 2 (no HOV 3+ lanes) by high value of time bin
TNC-single	Auto time, distance, and cost by shared-ride 2 (no HOV 3+ lanes) by high value of time bin
TNC-pool	Auto time, distance, and cost by shared-ride 2 (no HOV 3+ lanes) by low value of time bin
Microtransit	Auto time, distance, and cost by shared-ride 3+ by low value of time bin
NEV	Auto time, distance, and cost by shared-ride 3+ by low value of time bin
School bus	Auto time, distance, and cost by shared-ride 3+ by low value of time bin

** Notes on skims: Auto and transit skims are differentiated by five time of day periods and calculated across a planning network between TAZs; Auto skims are additionally differentiated by three value-of-time bins to represent travel time and cost heterogeneity. This is described more fully below; Auto costs include tolls on the auto network; Transit network level-of-service skims are differentiated by access and egress mode as well as the transit technology used in the path. Walk-transit skims are based on walk access and walk egress (walk-transit-walk). Park-and-ride, kiss-and-ride, and TNC skims assume auto is used at the home end of the tour. Skims must be built by direction for each time period (PNR-transit-walk and walk-transit-PNR, KNR-transit-walk and walk-transit-KNR, TNC-transit-walk and walk-transit-TNC); Walk to transit times are calculated from an all-streets network based on the MAZ centroid and the nearest stop(s), as differentiated by broad transit stop types (local, premium).*

SM 4.1: Intermediate Stop Frequency Model

Number of Models:	9 (by purpose, plus one model for at-work sub-tours)
Decision-Making Unit:	Persons
Model Form:	Multinomial Logit
Alternatives:	16, with a maximum of 3 stops per tour direction— 6 total stops on tour

The model determines the number of intermediate stops on the way to and from the primary destination. The SANDAG model allowed more than one stop in each direction (up to a maximum of three) for a total of six trips per tour (three 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 drove to transit picked up their cars at the end of the tour. The stop frequency model was based on the following explanatory variables:

- Household composition
- 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
- Discretionary and shopping accessibilities

SM 4.2: 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 model is a lookup table of probabilities based upon tour purpose, stop direction, departure time, and person type.

SM 4.3: Intermediate Stop Location Choice Model

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

The model predicts the location (MGRA) of each intermediate stop (each location other than the origin and primary destination) on the tour. In this model, a maximum of three stops in outbound and three stops in inbound direction are modeled for each tour. Since a large number (over 24,000) of alternative destinations exist, it is not possible to include all alternatives in the estimation data set. A sampling-by-importance approach was used to choose a set of alternatives. Each record was duplicated 20 times, then different choice sets with 30 alternatives each were selected based on the size term and distance of the alternative destination. This approach is statistically equivalent to selecting 600 alternatives for the choice set. It is not straightforward to segment the model by purpose, because size (or attraction) variables are related to purpose of the stop activity, while impedance variables are strongly related to the tour characteristics—primary tour purpose, primary mode used for the tour, etc. Therefore, a single model is estimated with size variables based on stop purpose and utility variables based on both stop and tour characteristics.

The stop location choice model includes the following explanatory variables:

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

Size variables:

- Employment by categories
- Number of households
- School enrollments: preschool, grades K–6, and grades 7–12, based on type of school child in the household; university and other college enrollments

SM 4.4: 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:	48 (stop departure half-hour time periods beginning at 3 a.m.)

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

SM 5.1: Trip Mode Choice Model

Number of Models:	6 (Work, University, K–12, Maintenance, Discretionary, and At-Work Sub-Tours)
Decision-Making Unit:	Person
Model Form:	Multinomial Logit
Alternatives:	23 (see Figure M.8 under the Tour Mode Choice section)

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

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

- The highest occupancy across all trips is used to code the occupancy of the tour.
- There is no mode switching on walk and bike tour modes.
- Shared-ride trips are allowed on walk–transit tours.
- Drive-alone is disallowed for walk–transit and Kiss & Ride–transit tours, since driving on a trip leg in combination with walk–transit would imply Park & Ride–transit as a tour mode.
- Walk trips are allowed on all tour modes except for driving alone and biking, since these modes imply that the traveler is attached to the mode of transport (the auto or bike) for the entire tour.
- Note that cases in which a traveler parks at a lot and then walks to their destination are treated as a single trip in the context of trip mode choice. A subsequent parking location choice model breaks out these trips into the auto leg and the walk leg for trips to parking-constrained locations.
- An additional restriction on availability is imposed on work-based sub-tours, where drive-alone is disallowed if the mode to work is not one of the three auto modes (drive-alone, shared-ride 2, or shared-ride 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 M.10: Tour and Trip Mode Correspondence Rules

Trip Mode	Drive-Alone	Shared-Ride 2	Shared-Ride 3+	Walk	Bike	e-bike	e-scooter	Walk–Transit	Park & Ride–Transit	Kiss & Ride–Transit	TNC–Transit	Taxi	TNC Single	TNC Pooled
Drive-Alone	A	A	A						A					
Shared-Ride 2		A	A					A	A	A	A	A	A	A
Shared-Ride 3+			A					A	A	A	A	A	A	A
Walk	A	A	A	A				A	A	A	A	A	A	A
Bike					A									
e-bike						A								
e-scooter							A							
Walk–Local Bus								A	A	A	A			
Walk–Premium								A	A	A	A			
Walk–Local Bus & Premium								A	A	A	A			
Park & Ride–Local Bus									A					
Park & Ride–Premium									A					
Park & Ride–Local Bus & Premium									A					
Kiss & Ride–Local Bus										A				
Kiss & Ride–Premium										A				
Kiss & Ride–Local Bus & Premium										A				
TNC–Local Bus											A			
TNC–Premium											A			
TNC–Local Bus & Premium											A			
Taxi												A		
TNC Single													A	
TNC Pooled														A
School Bus			A	A	A	A	A	A	A	A	A	A	A	A

Notes: A = Trip mode is available by that particular tour mode; School Bus: Available for school bus tour mode only, on school tours.

SM 5.2: Parking Location Choice

Number of Models:	1
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 three-quarters of a mile of the destination MGRA

The model determines where vehicles are parked at the terminal end of each trip with a destination in park area 1 (Parking-constrained area). The output of the model is used to obtain traffic assignments that are more accurate at small scales in the downtown area during the morning and afternoon peaks.

The parking location model explanatory variables include: number of stalls available to the driver (size variable); parking cost; and walking distance to destination.

Resident Travel Model Outputs

The resident travel model outputs detailed forecasts of travel patterns of residents in the region. At the household-level, auto and transponder ownership are available. At the person-level, work and school locations, transit pass ownership, employer parking subsidies, etc. are predicted. In addition, detailed trip information including origin and destination MGRAs, start and end times, mode (and vehicle details if auto), household participants, costs, etc. are simulated. The auto trips are aggregated by origin and destination TAZs by the five time-of-day (TOD) periods, three value-of-time (VOT) bins, and four vehicle classes to be assigned on to the road network. As a result, congested travel times and vehicle flows are estimated across the region. Similarly, transit trips are assigned to the transit network to estimate ridership and travel times. Prior to assignment, trips from resident model are combined with outputs of special market models which are described below.

Special Market Models

Crossborder Model

This model simulates travel of Mexico residents (both US and Non-US Citizens) on the San Diego transportation network. In other words, the model accounts for Mexico resident demand (such as auto volume, transit boarding, and toll usage) for transportation infrastructure in San Diego County. It also forecasts border crossings at each current and potential future border-crossing station. The model is based on the 2019 SANDAG Cross Border Survey, Mexico resident border crossings into the United States, and their travel patterns within the United States. Data were collected at the three border crossing stations: San Ysidro, Otay Mesa, and Tecate. The model flow and inputs are shown in Figure M.9.

One major update to the crossborder model was the addition of a wait time model. This model is only run in the first global iteration of ABM3 and determines the number of people crossing at each Port of Entry (POE). It is run three times, with each iteration shifting people to different POEs based on the wait times. Wait times are recorded separately for three different types of lanes: SENTRI lanes, Ready lanes, and general lanes. People need to apply for a SENTRI pass in order to use it, whereas the Ready lanes are available to people with multiple forms of ID, such as a passport card or enhanced driver's license. The general lanes are for crossborder travelers without a pass. Crossborder travelers in ABM3 are randomly assigned either a SENTRI pass, a Ready Lane-compatible pass, or no pass based on specified probabilities.

Crossborder Tour Purposes

There are six tour purposes for the Mexico resident model. These are randomly assigned to each traveler based on the pass that the traveler holds. They were coded based on the activity purposes engaged in by the traveler in the United States according to a hierarchy of activity purposes as follows:

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

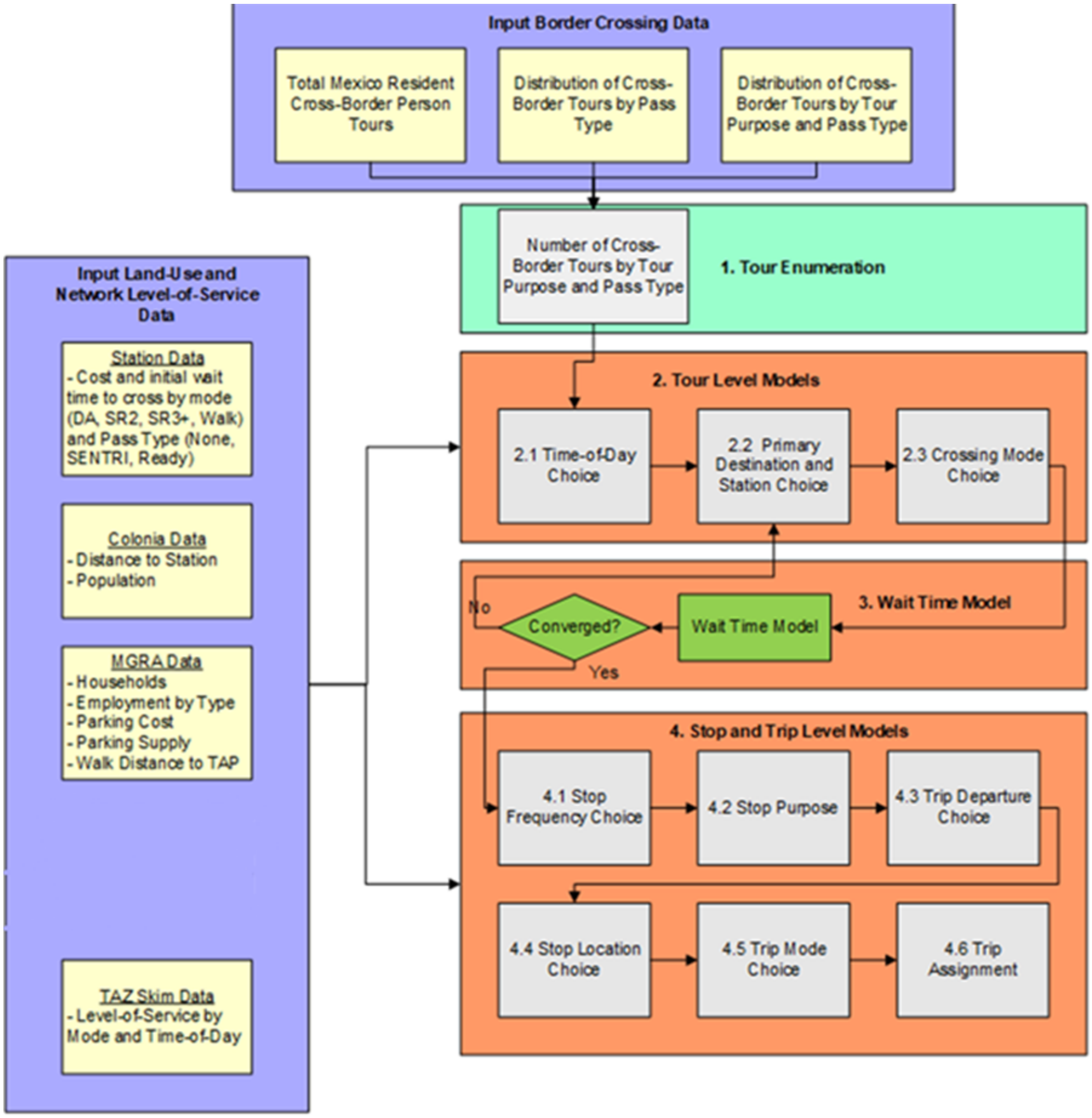
Tour Mode

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 and the occupancy if by auto. The auto wait times are determined by what pass the traveler holds.

Trip Mode

The trip modes used in the Mexico resident travel model are a subset of the modes available in the resident travel model, including auto (drive alone, shared ride 2, and shared ride 3+), walk, walk to transit (local, premium, and mixed), and ridehail (taxi, single TNC, and pooled TNC). Usage of these facilities in the model is based upon the characteristics of the trips/vehicle occupancies and income (VOT) of travelers and validated along with resident demand models.

Figure M.9: Mexico Resident Crossborder Travel Model



Source: SANDAG

Treatment of Space

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

San Diego International Airport Ground Access Model

The model captures the demand of airport travel on transport facilities in San Diego County, a model of travel to and from the airport for arriving and departing passengers. It allows SANDAG to test the impacts of various parking price and supply scenarios at the airport. The model is based on the 2008 SDIA survey of airport passengers in which data was collected on their travel to the airport prior to their departure. A new airport passenger survey was conducted in 2024 and will be used in a future update to ABM3.

The SDIA ground access model has the following features:

- A disaggregate microsimulation 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 M.10 and described in detail in the following sections.

San Diego International Airport Model Trip Purposes

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

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

San Diego International Airport Model Trip Mode

The model of airport ground access is trip-based. The survey only collected information on the trip to the airport before the passenger boarded their plane; information was not collected on the trip in which passengers arrived at the airport and traveled to a destination in San Diego County. Therefore, symmetry is assumed for the non-reported trip. If private auto is used to access the airport, the choice of parking versus curbside pick-up/drop-off is explicitly represented. For travelers who park, the chosen lot (terminal, airport remote lot, private remote lot) is explicit as well. Note that auto occupancy is not a choice for airport ground access trips. Auto occupancy is based upon travel party size, which is simulated as part of the attribution of ground access trips.

San Diego International 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 ABMs):

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

San Diego International Airport Model Description

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

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

- Travel purpose
- Party size
- Duration of trip
- Household income

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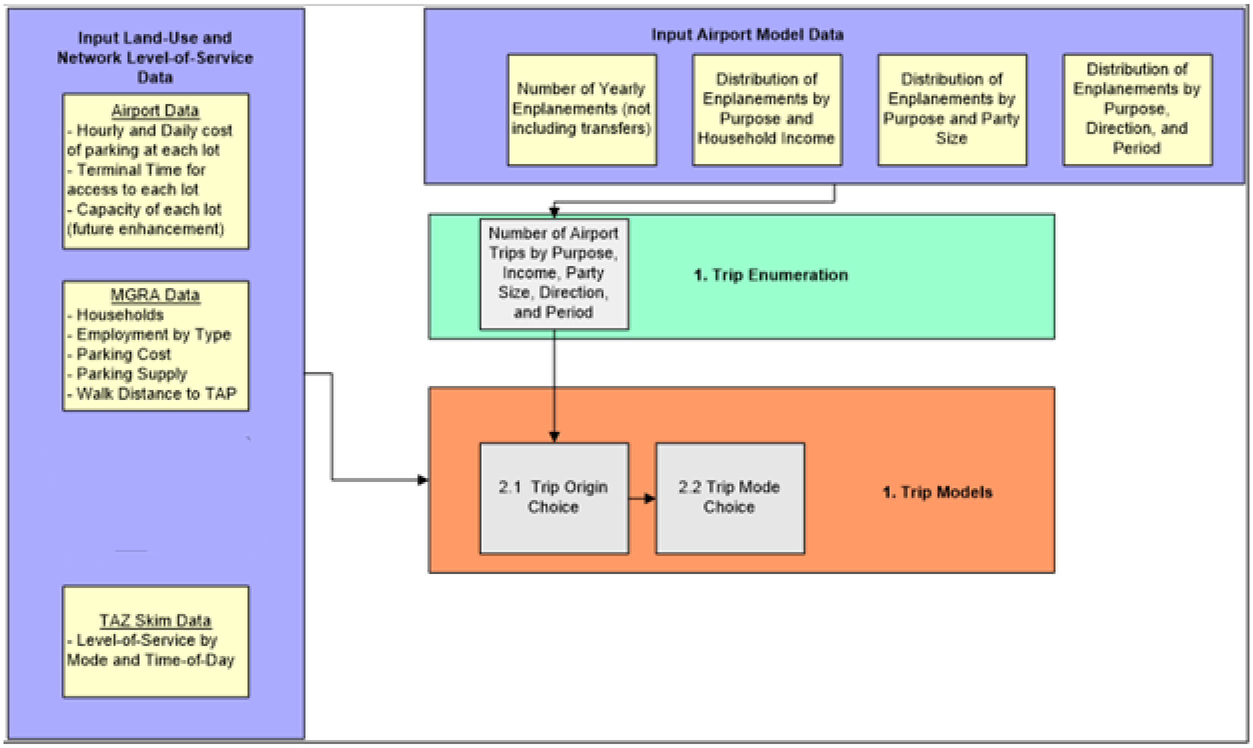
[3] Airport Development Plan: San Diego International Airport, Leigh|Fisher, March 2013, page 47–68 (Table 22).

- Trip direction (it is assumed that 50% of the daily enplanements are arriving passengers and 50% are departing passengers)
- Departure time for airport

Trip Models

- **Trip origin:** each travel party is assigned an origin MGRA.
- **Trip mode:** each travel party is assigned a trip mode.

Figure M.10: San Diego International Airport Ground Access Travel Model



Source: SANDAG

Cross Border Xpress Terminal Model

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

The model structure is borrowed from the SDIA ground access model. The model is calibrated based on a passenger survey conducted beginning of April 2016 at Tijuana International Airport. The survey collected information from departing passengers who either used the CBX facility or could have used the facility but chose to cross at one of the other border crossings instead.

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

Visitor Model

San Diego is a major vacation destination, and these travelers use the county's transportation infrastructure when traveling to and from San Diego's various attractions. The visitor model captures the demand of this travel on transport facilities in San Diego County. A synthetic population of visitors is created with their lodging location as their home location, and a day of travel within San Diego County is simulated. The model is estimated based on the 2011 SANDAG Visitor Survey of airport passengers and hotel guests in which data was collected on their travel while visiting San Diego.

The visitor model has the following features:

- A disaggregate microsimulation 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 M.11 and described in detail in the following sections.

Visitor Model Inputs

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

- **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

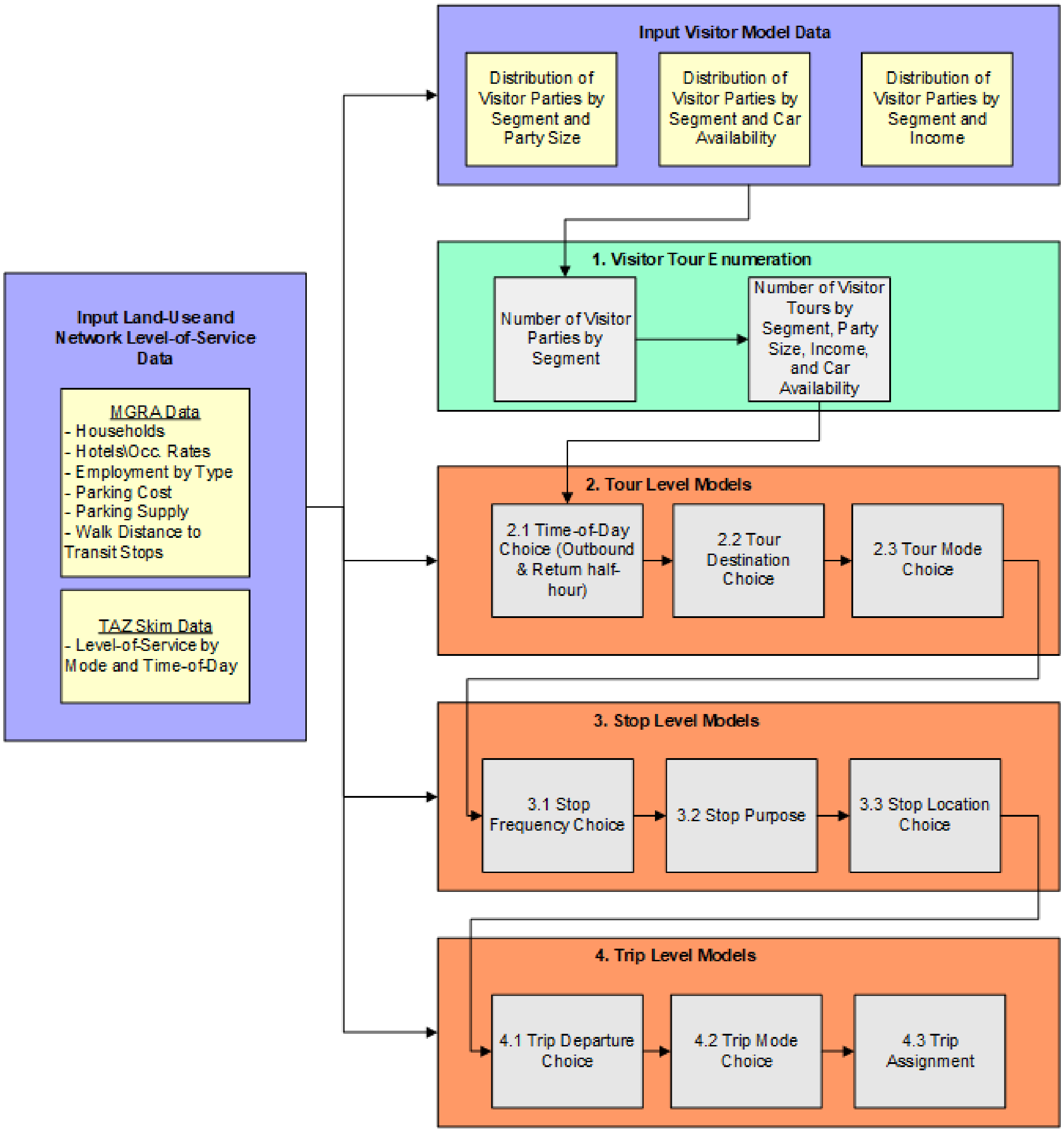
- The distribution of stops by stop purpose and tour purpose
- The distribution of stops on outbound tour legs by half-hour offset period from tour departure period and time remaining on tour
- The distribution of stops on inbound tour legs by half-hour offset period from tour arrival period and time 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 ABM.
- **TAZ skim data:** Auto and transit network level-of-service between each TAZ. This provides sensitivity to auto and transit network supply and cost. These are the same data sets as are used in the resident ABM.

Visitor Model Description

This section briefly describes the model system.

Figure M.11: SANDAG Visitor Model Design



Source: SANDAG

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.

Tour-Level Models

- **Tour Time of Day:** Each tour is assigned a time of day, based on probability distribution.
- **Tour Destination Choice:** Each tour is assigned a primary destination, based on the coefficients estimated through a multinomial logit model.

- **Tour Mode Choice:** Each tour selects a preferred primary tour mode, based on an asserted nested logit model (the resident tour mode choice model without PNR, KNR, or TNC to transit or micromobility).

Stop Models

- **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.
- **Stop Purpose:** Each stop is attributed with a purpose based upon sampling from a distribution.
- **Stop Location Choice:** Each stop is assigned a location based upon a multinomial logit model (asserted based upon resident stop location choice models).

Trip-Level Models

- **Trip Departure Choice:** Each trip is assigned a departure time period based upon sampling from distributions.
- **Trip Mode Choice:** Each trip within the tours selects a preferred trip mode based on an asserted nested logit model.
- **Trip Assignment:** Each trip is assigned to the network.

Commercial Vehicle Model

The SANDAG Commercial Vehicle Model (CVM) simulates the weekday demand patterns of commercial vehicle movements throughout the San Diego region. The CVM is an important part of the complete travel demand modeling system for the region, representing a market of travel that dominates the middle part of most weekdays and has been steadily growing as consumer demands for home deliveries and personal services have increased.

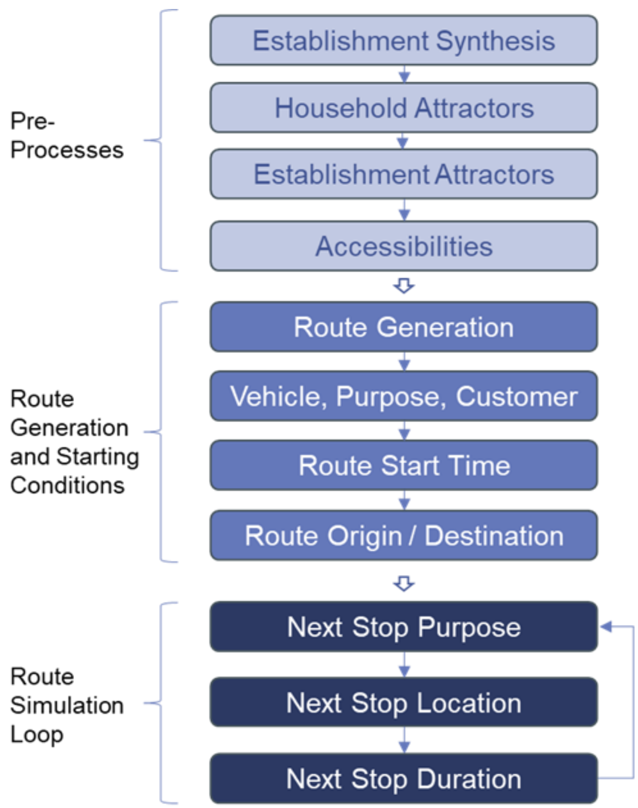
The primary sources of data for developing the CVM were the 2022 SANDAG Commercial Vehicle Establishment and TNC-driver surveys, which focused on goods, services, and maintenance trips, and obtained travel diaries from employees of these establishments whose jobs involve routine travel for either goods pick-up and delivery or for service provision. The TNC driver survey used an identical travel diary format to the Establishment survey, the difference being that individual TNC drivers were surveyed as their own establishments who worked on behalf of an online pick-up and delivery service. The Establishment and TNC surveys provided detailed travel pattern data for individual drivers and vehicles, which formed the basis for estimating and calibrating model components. The categorical definitions of attribute variables in the two surveys set the possibilities for segmentation of the model system, such as establishment industry sectors; trip origin and destination purposes, land uses, and place types; and vehicle types.

The geographic scope of the CVM are internal-to-internal trip movements. The market scope of the model includes commercial goods movements (pick up and deliveries) as well as trips made for commercial and public services. Trips made for other purposes, namely maintenance and personal, are also included in the CVM if these trips are made in the context of a commercial vehicle tour pattern. The CVM explicitly distinguishes between residential and non-residential customer types, and between three vehicle types—light, medium, and heavy—consistent with the definitions used in the Establishment Survey.

The CVM does not cover the types of work-related travel that would be expected to be covered in the ABM3 Resident model, namely workers traveling for meetings, sales calls, out-of-town travel, and similar activities. The CVM also does not model long-distance freight truck movements that enter and exit the region, which are covered by the Heavy Truck Model (HTM).

A flow diagram portraying the CVM system is shown in Figure M.13. The CVM comprises three primary modeling stages: (1) pre-processing models which create inputs variables that are essential to the simulation; (2) generation of vehicle routes and their starting conditions; and (3) the dynamic simulation of stops and travel for each route.

Figure M.12: Commercial Vehicle Model Tour-Based Model Structure



Source: SANDAG

Twelve industries that the establishments belongs to are considered:

1. AGM: Agriculture, Forestry, Fishing and Hunting, and Mining
2. MFG: Manufacturing
3. IUT: Industrial Utilities
4. RET: Retail Trade
5. WHL: Wholesale Trade
6. CON: Construction
7. TRN: Transportation and Warehousing

8. IFR: Information, Financial, Insurance, Real Estate, and Professional Services
9. EPO: Education, Public, and Other Services
10. MHS: Medical and Health Services
11. LAF: Leisure, Accommodations, and Food
12. MIL: Military

Three Commercial vehicle types are used:

13. LCV: Light Commercial Vehicle (LCV)
14. SUT: Single-Unit Truck
15. MUT: Multi-Unit Truck

The CVM-ABM3 interface converts trip lists into trip tables by ABM3 vehicle types for network assignment. The outputs of the CVM are trips by OD, trip purpose and travel time. These trips are added to all other trips prior to traffic assignment.

External Models

The external travel models predict characteristics of all vehicle trips crossing the San Diego County border. This includes both trips that travel through the region without stopping and trips that are destined for locations within the region. See Figure M.12 for current crossing locations, also known as cordons. Future crossing locations that can also be modeled depending on scenarios include Otay Mesa East, and Jacumba. Components modeling internal-external travel were added to the resident model (external worker identification, external workplace location, external tour identification, external tour location). External to internal San Diego travel from Mexico is covered by the Cross Border Model.

External Model Trip Type Definition

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

- **US–US:** External–external trips whose production and attraction are both in the United States, but not in San Diego County.
- **US–MX:** External–external trips with one trip end in the United States and the other in Mexico.
- **US–SD:** External–internal trips with a production elsewhere in the United States and an attraction in San Diego County.

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:

The number of trips made by Mexico residents to attractions in San Diego was previously determined during development of the Mexico resident travel microsimulation model.

- 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.

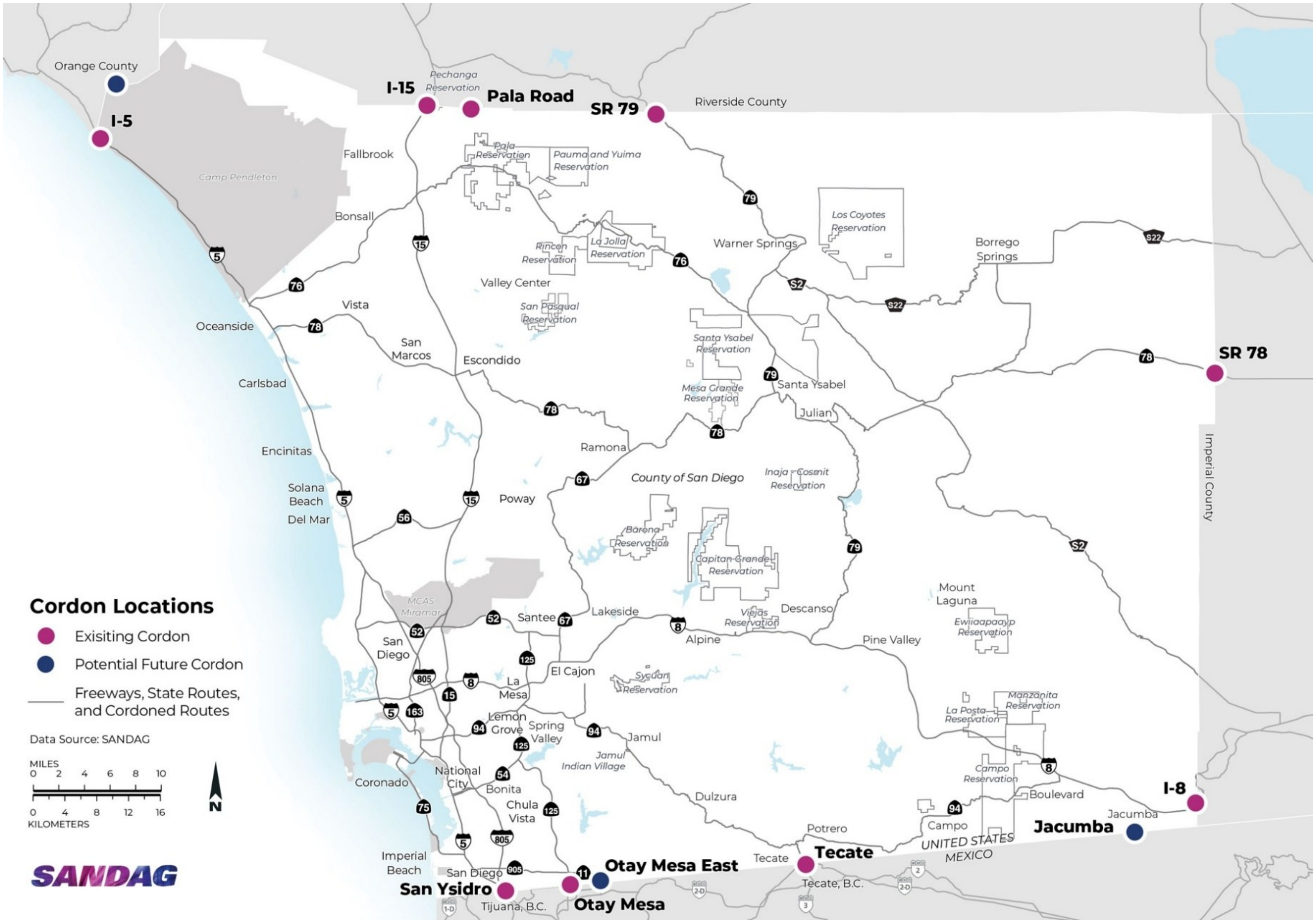
- The number of MX–SD (1) and SD–MX (2) trips was subtracted from the total number of border crossings to derive an estimate of the number of US–MX trips. The distribution of US–MX trips among external stations on the U.M. side of San Diego County is assumed to be proportional to the total volume at each external station, regardless of the point of entry at the Mexico border.
- The number of US–MX trips was then subtracted from the total number of trips in the Southern California Association of Governments (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.
- 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 trips 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 Mexico 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.

Figure M.13: San Diego County Cordons



Source: SANDAG

US–SD External–Internal Trips

The US–SD External–Internal (EI) trip model covers vehicle trips with destinations in San Diego County 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.

External–Internal Destination Choice Model

Number of Models: 2 (Work and Non-Work)
Decision-Making Unit: Tour
Model Form: Multinomial Logit
Alternatives: MGRAs

The model distributes the EI trips to destinations within San Diego County.

The EI destination choice model explanatory variables are distance and the size of each sampled MGRA

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

Table M.11: US–SD Vehicle Occupancy Factors

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

Table M.12: US–SD Diurnal Factors

Time Period	Work Percentage Production to Attraction	Work Percentage Attraction to Production	Non-Work Percentage Production to Attraction	Non-Work Percentage Attraction to Production
Early a.m.	26%	8%	25%	12%
a.m. Peak	26%	7%	39%	11%
Midday	41%	41%	30%	37%
p.m. 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 and 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 in-vehicle time and toll cost as explanatory variables.

14Heavy Truck Model

The HTM covers long-distance freight movements into and out of San Diego County. The source of the demand in the HTM are commodity flows between shippers and receivers throughout North America, focusing on those with either a trip end (shipper or receiver) in San Diego County or which pass through San Diego County, for example, between Mexico and Los Angeles. Commodity flows are derived from the Federal Highway Administration (FHWA) Freight Analysis Framework version 5 (FAF5), which was important to represent commodity trading and supply chain trends after the COVD-19 pandemic. The model design assumes that freight truck trips between establishments within San Diego County are covered by the CVM, which has been designed to explicitly account for truck movements involving warehouse and distribution centers and port facilities.

The key input demand source driving the HTM is the set of commodity flows between shippers and receivers throughout North America that focus on:

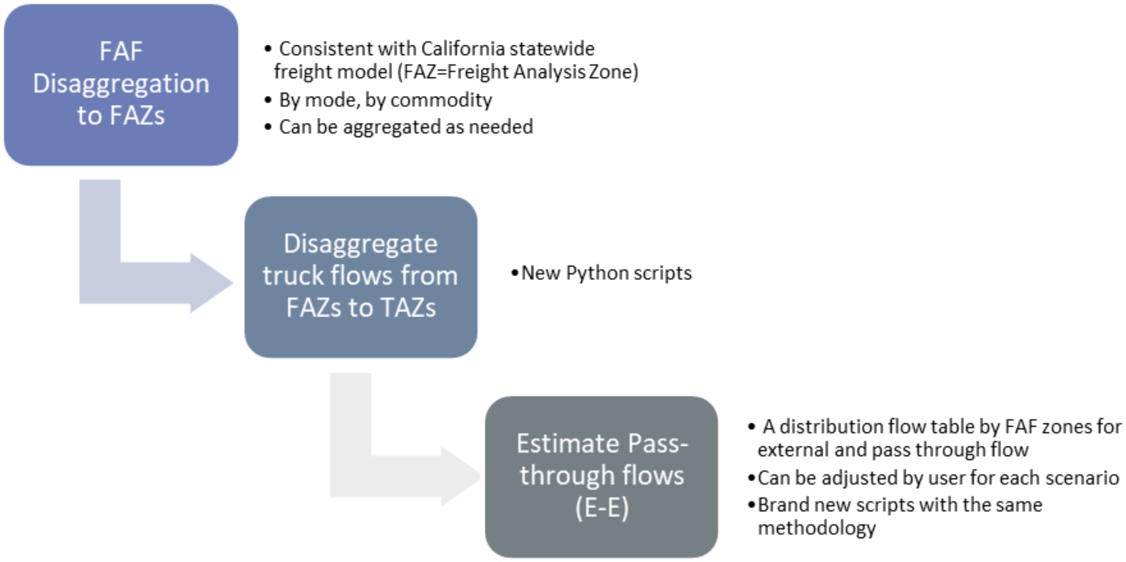
- Flows with one trip end (shipper or receiver) in San Diego County which are also referred to as internal-to-external or external-to-internal flows such as flows between Chicago and San Diego; and
- Flows which pass through San Diego County which are also referred to as “through trips.” An example of such flows would be freight flows between Mexico and Los Angeles.

The HTM workflow is shown in Figure M.14. The first key enhancement of the HTM model is the use of the FAF disaggregation process to California Freight Analysis Zones (FAZ) instead of the national county-to-county truck trip table used in earlier databases. This approach is consistent with the California statewide freight model which provides a better starting point for the HTM model for the San Diego area. The detail available includes mode and commodity information and the user has greater flexibility to aggregate geographies of interest.

The second step of the process involves the disaggregation from FAZ to TAZ using a set of newly developed Python scripts. This step includes the assessment of updated “internal-to-external” and “external-to-internal” long-distance truck flows.

The third step focuses on the “pass through” long-distance truck flows (also referred to as “external-to-external” long distance truck flows) with scripts that allow the user to customize the analysis for different scenarios under study.

Figure M.15: HTM Workflow in ABM3



Source: SANDAG

Trip Assignment

The final steps of the SANDAG ABM3 are to assign the trip demand onto the roadway and transit networks. Assignments are run for the five time periods identified in Table M.2.

Traffic Assignment

The traffic assignment for the ABM3 is a 15-class assignment with generalized cost by five time periods. Auto vehicle classes are broken out by VOT bins for $8.81 and $18 per hour representing the 33rd and 66th percentiles for the low-income and medium-income groups, respectively. The 15 classes are drive-alone non-transponder, drive-alone transponder, shared-ride 2, and shared-ride 3+ by three VOT bins and heavy truck by three weight classes: light-heavy (8,500-14,000 lbs), medium-heavy (14,000-33,000 lbs), and heavy- heavy (33,000+ lbs).

The SANDAG volume-delay function (VDF) is a link-based function that consists of both a mid-block and an intersection component. The intersection component is only active when the B-node of the link is controlled by a traffic signal, stop sign, roundabout, or ramp meter. Otherwise, the intersection component adds no delay. The VDF results in travel times that increase monotonically with respect to volume. Capacities are based on link and intersection characteristics but do not consider volumes on upstream links or opposing volumes. New VDF coefficients were last estimated based on 2015 INRIX data. The estimated alpha parameter is 0.8, and the estimated beta parameter is 4 for mid-block of all link types except freeway in the a.m. and p.m. period with alpha of 0.6 and beta of 4 and off-peak with alpha of 0.24 and beta of 5.5. These parameters are not very different from the widely used Bureau of Public Roads (BPR) formula parameters of 0.15 and 4, respectively. Non-freeway links use BPR factors of 4.5 (or 6.0 for metered ramp) and 2.0 for intersection components.

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

Transit Assignment

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

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

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

ABM3 has four access modes to transit (walk, Park & Ride, and Kiss & Ride, including TNC to transit) and three transit sets (local bus only, premium transit only, and local bus and premium transit sets), for twelve total demand classes by five times of day. These classes are assigned by slices, one at a time, to produce the total transit passenger flows on the network.

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

Data Sources

SANDAG ABM3 uses a variety of data as inputs. The most important data source is household travel survey data. The latest household travel survey conducted for SANDAG was the 2022 Household Travel Behavior Survey (HTS2022) with smartphone-based travel diaries as the primary means of travel data collection. HTS2022 surveyed 2,800 households in San Diego County. The survey asked all households with smartphones to participate using the smartphone-based GPS travel diary and survey app (rMove) for one week and accommodated participating households without smartphones by allowing them to complete their one-day travel diary online or by calling the study call center.

Additional data were used from the 2016 household travel survey to estimate statistical models when sample size from just HTS2022 alone was not high enough. The 2015 Transit On-Board Survey (OBS2015) numbers were scaled up to match 2022 ridership counts to derive calibration targets for ABM3. OBS2015 collected data on transit trip purpose, origin and destination address, access and egress mode to and from transit stops, the on/off stop for surveyed transit routes, number of transit routes used, and demographic information. The most recent OBS was completed in 2023 and will be used in a subsequent update to the transportation model.

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

Table M.13: SANDAG Surveys and Data

Survey Name	Year
Household Travel Behavior Survey	2016–2017 & 2022
Transit On-Board Survey	2015
Remote Work Survey	2023
Parking Inventory Survey	2022
Parking Behavior Survey	2022
Border Crossing Survey	2019
Commercial Establishment & Vehicles Diary Survey	2022

Table M.14: Outside Data Sources

Source	Year
SDIA Passenger Forecasts – Airport Development Plan: San Diego International Airport	2019
FAF 5	2017
Transit Ridership Counts	2022
Jurisdiction annual traffic counts	2022
Caltrans PeMS	2022
Caltrans Highway Performance Monitoring System (HPMS) – California Public Road Data	2022
Caltrans Traffic Census Program – Annual Average Daily Traffic	2022
Replica Origin–Destination Location-Based Services Data	2022

Travel Model Validation

Model validation compares base year 2022 model outputs to independent data, not used to estimate or calibrate model parameters, to ensure that the model is ready to be used for forecasting. Estimated traffic volumes from the model are compared with traffic counts and estimated transit ridership is compared with observed transit boardings. SANDAG maintains a traffic count database that is assembled from various sources: PeMS counts, Caltrans District 11 State Highway Traffic Census Counts, arterial counts from local jurisdictions, and some special counts collected by SANDAG. Average weekday traffic was derived from PeMS daily counts collected over Fall 2022 — the most reliable count data source for model validation. SANDAG modeling staff went through an extensive effort to create a new PeMS inventory with 564 counts in 2022 which is an improvement over 498 counts in 2019. The new count inventory was built based on observed five-minute data rather than the one-hour data used in the previous count inventory. This improvement provides more accurate observed count inventory for validating traffic flow of each ABM TOD. Combined with other count inventories, the final count inventory has 1,594 counts available for validating traffic flow of main lane freeway. Local jurisdiction traffic counts typically do not cover the entire year and therefore are subject to larger error than the PeMS counts. Estimated transit boardings from the model are validated against 2022 daily transit ridership obtained from transit agencies in the region.

SANDAG performed roadway validations at regional, subregional (Major Statistical Areas), and highway corridor levels, segmented by time of day and roadway facility types and by road type and volume group. Overall validation results are satisfactory with no systematic deviation from the 45-degree line in validation scatter plots. Estimated regional vehicle miles traveled (VMT) was allowed to deviate from the 2022 Caltrans Highway Performance Monitoring System (HPMS) Data to better match VMT implied by observed count locations. In other words, region-wide VMT was about 78 million compared to 72 million from HPMS but modeled VMT at count locations matched well with that at count locations (20 million and 21 million respectively).

Validation by road type shows freeway results fare better than those of other road types. Validation by volume group shows that the larger estimated link volumes are the better they match the counts; percent root mean square errors decrease as the estimated volumes increase. Validation was performed on major highway corridors, including I-5,

I-15, I-805, SR 67, SR 125, SR 163, I-8, SR 52, SR 54, SR 56, SR 78, and SR 94. Overall, the model performs well at corridor level. Transit validations were performed by transit line haul mode, including commuter rail, light rail, Express Bus, Rapid Bus, and local bus. Overall, the model-estimated transit ridership matched the observed 2022 transit passenger counts well, with a 2.1% overestimation of total regional transit ridership.

Input Assumptions

Telework

Working from home, or teleworking, may contribute to reductions in driving since employees do not have to travel to a workplace. The SANDAG ABM explicitly accounts for this reduction by identifying the work location of some workers as "home." In the SANDAG ABM, persons who work from home do not make work trips, but they can make other trips during the simulation day that may offset the reduced home–to-work VMT. Since COVID-19, telecommuting has increased significantly. SANDAG projects modest increase in primary telework over time beyond 2022 as shown in Table M.15. The main contributing factor to this dynamic is that SANDAG's employment forecast anticipates non-wage and salary jobs growing as a share in the Region. This projection aligns with the distribution of jobs across sectors and the unique occupational composition of each sector. For example, Professional, Scientific and Technical Services is among the strongest growing sectors in terms of job creation. This sector also has higher shares of non-wage and salary jobs and occupations that are more accommodating of remote work arrangements. As a result, it feeds into SANDAG's projection of non-wage and salary jobs where individuals work from home. Occasional telework reflects the share of the workforce that can work at home at least one day a week and do not identify working from home as their primary place of work. This is assumed to be constant at the base year (2022) level of about 15.6%.

Table M.15: Telework Future Assumptions

Year	Telework Always or Primarily	Telework Occasionally	Telework Total
2022	18.60%	15.6%	34.2%
2026	18.72%	15.6%	34.3%
2029	18.81%	15.6%	34.4%
2035	18.99%	15.6%	34.6%
2050	19.45%	15.6%	35.1%

Auto Operating Costs

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

For the 2015 SCS and California Senate Bill 375 (Steinberg, 2008) GHG target setting, SANDAG and the other large metropolitan planning organizations (MPOs) in the state developed a consistent approach to define, estimate, and forecast AOC. After the second SCS cycle, the California Air Resources Board (CARB) produced an AOC draft calculator that provides a framework for producing an average AOC for all fuel types.

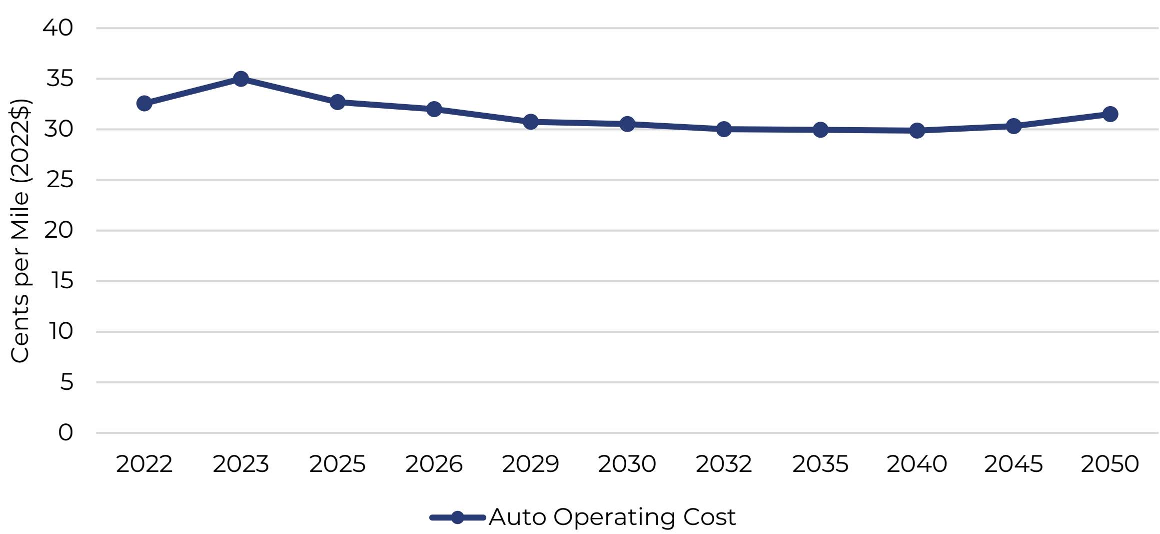
In addition to the CARB AOC draft calculator, SANDAG uses the Oil Price Information Service (OPIS) by IHS Markit for current and historical gasoline prices and the U.M. Energy Information Administration (EIA) for future gasoline prices. The OPIS data was purchased for San Diego County specifically.

The EIA publishes an Annual Energy Outlook (AEO) forecast with several variations of forecasts for economic growth, oil prices, and resources and technology based on different assumptions (effectively resulting in a range of forecasts). The Big 4 MPO group for the second SCS used the U.M. EIA AEO low forecast plus 75% of the difference between the high and low oil price forecast with an adjustment from U.M. costs to California costs. U.M. to San Diego cost differences have been escalating in recent years, with the 2019 San Diego average costs reaching $1 per gallon higher than the U.M. average.

For the 2025 Regional Plan and fourth SCS, SANDAG followed CARB's **2019 Final Sustainable Communities Strategy (SCS) Program and Evaluation Guidelines Appendix D** to calculate AOC. AOC is comprised of fuel cost and non-fuel related costs (maintenance, repair, and tire wear). Fuel cost (cents/mile) is based on fuel price (dollar/gallon or dollar/gallon of gasoline equivalent (GGE)) divided by fuel efficiency (miles/gallon or miles/GGE). Fuel efficiency is also referred to as fuel economy. AOC is computed using data specific to vehicles by fuel type as identified in the current EMFAC model (EMFAC 2021). These fuel types include gasoline, diesel, PHEV (powered by gas and by electricity), and electricity.

Figure M.15 shows the calculated AOC values for current and future years used in the ABM3.

Figure M.16: ABM3 Auto Operating Costs (in 2022$)

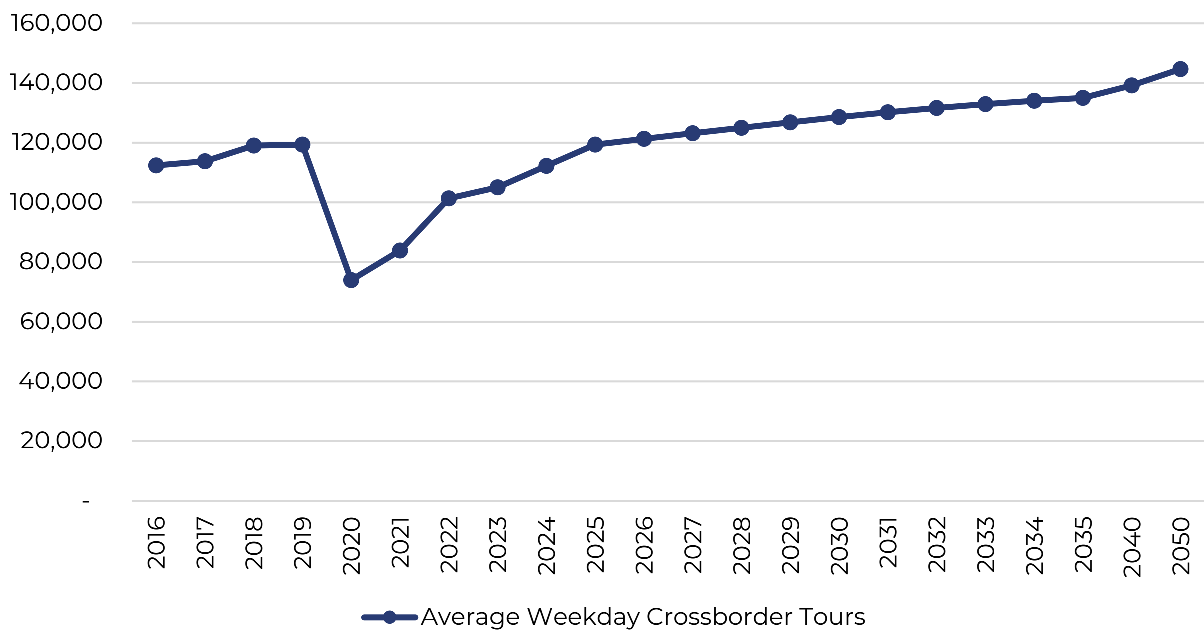


Source: IHS Markit, U.M. Energy Information Administration (EIA), California Air Resource Board (CARB), SANDAG

Crossborder Tours

For updating crossborder tours, historical crossings data from Bureau of Transportation Statistics (BTS) was used to project 2025 numbers to be at pre-pandemic (2019) levels. Beyond 2025, crossborder tours were grown at the rate of increase of the adult population in Baja California. Figure M.16 below shows the decline in crossborder tours associated with COVID-19 and the projected recovery and growth.

Figure M.17: Average Weekday Crossborder Tours



Source: Bureau of Transportation Statistics (BTS), SANDAG

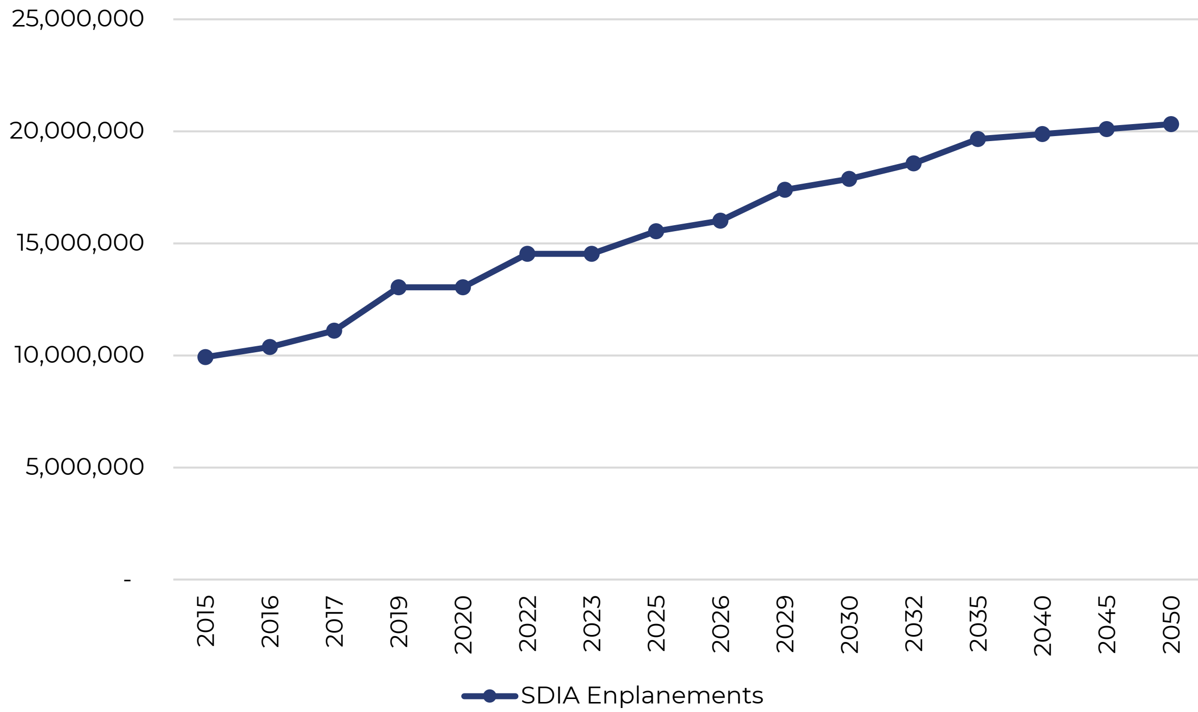
Airport Enplanements

As discussed earlier, enplanements are a key input to the ground access model for SDIA. The total number of yearly enplanements at SDIA (without counting transferring passengers) is input for each simulation year (Figure M.18). The base year (2022) number were obtained from SDIA air traffic reports and future year projections are available in the San Diego International Airport Development Plan.[4] Enplanements for the Cross Border Express terminal (CBX) for Tijuana airport were obtained from Grupo Aeroportuario del Pacífico (Pacific Airports Group) traffic reports[5] and future annual growth of approximately 1.2% was assumed (Figure M.19).

[4] San Diego International Airport Development Plan, Leigh|Fisher, September 2019, Appendix R-B, page 32 (Table 5-1).

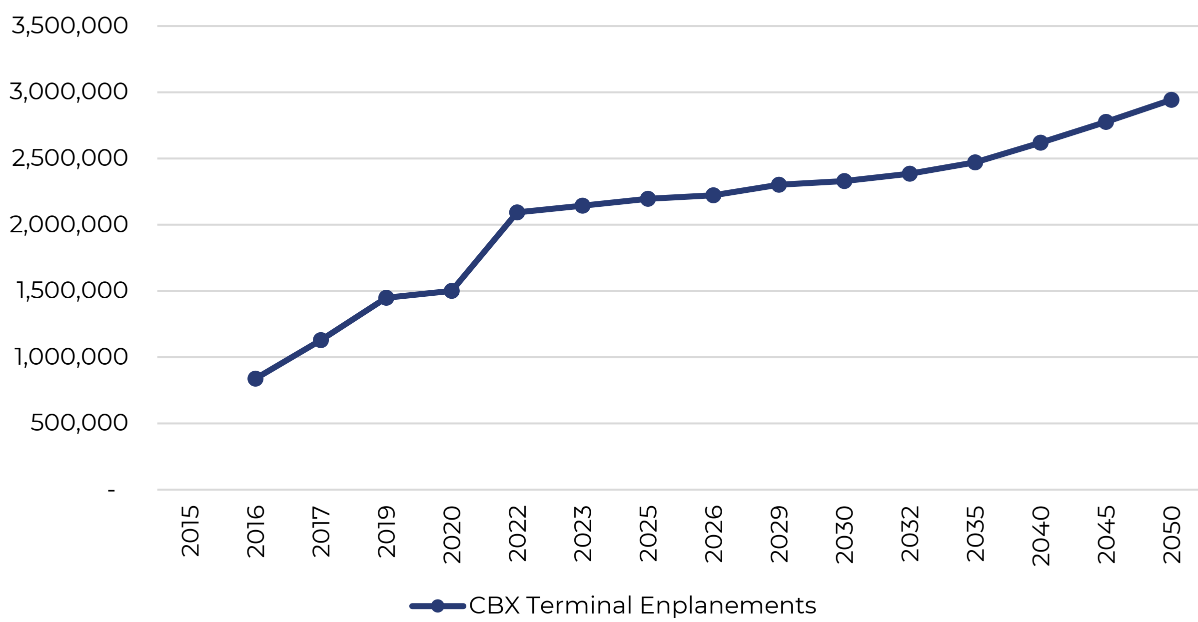
[5] "Reporte de Trafico (Traffic Report)." Grupo Aeroportuario del Pacifico (Pacific Airports Group), https://www.aeropuertosgap.com.mx/es/, accessed 4/21/2023.

Figure M.18: San Diego International Airport Enplanements



Source: San Diego International Airport (SDIA), SANDAG

Figure M.19: Tijuana International Airport Enplanements Through the Cross Border Xpress Terminal

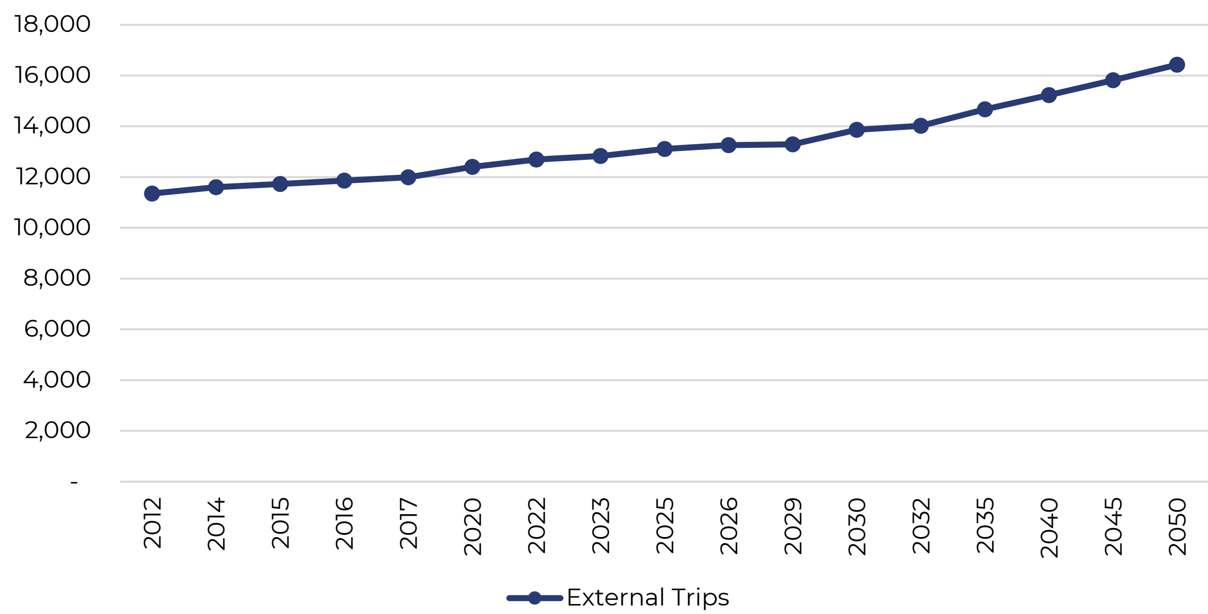


Source: Grupo Aeroportuario del Pacífico (Pacific Airports Group), SANDAG

External Cordon Trips

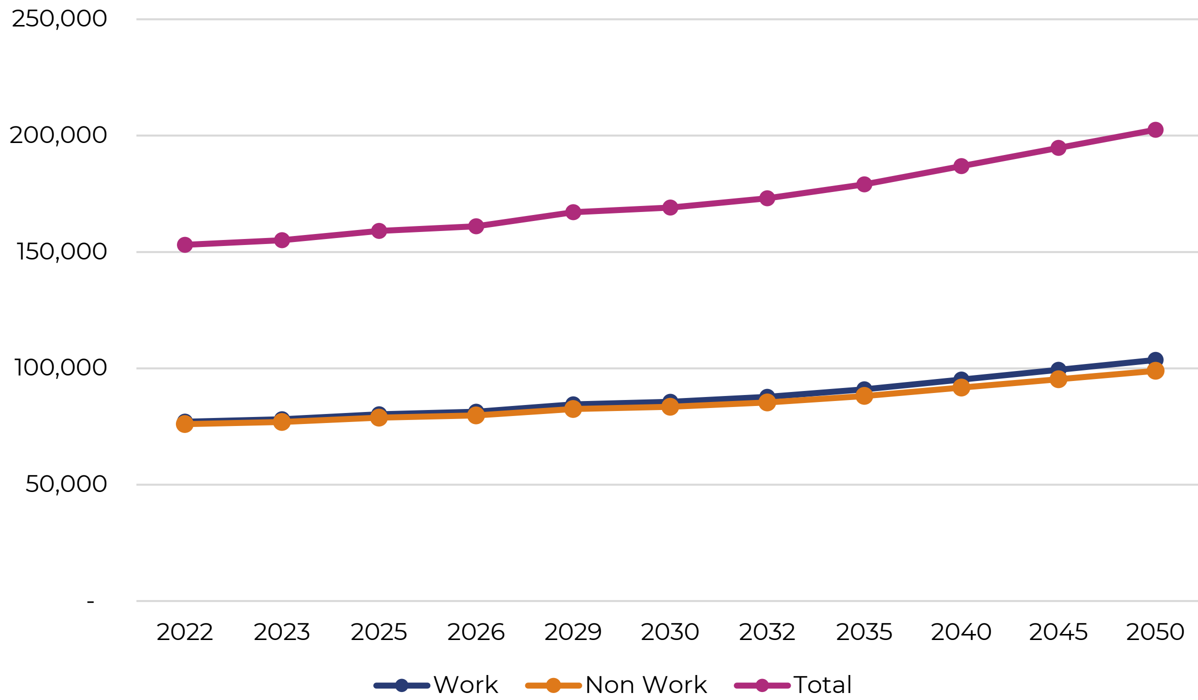
External cordon trips are those trips originating external to the San Diego region and destined for either within the region or to another external area. These are based on commercial big data provider estimates, traffic counts at the cordons, and projections in population growth from the California DOF.

Figure M.20: External Trips



Source: California Department of Finance (DOF), Replica, SANDAG

Figure M.21: Non-Crossborder External Trips into the San Diego Region



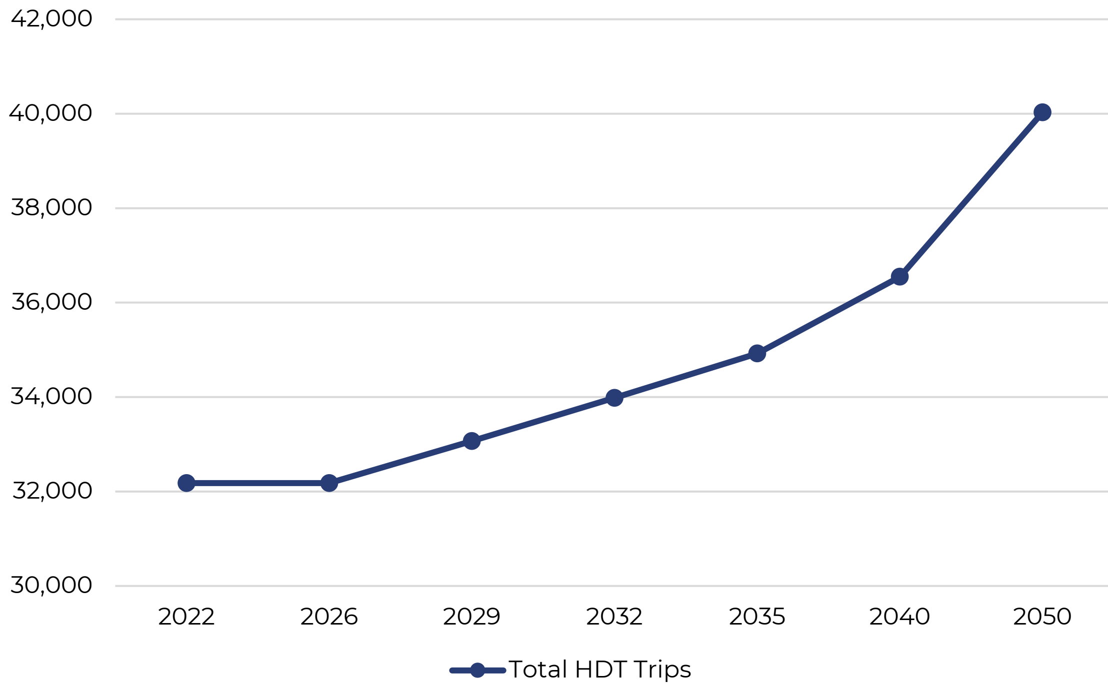
Source: California Department of Finance (DOF), Replica, SANDAG

External Heavy-Duty Truck Trips

While the San Diego region is known for its multiple land ports of entry (the second busiest along the US-Mexico border after Laredo), the region's freight movement also has domestic significance. San Diego's freight network is a critical link in California's economy and national supply chains.

Heavy duty truck trips are based on data reported in the Bureau of Transportation Statistics' Freight Analysis Framework (FAF) database. The FAF data provides forecasted freight tonnage moved by truck in and out of San Diego County (domestic and international). Between 2022 and 2026, truck trips are held constant, reflecting recent truck volumes and current economic conditions of slower trade and weakened consumer spending. After 2026, the long-term growth is projected at 0.9% (compound annual growth rate), as reflected in the FAF forecast.

Figure M.22: Heavy Duty Truck Trips into the San Diego Region



Source: Federal Highway Administration (FHWA), Bureau of Transportation Statistics (BTS), SANDAG

ABM3 Technical Advisory Committee Expert Review

To guide ABM3 development, SANDAG formed an ABM Technical Advisory Committee (TAC). The 11-member TAC is comprised of nationally recognized leaders in the travel demand modeling field who come from a vast array of organizations, including FHWA, CARB, major MPOs, academia, and independent consultancies.

SANDAG hosted two rounds of TAC review and evaluation. The first TAC meeting was held in March 2023 to evaluate the overall model design, with a particular focus on the new improvements micromobility (e.g., e-scooters, dockless bicycles), microtransit, electric vehicle (EV) policy modeling. The committee determined ABM3 as being a state-of-the-practice model and were confident that it meets federal and state requirements. The second TAC meeting was held in March 2024 to follow up on implementing the TAC's short-term model recommendations from the first meeting and to evaluate ABM3 and its usage for the 2025 Regional Plan. TAC members reviewed extensive material prepared by modeling team about estimation, calibration, and validation of ABM3 for 2022 base year. In addition, SANDAG staff shared preliminary sensitivity testing results from approximately a dozen model runs. The TAC expressed strong approval of ABM3, concluding that it not only remained well above the state of the practice, but that some components were state-of-the-art for travel demand models.

ABM3 Sensitivity Testing

In response to the Final Sustainable Communities Strategy Program and Evaluation Guidelines issued by CARB, to examine the responsiveness of ABM3 to potential SANDAG 2025 Regional Plan strategies, SANDAG modeling staff conducted a series of sensitivity tests to demonstrate the effects of various inputs on VMT, mode share, trip length, and transit boardings. These were conducted after the calibration and validation of ABM3 for the new base year 2022.

Following CARB's sensitivity test guidelines and recommendations from ABM TAC, SANDAG modeling staff conducted land use, transit fares and services, active transportation (AT), parking pricing, shared micromobility, microtransit, and exogenous variable sensitivity tests. Most sensitivity tests were based on a 2035 scenario year. The population and employment forecasts were prepared by SANDAG Economic and Demographic Analysis staff in Spring 2023. Land use–related tests used a 2050 scenario to account for the full potential impact of population growth on VMT and mode share. The tests showed that ABM3 was adequately sensitive to key inputs and policies affected by the 2025 regional plan and the elasticities were consistent with those in previous studies and literature.

Additional Assumptions for Regional Plan

In addition to exogenous input assumptions described in the section above, there were several model assumptions made to reflect policy and pricing strategies in the Regional Plan. Table M.16 shows them for both 2035 and 2050.

Table M.16: Regional Plan Policy and Pricing Assumptions

Category	Description	2035*	2050*
Highway fee	Managed Lane (ML) rates	$0.30/mile	$0.30/mile
Highway fee	HOV incentives	No toll for vehicles of three or more persons; 50% discount for vehicles of two persons; Single-occupant vehicles pay full rate.	No toll for vehicles of three or more persons; 50% discount for vehicles of two persons; Single-occupant vehicles pay full rate.
Highway fee	SR 11 toll rates – freeway connection to OME POE	Northbound: $2 for cars, $15 for trucks; Southbound: $1.25 for cars, $10 trucks	Northbound: $2 for cars, $15 for trucks; Southbound: $1.25 for cars, $10 trucks
Highway fee	SR 125 toll operation***	Toll remains	Toll removed; switch to GP configuration by 2050
Ridehail fee	Single reservation (non-pooled)	$1.25/trip	$1.25/trip

Table M.16: Regional Plan Policy and Pricing Assumptions Continued

Category	Description	2035*	2050*
Ridehail fee	Shared rides (pooled, such as UberX Share)	$0.65/trip	$0.65/trip
Parking pricing**	Parking in high demand areas of urban sheds, major employment centers, U.S Mexico Border	Hourly: $3.25 Daily: $23.26 Monthly: $323.58	Hourly: $5.06 Daily: $36.24 Monthly: $504.13
Parking pricing**	Parking in high demand areas of coastal communities	Hourly: $2.29 Daily: $15.25 Monthly: $234.94	Hourly: $3.84 Daily: $23.76 Monthly: $366.03
Parking pricing**	Parking in high demand areas of suburban communities	Hourly: $1.53 Daily: $11.71 Monthly: $146.31	Hourly: $2.56 Daily: $18.24 Monthly: $227.95
Transit fare	Most routes (Local bus, Arterial Rapids, non-Express Freeway Rapids, Express Bus, Trolley, SPRINTER, Microtransit/NEV)	$1.25 one way/$3 day (50% reduction from current fares)	$1.25 one way/$3 day
Transit fare	Express Freeway Rapid	$2.50 one way/$6 day (50% reduction from current fares)	$2.50 one way/$6 day
Transit fare	COASTER	$3 one way/$6 day (50% or more reduction from current fares)	$3 one way/$6 day
Transit fare	COASTER connection	Free	Free
Micromobility	Speed	12 mph average	12 mph average
Micromobility	Cost	Micromobility cost: $1 fixed + $0.39/min $0 for access/egress to transit	Micromobility cost: $1 fixed + $0.39/min $0 for access/egress to transit
Micromobility	Wait time	3 minutes in urban and suburban	3 minutes in urban and suburban
E-Bikes	Personally owned e-bike (percentage of bikes that are e-bikes)	36% of privately owned bikes are e-bikes	64% of privately owned bikes are e-bikes
NEV Services	Speed	17 mph	17 mph
NEV Services	Wait time	12 minutes	12 minutes
NEV Services	Added wait time for passenger pick up	6 minutes	6 minutes
NEV Services	Max Distance	3 miles	3 miles
Microtransit	Speed	30 mph	30 mph
Microtransit	Wait time	12 minutes	12 minutes

Table M.16: Regional Plan Policy and Pricing Assumptions Continued

Category	Description	2035*	2050*
Microtransit	Maximum distance	4.5 miles	4.5 miles
Transit	Transit dwell time for Rapid	15% Reduction	15% Reduction
Transit	Weight/penalty of Wait time for Rapid	13% Reduction	13% Reduction
Transportation technology	Capacity increase from Integrated Corridor Management of roadway system yielding increase in travel reliability	7% unreliability reduction	7% unreliability reduction
Smart Signals	Benefits from reduced intersection delays	Delay at signalized intersections decreased by 20% (arterials)	Delay at signalized intersections decreased by 20% (arterials)
Port of Entry	Future POE Crossings (Otay Mesa East)	Otay Mesa East (2027). Seven northbound passenger vehicle lanes Five northbound commercial vehicle lanes Zero northbound pedestrian lanes	Otay Mesa East (2050 expansion). 25 northbound passenger vehicle lanes 20 northbound commercial vehicle lanes 12 northbound pedestrian lanes
Electric Vehicles	EV Penetration Rates	25%	45%
Electric Vehicles	EV Charger Population	40,000 chargers	143,410 chargers
Electric Vehicles	EV Infrastructure Incentives	Yes	Yes

*Notes: * Costs listed are in $2022; ** The 2025 Regional Plan assumes priced parking only in parking-constrained areas and surrounding neighborhoods with many transportation options.; *** Under the current Franchise Agreement with Caltrans, the SR 125 toll is currently scheduled to terminate in year 2042.*

Abbreviations List

Acronym	Description
ABM	Activity-based model
ACS	American Community Survey
AEO	Annual Energy Outlook
AGEB	Área Geoestadística Básica
AOC	Auto operating costs
AT	Active transportation
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CBD	Central business district
CBX	Cross Border Xpress
CDAP	Coordinated daily activity pattern
CVM	Commercial vehicle model
DAP	Daily activity pattern
DC	Destination choice
DOF	California Department of Finance
EE	External to external
EI	External to internal
EIA	U.M. Energy Information Administration
Emme	Modeling software made by Bentley
FAF	Freight Analysis Framework
GIS	Geographic information system
HDTM	Heavy-duty truck model
HOT	High-occupancy toll
HOV	High-occupancy vehicle
HTS	Household Travel Behavior Survey
IE	Internal to external
MGRA	Master Geographic Reference Area
MPO	Metropolitan planning organization
OBS	Transit On-Board Survey
OPIS	Oil Price Information Service
PeMS	Caltrans Performance Measurement System
RTP	Regional Transportation Plan

Abbreviations List Continued

Acronym	Description
SANDAG	San Diego Association of Governments
SCAG	Southern California Association of Governments
SCS	Sustainable Communities Strategy
SDIA	San Diego International Airport
SOV	Single-occupancy vehicle
TAC	Technical Advisory Committee
TAP	Transit access points
TAZ	Transportation analysis zone
TNC	Transportation network company
TOD	Time of day
VDF	Volume-delay function
VOT	Value of time

Travel Modeling Glossary

its.uci.edu/~mmcnally/tdf-glos.html

Part 2: Off-Model Strategies

Off-Model Overview

Travel models are the principal tools used to evaluate transportation and land use scenarios and alternatives. They provide planners and policymakers alike with information needed to help make informed decisions. The SANDAG travel model, an activity-based model (ABM), provides a systematic analytical platform so that different alternatives and inputs can be evaluated in an iterative and controlled environment. Travel models can be updated over time to reflect changes in updated travel data, travel behavior, and new travel options. The travel model version used to evaluate San Diego Forward: The 2025 Regional Plan (2025 Regional Plan)/Sustainable Communities Strategy (SCS) is referred to as ABM3. Though travel models are comprehensive and complex tools, there may be instances where the impacts of certain 2025 Regional Plan/SCS policies under consideration cannot be measured in ABM3. In these instances, SANDAG relies on off-model techniques to evaluate the impacts of these strategies. Off-model methodologies are based on evidence from empirical data and research and were developed in collaboration with other metropolitan planning organizations (MPOs), research institutions, and consultation with the California Air Resource Board (CARB) Policies and Practices Guidelines.

For the 2025 Regional Plan, the off-model analysis includes vanpool and carshare. Strategies proposed in this methodology include programs facilitated and administered by SANDAG as well as services operated by third parties, as detailed below.

- **Vanpool:** The Vanpool Program encourages the formation of vanpools in the San Diego region by providing a monthly subsidy for eligible commuters
- **Carshare:** The Flexible Fleets strategy supports the deployment of carshare services that provide vehicles as short-term rentals and help reduce the reliance on owning a personal vehicle

Summary of Off-Model Calculators

Table M.17 summarizes the daily carbon dioxide (CO2) and percent per capita reduction impacts of the various TDM off-model methodologies.

Table M.17: Carbon Dioxide Reduction Impacts of Off-Model Methodologies

Off-Model Strategy	Daily Total CO2 Reductions (short tons) 2035	Daily Total CO2 Reductions (short tons) 2050	% per Capita CO2 Reduction as Compared to 2005 2035	% per Capita CO2 Reduction as Compared to 2005 2050
Vanpool	67.7	66.4	0.15%	0.15%
Carshare	34.0	—	0.08%	—
Total	**101.7**	**66.4**	**0.23%**	**0.15%**

Off-Model Calculators

The off-model methodology for estimation of vehicle miles traveled (VMT) and greenhouse gas (GHG) emission reductions from strategies share a common overall methodology. These strategies are part of the SANDAG regional TDM program, also known as Sustainable Transportation Services. The Sustainable Transportation Services team works with employers throughout the region to design and implement commuter benefit programs and provides residents with information about vanpool and carpool services, shared mobility, support for biking, information about teleworking, a vanpool subsidy and transit solutions and incentives.

The VMT reductions are based on historical data, applicable research, and case study findings for each strategy. Where possible and if available, local data were used to inform the assumptions used in the methodology. To minimize double counting, the methodology intentionally employs a conservative approach to estimate reasonable program impacts. While the off-model calculators use mode-based inputs from ABM3 to estimate program impacts, calculator outputs remain off-model and do not interact or feed back into ABM3.

In general, the research is used to estimate the following methodological parameters:

1. **Population that has access to the mobility service, or market:** The market may be defined in terms of persons or households.
2. **Level of supply/geographic extent:** The level of supply may be defined as a function of cities, neighborhoods, or employers in which the program or service is available.
3. **Regional infrastructure and policy:** Regional investments in transportation infrastructure, policies, or programs that may help facilitate or incentivize use of the strategy and impact travel behavior.
4. **Baseline VMT:** An estimate of the average VMT per person or per household among persons/households that do not participate in the program or mobility service.
5. **Project VMT:** An estimate of the average VMT per person or per household expected among persons per households that participate in the program or mobility service. This is estimated directly from average trip lengths and indirectly from mode shifts, changes in car occupancy, and/or reductions in average number of trips.
6. **GHG emission factors:** Based on total trip forecasts produced by the SANDAG ABM and CO2 estimates developed with Emission Factors (EMFAC) 2021.

The following sections detail specific program characteristics along with the methodologies and assumptions for each off-model calculator.

Vanpool

Strategy Overview

The SANDAG Vanpool Program is offered as part of the Sustainable Transportation Services. This program provides a subsidy of up to $600 per month for eligible vanpool groups. Vanpools can also leverage Managed Lanes and high-occupancy vehicles (HOVs) for travel and can take advantage of priority parking for rideshare at employment sites. The program requires that vanpools have either an origin or destination in San Diego County, and maintain 80% vehicle occupancy. Vanpools have been shown to reduce GHG emissions since only one (albeit larger) vehicle is required to transport the same number of people that would normally take 7 to 15 single-occupant vehicles to transport. In FY 2022, the VMT reduction attributed to the Vanpool Program was approximately 44.9 million miles.

The Sustainable Transportation Services team works closely with major employers and conducts targeted marketing campaigns to encourage the formation of vanpools in the region. More than half of the vanpools are military or federal employees who also benefit from the Transportation Incentive Program stipend, making vanpooling a cost-effective alternative to driving alone. More than 85% of vanpools in the SANDAG program use vehicles with a maximum occupancy of seven to eight passengers, and almost half of vanpools originate from Riverside County. The influx of vanpools traveling into the region from Riverside County can leverage Managed Lanes on the I-15 that allow vanpoolers to use the HOV lanes free of charge and offer travel time reliability.

Off-Model Calculator Assumptions and Methodology

The following assumptions are incorporated into the OMC for the Vanpool Program. The calculation of VMT reductions is based on the Vanpool Program data, including vanpool fleet and trip information. These data include the total number of active vanpools, vehicle type, vanpooler industries, commute trip origin and destination, distance traveled within San Diego County, and vehicle occupancy. Historical program data indicate that the Vanpool Program caters to a workforce that commutes long distances to work (50 miles one way on average) and works for large employers that have fixed schedules.

Based on existing Vanpool Program trends, the vanpool off-model calculator estimates that vanpooling in the region will grow relative to the total workers employed in San Diego County. Therefore, as the region adds jobs within industries that have historically had higher rates of vanpooling (i.e., military, biotech, federal employers), it is assumed that enrollment in the Vanpool Program will also grow. The industries in which vanpooling thrives are those that in large part are considered “non-teleworkable,” such as manufacturing and military, which require employees to perform their job duties on site.

The reliability of the Managed Lanes makes vanpooling an attractive option. Consistent with this assumption, the vanpool off-model calculator assumes that as the region’s Managed Lane network expands, commuters who choose to vanpool are likely to experience shorter travel times than commuters driving alone. This travel time savings will encourage a shift from driving alone to vanpooling.

Based on historical program participation data, two vanpool markets were defined based on the vanpoolers' employer industry: military vanpools, and non-military vanpools. This segmentation was used to calculate employment growth factors that are specific to each of these industries. The travel time savings methodology also varies depending on industry type, because the destinations of the future military vanpools are defined. Other inputs used to derive the impact of vanpooling on GHG and VMT, such as average distance traveled and average vehicle occupancy, also vary by type of industry and are based on historical Vanpool Program data.

Table M.18: Vanpool Off-Model Results

Vanpool Off-Model Results	2035	2050
Total Vanpools	508	534
Daily VMT Reduction	235,993	248,144
Daily Total CO_2 Reduction (short tons)	67.7	66.4
Daily Per Capita CO_2 Reduction	0.15%	0.15%

Carshare

Strategy Overview

Carshare services offer access to vehicles as short-term rentals 24 hours a day, 7 days a week. Carshare can provide first- and last-mile connections to transit or fill gaps in the region's transit services by providing an efficient transportation alternative for commute and non-commute trips. In recent years, the carshare market in the region has changed with the exit of the one-way carshare service provider car2go from the region. To date, only round-trip and peer-to-peer services offered by ZipCar, Turo, and Getaround exist in the San Diego region.

As part of the Vision for the 2025 Regional Plan, Flexible Fleets are envisioned to operate throughout the region. Flexible Fleets provide more travel options that reduce the reliance on owning a personal vehicle and offer reliable connections to and from transit. To help encourage deployment of Flexible Fleets like carshare in the region, SANDAG will support carsharing through Sustainable Transportation Services outreach and incentives as well as the provision of infrastructure (e.g., EV chargers, designated/priority parking, or curb space) needed to support carsharing in areas with higher densities and with available multimodal transportation.

Research indicates that households that participate in carsharing tend to own fewer motor vehicles than non-member households.[6] With fewer cars, carshare households shift some trips to transit and non-motorized modes, which helps to contribute to overall trip-making reductions. Estimates of the VMT reductions attributed to carshare participation have been reported to be 7 miles per day[7] and up to 1,200 miles per year[8] for round-trip carshare.

Off-Model Calculator Assumptions and Methodology

The carsharing methodology only accounts for VMT and GHG emission benefits associated with round-trip carshare service. While the off-model calculator is able to account for the VMT reduction impacts of free-floating carshare service, it is assumed that this type of service will not return to the San Diego region due to the rise and popularity of on-demand ridehailing service providers like Uber, Lyft, and Waze Carpool.

Based on market trends in the San Diego region, it is expected that carshare will remain a viable transportation option in neighborhoods that exhibit similar supporting land uses as those where carsharing is provided today. The Sustainable Transportation Services program seeks to promote and encourage the provision of carshare within the region's employment centers, colleges, military bases, and within the areas that have a concentration of population, housing, and multimodal transportation options (Figure M.21). Given the future trend toward mobility-as-a-service, it is assumed that carsharing will evolve to be part of a fleet of shared, electric, and on-demand vehicles by the year 2050; therefore, carshare coverage areas are only defined until 2035. Within these defined carshare service areas, it is assumed that participation in the carshare program may vary depending on the supporting density.[9] The population density thresholds that support carshare participation in the region are based on the car2go service area prior to its exit from the San Diego market. Based on the 2016–2017 San Diego Regional Transportation Study and available research on carshare participation rates, it is assumed that areas with a population greater than 17 people/acre will have a 2% participation rate. Areas with a population density lower than 17 people/acre will have a 0.5% participation rate. These density thresholds are specific to carshare trends exhibited in the San Diego region. VMT reduction impacts from round-trip carshare also assume a daily average reduction of seven miles per day per round-trip carshare member based on the latest available research.[10]

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[6] E. Martin and S. Shaheen (2016). Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions. An Analysis of Five North American Cities.

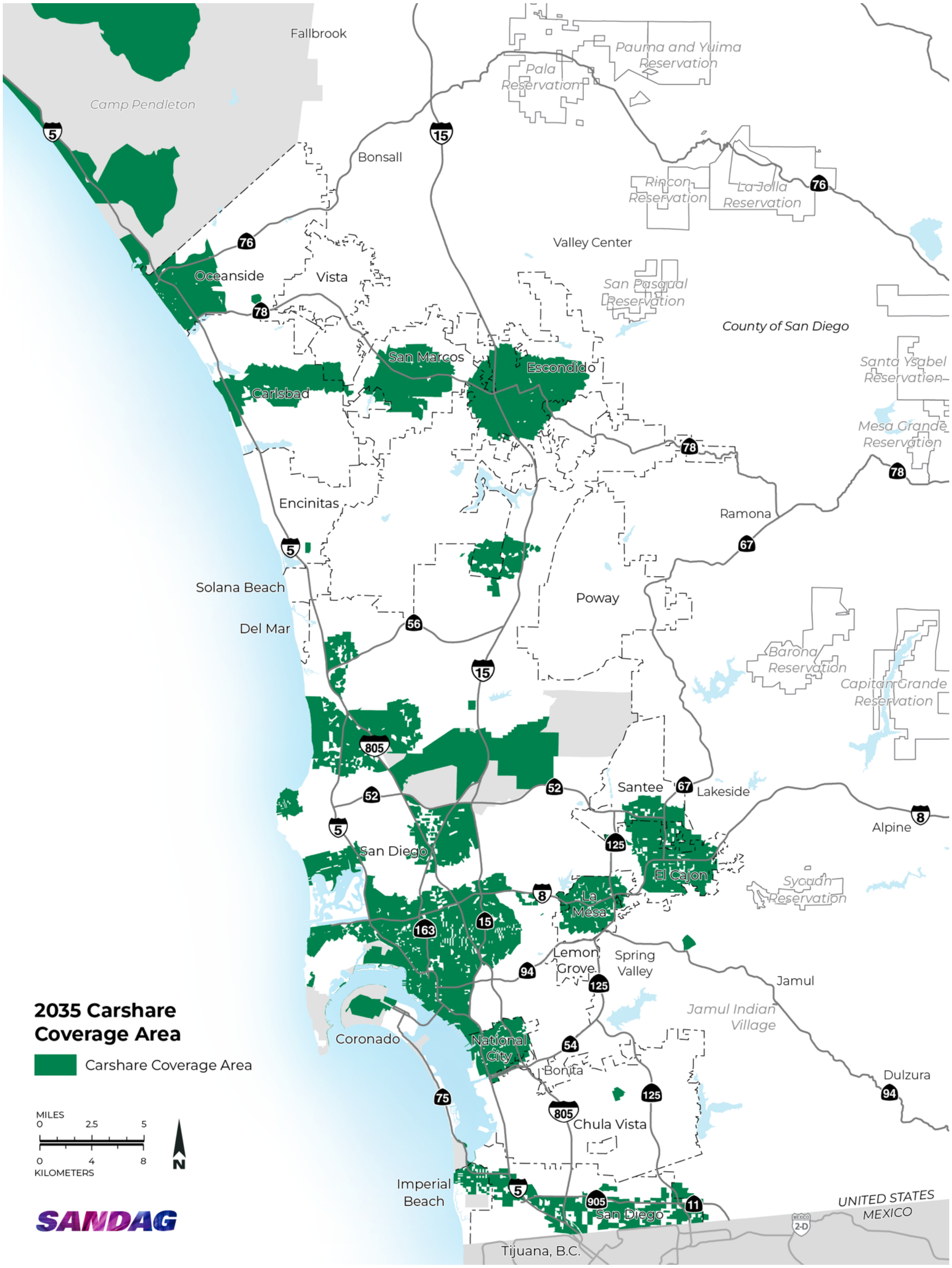
[7] Cervero, R. A. Golub, and Nee (2007) "City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts", Presented at the 87th Transportation Research Board Annual Meeting, Washington, D.C.

[8] E. Martin and S. Shaheen (2010), "Greenhouse Gas Emission Impacts of Carsharing in North America," Mineta Transportation Institute. MTI Report 09-11.

[9] Transportation Sustainability Center (2018), Carshare Market Outlook. its.berkeley.edu/node/13158.

[10] Cervero, R. A. Golub, and Nee (2007) "City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts," Presented at the 87th Transportation Research Board Annual Meeting, Washington, D.C.

Figure M.23: Carshare Coverage Area 2035



Source: SANDAG

Table M.19: Carshare Off-Model Results

Carshare Off-Model Results	2035	2050
Carshare Membership	17,000	—
Daily VMT Reduction	119,025	—
Daily Total CO_2 Reduction (short tons)	34	—
Daily Per Capita CO_2 Reduction	0.08%	—

Attachments

- Attachment 1: Off Model Calculators Review Memo

Attachment M1:
Off Model Calculators Review Memo

Memorandum

Date: 10/8/2024

To: SANDAG Modeling Team

From: Maddie Hasani, Mike Wallace, Ali Ahmadi, Fehr & Peers

Subject: 2025 Regional Plan Off-Model Calculator Update Framework for Vanpool and Carshare

SD23-0482

Introduction

Travel models are designed as extensive and intricate tools, but there are situations where the effects of specific Regional Plan/Sustainable Communities Strategy (SCS) policies being examined may not be quantifiable within the Regional Model. In such cases, SANDAG turns to Off-Model Calculators (OMC) to assess the consequences of these strategies.

The OMC relies on empirical data and research findings, developed in partnership with other Metropolitan Planning Organizations (MPOs), and research institutions, and in consultation with the California Air Resource Board (CARB) Policies and Practices Guidelines.

The objective of this memorandum is to review the existing OMC developed for ABM2+, as detailed in the Regional Plan 2021, *Appendix S: Part 2 (December 2021)*, and assess its applicability to the upcoming ABM3 Travel Demand Model. This document also provides recommendations where applicable to update the assumptions, inputs, and parameters used in the existing OMC.

This document reviews the following two (2) OMCs:

1. Vanpool OMC: Python-Based
2. Carshare OMC: Python-Based

Please note that the tools reviewed in this document do not address curb space management's impact on the VMT. Although reviewed tools are mainly used to estimate VMT reductions on a regional level and for application on the SCS, enhancements for use on Comprehensive Multimodal Corridor Plan (CMCP) or other project level application are included for consideration.

1. Vanpool OMC (Python-Based)

Purpose

The SANDAG Vanpool Program promotes vanpools in the San Diego region through a monthly subsidy to eligible commuters. Based on historical program data, the SANDAG Vanpool Program supports a workforce that commutes long distances to work (50 miles one way on average) and is anticipated to be more practical for large employers that have fixed schedules. As such, the participation data is collected in three vanpool markets based on the vanpoolers' employer industry: military vanpools, federal non-military vanpools, and non-federal vanpools.

The Vanpool OMC estimates VMT and GHG reduction based on the SANDAG Vanpool Program data. This data includes information on the active vanpools, vehicle type, vanpool industries, commute trip O/D, distance traveled, and vehicle capacity. The Vanpool OMC also assumes that as the region's Managed Lane network expands, commuters who choose to vanpool are likely to experience shorter travel times than commuters driving alone.

Methodology

The following provides the methodology used in the Vanpool OMC:

1. Segment active vanpools in the program and summarize their associated travel characteristics (average round-trip mileage, occupancy).
2. Estimate vanpool growth due to employment. New vanpools = base year vanpools × percent change in employment markets. Employment growth is based on the Series 15 Regional Growth Forecast.
3. Estimate vanpool growth due to induced demand from travel time savings on regional Managed Lane investments for each vanpool market. Travel time savings are calculated via ABM3 and defined as the difference between the travel time experienced when using all available highways, and the travel time experienced using general-purpose lanes only (excluding HOV and Express Lanes). The elasticity of vanpooling with respect to travel time = (marginal disutility wrt travel time) × (travel time) ⁄ (1 − probability of vanpooling). Compute the demand induced by travel time savings by applying the demand elasticity formula to the estimated number of vanpools for each scenario year, after accounting for employment growth. New vanpools = (elasticity wrt travel time) × (% change in travel time).
4. Estimate VMT reduction based on vanpool trip characteristics. Daily VMT reduction = total vanpools [2 + 3] × average occupancy (excluding the driver) × round-trip mileage within San Diego County only.
5. Estimate daily total GHG reduction, which is the summation of the GHG reduction due to cold starts and GHG reduction due to VMT:

Cold start GHG Reduction (tons) = (Daily trip reductions) x (CO_2 StrEx Emission Factor (tons/trip))

Where:

Daily trip reductions = (2 trips*) x (Average Number of Passengers per Vanpool) x (Number of Vanpools)

* *Assuming each passenger would have made a single trip if not using vanpool service*

GHG reduction due to VMT = (Daily VMT reduction) x (CO_2 RunEx Emission Factor (tons/mile))

Where:

Daily VMT reduction = (Average Number of Passengers per Vanpool) x (Number of Vanpools) x (Average roundtrip mileage)

6. Estimate daily GHG reduction per Capita. Daily GHG Reduction per Capita (lbs/person) = Daily total GHG reduction [5] x 2000 (lbs/ton) / (Regional Population)

Table 1 provides a summary of the inputs and parameters incorporated in the Vanpool OMC. This table also describes updates required based on the updated ABM3 regional travel demand model.

Table 1: Inputs and Parameters – Vanpool OMC

Input/Parameter	Source	Detail	Updates
Inputs			
mgra_base_input_file	ABM	MGRA-based land use report file including jobs, households, income, and parking among other information by MGRA	No change to the input
mgra_scen_input_file	ABM	MGRA-based land use report file for the scenario year	No change to the input
skim_base_file	ABM	Travel time skim matrices, auto modes for the base year	No change to the input
skim_scen_file	ABM	Travel time skim matrices, auto modes for scenario year	No change to the input
individual_tours_output_file	ABM	Individual person tours	No change to the input
vanpool_od_file	Active vanpools data from SANDAG Vanpool Program	Vanpool program database. This database contains anonymized Vanpool Program utilization (one record per van), including origin, destination, vanpool size, and other vanpool program participant information. The database quantifies the base year Vanpool Program utilization.	Update to use the SANDAG vanpool report update for September 2022
employment_forecast_scag_file	SCAG	County-level total employment forecast for counties in the Southern California Association of Governments region. Employment forecasts are required for 2035, and 2050.	Update to SCAG estimates from most recent data provided on November 2023 (SCAG Draft 2024 RTP)
emission_factors_file	EMFAC Model	Average GHG emission factors, in grams per mile, based on EMFAC factors.	Update tool to use EMFAC 2021 outputs
Corridors_mgra_file	CMCP Corridors	Cross-walk between CMCP corridors and MGRAs. Each MGRA is assigned to one corridor only.	The input does not apply to the regional plan. Factor are removed from the VMT reduction calculation process
zipcode_coordinates_file	Zip Code Geometry	Latitude and Longitude coordinates of all Zip Code area centroids in San Diego County. Used to estimate distance traveled by vanpool participants.	No change to the input data

Input/Parameter	Source	Detail	Updates
external_gateways_file	US Census Bureau TIGER line file	Indicates the entry gateway (roadway) used by Vanpool Program participants who reside outside of San Diego County. Gateways are assigned by county of residence. Gateways are assumed as follows, based on the home county: • Los Angeles and Orange counties: Interstate 5 • Riverside and San Bernardino counties: Interstate 15 • Imperial County: Interstate 8	No change to the input data
geography_xwalk_file	MGRA, TAZ, MSA geographies	Cross-walk between Master Geographic Reference Area (MGRA), Traffic Analysis Zone (TAZ), and Metropolitan Statistical Area (MSA).	Update relationship table to latest geographies used in Series 15
msa_names_file	MSA	MSA code to name mapping	No change to the input data
Parameters			
base_year	-	Base year, corresponding to Vanpool Program utilization reported in vanpool_od_file.	Update base year to 2022 corresponding to SANDAG vanpool program data
scen_year	-	Scenario year used for selecting the GHG emission factors	Update scenario years based on ABM3 scenario years
c_ivt	ABM (based on a method by *Train, 1993*)	In-vehicle time coefficient used to estimate the elasticity of vanpool demand with respect to travel time	Update to reflect ABM3
avg_vanpool_occupancy	SANDAG Vanpool Program Guidelines (July 2023)	Average share of occupied seats per van	No update to the input parameter. Minimum vehicle occupancy is 80% based on Vanpool Program Guidelines.
pct_work_trips_over_50mi	Active vanpool data from the SANDAG Vanpool Program	The proportion of vanpool trips that travel more than 50 miles one-way	Update to use the SANDAG vanpool report update for September 2022
sov_am_time_core_name	ABM	Name of the travel time matrix, AM period, single-occupant car mode	Update travel time matrix input files to use ABM3
hov_am_time_core_name	ABM	Name of the travel time matrix, AM period, carpool car mode	Update travel time matrix input files to use ABM3
military_base_taz	TAZ	List of San Diego County TAZs with military bases	Update to Series 15 TAZ

Input/Parameter	Source	Detail	Updates
abm_version	-	SANDAG ABM model version. Required for compatibility with the skim matrix files.	Update version name to "ABM3"

Additional Considerations

In addition to updates intended for application of the OMC at the SCS scale in **Table 1** , the following considerations are also recommended to be explored for applications of the OMC at a project scale where data is available.

- Consider segmenting workers by home and work location, large employers, and those who are forecast by ABM3 to drive alone. Those who drive alone would be the primary target market for vanpool since their travel behavior would not require multiple people to participate in the vanpool. By understanding the home and work location of van pool areas, those driving alone that live and work in a vanpool service area but not working at a large employer may be able to participate in the vanpool program in addition to those working for large employers. This level of detail may only be possible on a project scale due to the detail and uncertainty in home and work location across the entire region. This consideration is recommended only for project level application and not the SCS.
- Consider using true distance based on the address for trips beyond the county boundary rather than zip code centroid data. To more accurately reflect VMT savings, the smaller geographic area reflecting trips that are forecast to use the vanpool program. If address is not possible for privacy, Census Block Group outside of the model area and TAZ within the model area may be appropriate. This level of detail may only be possible on a project scale due to the detail and uncertainty in home and work location across the entire region. This consideration is recommended only for project level application and not the SCS.
- Consider using speed bins and their associated GHG emission factors based on the EMFAC model for more accurate reduction estimation. The travel time (and presumably speed of travel) saved is one influencing factor shifting trip to van pool. Emissions vary by speed, with more consistent and uncongested speeds typically producing fewer emissions. Since the home and work location are uncertain at the regional scale for the SCS, the specific route taken and the associated travel time congested speed are considerations for project scale application of the OMC.
- Consider refined EMFAC emissions factors based on the routes anticipated to be used by those shifting to vanpool. Once speed is introduced to the emissions calculations, the specific route used by the vanpool vehicles could be used to estimate more accurately the emissions savings. Without the specific route and congested speed noted above, it is recommended that average emissions rates be used at the regional and SCS level of analysis, and the emissions factors by speed range only be considered when the specific route and congested travel speed is available at the project scale.

2. Carshare OMC: Python-Based

Purpose

The Carshare OMC estimates VMT and GHG reductions associated with round-trip carshare services. While the tool can account for the VMT reduction impacts of free-floating carshare services, it is assumed that such services will have limited operations considering ride-hailing services such as Uber and Lyft.

Methodology

The following provides the methodology used in the Carshare OMC:

1. Define geographic areas (Master Geographic Reference Areas) and target markets (e.g., Mobility Hubs, colleges/universities, military) deemed suitable for carsharing based on existing trends.
2. Estimate the "eligible adult population" within carshare coverage areas through 2035 using the SANDAG Series 15 population forecast. Segment the population within the coverage area into higher-density areas (>17 persons/acre) or lower-density areas (≤17 persons/acre) based on local carshare participation research.
3. Estimate carshare participation by applying the participation rate to eligible populations. Carshare participation = eligible adult population [2] × carshare participation rates (2% in high-density areas or 0.5% in low-density areas).
4. Estimate VMT reduction = total carshare membership [3] × round-trip carshare VMT reduction.
5. Estimate Total Daily GHG Reduction for all market segments (college employees, college students, and military). Total Daily GHG Reduction (short tons) = Total Daily VMT reduction [4] x (CO_2 RunEx Emission Factor (tons/mile))
6. Estimate Daily GHG Reduction per Capita. Daily GHG Reduction per Capita (lbs/capita) = Total Daily GHG reduction [5] x 2000 (lbs/ton) / Regional Population

Table 2 provides a summary of the inputs and parameters incorporated in the Carshare OMC. This table also describes updates required based on the updated ABM3 regional travel demand model.

Table 2: Inputs and Parameters – Carshare OMC

Input/Parameter	Source	Detail	Update
Inputs			
mgra_scen_input_file	ABM	MGRA-based land use report file including jobs, households, income, and parking among other information by MGRA	No change to the input
person_input_file	ABM	Synthetic population person file	No change to the input
household_input_file	ABM	Synthetic population household file	No change to the input
corridors_mgra_xwalk_file	CMCP Corridors	Cross-walk between CMCP corridors and MGRAs. Each MGRA is assigned to one corridor only.	CMCP Corridors. The input does not apply to the regional plan.
carshare_mgra_file	MGRA	Carshare strategy file that Indicates which MGRAs have carshare service, by forecast year and type of carshare market. Carshare markets include Mobility Hubs, colleges, and military bases.	Update list of MGRA carshare service based on ABM3 input geographies
geography_xwalk_file	MGRA, TAZ, MSA geographies	Cross-walk between Master Geographic Reference Area (MGRA), Traffic Analysis Zone (TAZ), and Metropolitan Statistical Area (MSA).	Update relationship table to latest geographies used in Series 15
emission_factors_file	EMFAC Model	Average GHG emission factors, in grams per mile, based on EMFAC factors.	Update tool to use EMFAC 2021 outputs
Parameters			
scen_year	-	Scenario year used for selecting the GHG emission factors	Update scenario years based on ABM3 scenario years
population_density_threshold	-	Density value used to classify MGRAs between low-density areas and high-density areas	Use updated for each scenario

Input/Parameter	Source	Detail	Update
high_density_mobility_hub_carshare_ participation	SANDAG Travel Survey Data	Carshare participation rate for persons living in high-density areas. According to the 2016-2017 San Diego Regional Transportation Study, approximately 2% of the San Diego population are carshare participants. In the San Diego region, coverage areas with a population density greater than 17 persons per acre are assumed to reflect these participation rates.	No change to the input data.
Low_density_mobility_hub_carshare_participation	Petersen et al, 2016	Carshare participation rate for persons living in low-density areas. Data for the Puget Sound region indicates that carshare participation in the Seattle-Bellevue-Redmond area is 2 percent in urban neighborhoods and 0.5 percent in suburban neighborhoods. In the San Diego region, coverage areas with a population density of less than 17 persons per acre are assumed to reflect the participation rates of lower-density neighborhoods in the Puget Sound region.	No change to the input data.
college_carshare_participation	-	Carshare participation rate for college students Local data on the carshare participation at colleges is unavailable. Participation rates are assumed equal to higher-density area carshare participation rates.	No change to the input data.
military_carshare_participation	-	Carshare participation rate in military bases. Local data on the carshare participation at military bases is unavailable. Participation rates are assumed equal to higher-density area carshare participation rates.	No change to the input data.
daily_vmt_reduction_carshare	Cervero et al, 2007	Daily average VMT reduction of carshare participants (7 miles)	No change to the input data.

Additional Considerations

In addition to updates intended for the SCS provided in **Table 2**, the following considerations are also recommended to be explored on project level application of the OMC where data is available.

- Consider updating participation rates and milage to reflect the utilization of (Mobility as a Service) MaaS. The usage or rate of carshare may continue into the future depending on the type of trip and the cost of carshare relative to TNCs. Research into the usage of carshare should be conducted to reflect post-COVID conditions. Since the travel options and availability of MaaS at a regional scale is uncertain, this level of analysis is only recommended for consideration on a project scale.
- Consider updating potential populations to be those who own an auto, and those who have not already had reductions due to other OMCs. Rather than the entire population, it is more reasonable for only those who do not own autos or have shifted to another mode in the OMCs would be eligible for the carshare reduction. Since the individual travelers and the details of their journey and individual trips being compatible with carshare is uncertain, this level of analysis is only recommended for consideration on a project scale.
- Consider using speed bins and their associated GHG emission factors based on the EMFAC model for more accurate reduction estimation. Since emissions are influenced by the speed of the vehicle, drive alone trips in congested areas that were removed or shifted to carshare may have a higher emissions reduction. With the specific location and route used in the use of a carshare vehicle being uncertain at the regional scale for the SCS, the specific route taken, the associated travel time congested speed, and the emissions by speed bin are considerations for project scale application of the OMC.