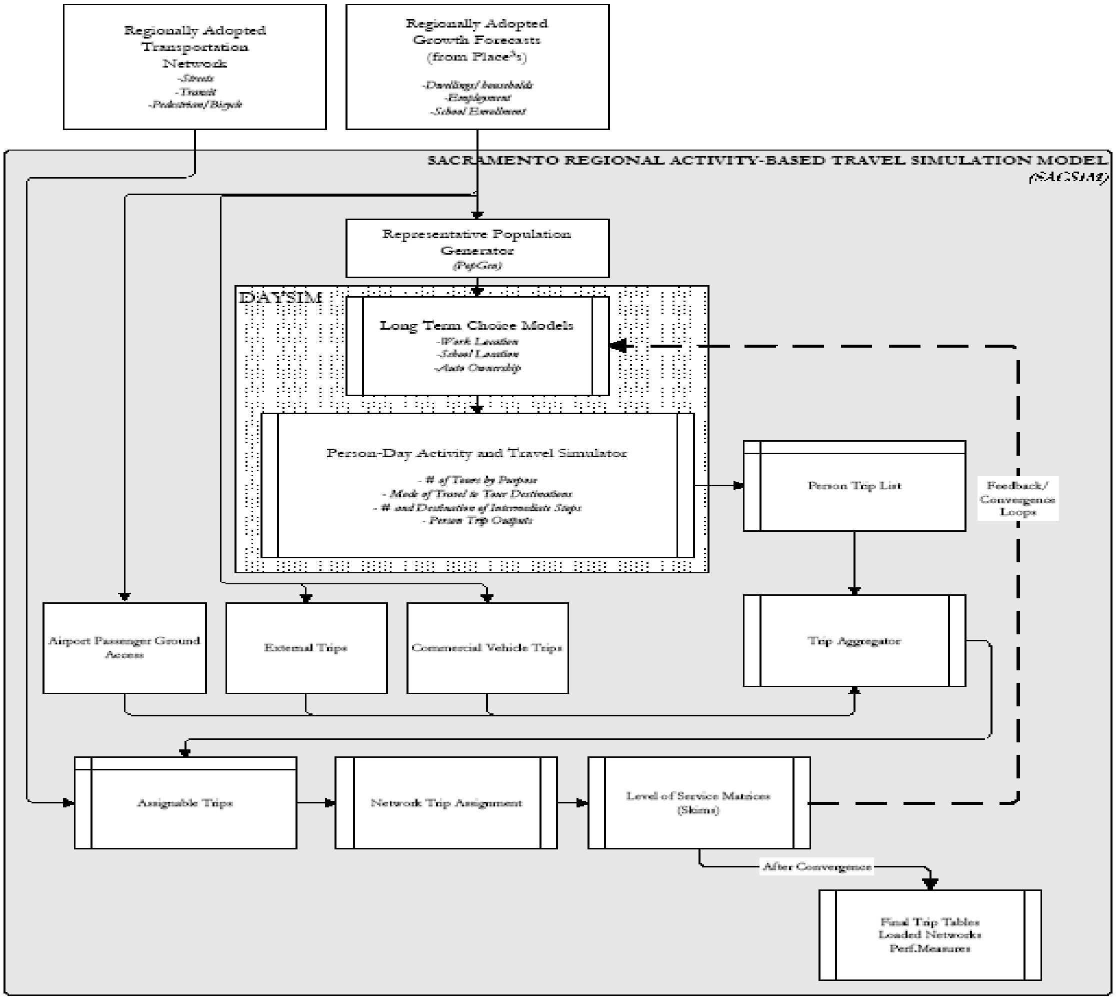
3 Model Structure

This chapter will expand upon the model concepts and parameters from Chapter 2 and describes the theory and relationships between submodels of SACSIM. The overall SACSIM model system is illustrated in Figure 3-1 below. Each submodel captures a component of travel behavior. The key submodels are:

3.1 DAYSIM – Person Day Activity-Based Tour Simulation Model
3.2 Commercial vehicle travel
3.3 External travel
3.4 Airport passenger ground access
3.5 Vehicle trip table preparation and assignment
3.6 Transit path building and assignment

Figure 3-1 SACSIM Model Structure



3.1 DAYSIM - Person Day Activity-Based Tour Simulation

DAYSIM is a regional activity-based, tour (ABT) simulator for the intra-regional travel of the region's residents only. Around the country, ABT models are increasingly used as replacements for more conventional, four-step trip models. ABT models seek to represent a person's travel as it actually occurs: in a series of trips connecting activities which a traveler needs or wants to participate in during the course of a day.

This chapter gives high level introductions about DAYSIM. Please refer to Appendix A – DAYSIM Reference Guide for details.

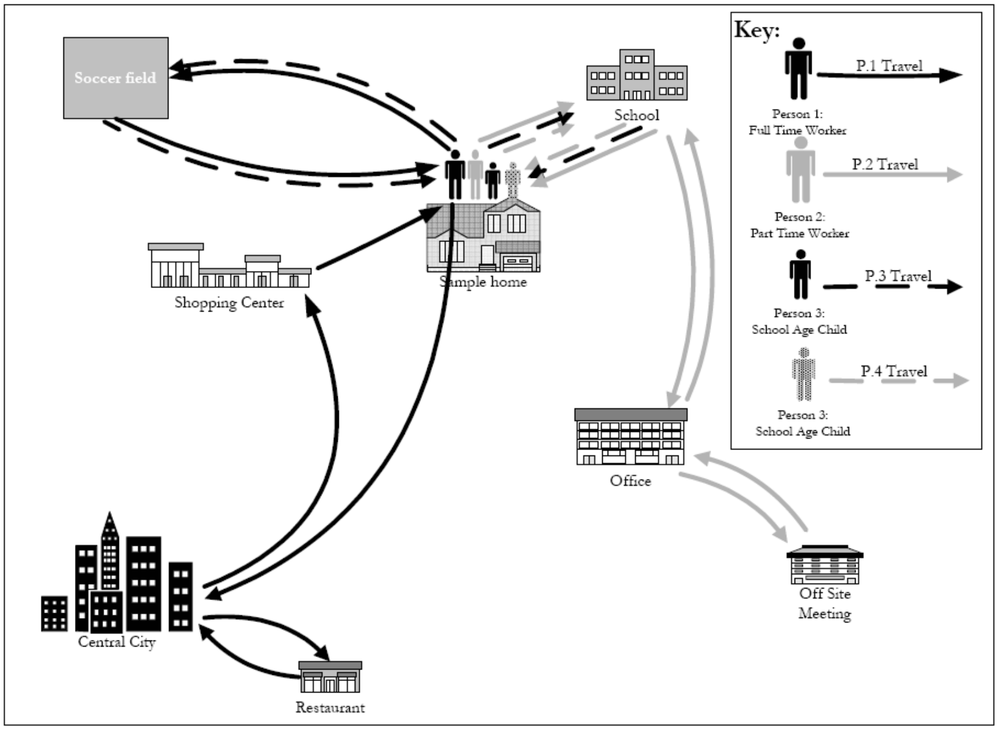
3.1.1 DAYSIM Terminology and Concepts

The specific definitions of *activities* and *tours* as used in this documentation are as follows:

> *Activities* are the things that people do during the course of the day, either to meet basic needs or for pleasure. The range of activities which people engage in is nearly infinite. For purposes of DAYSIM, activities are simplified into a set of seven generic categories, as follows:
>
> - Work (full time or part time)
> - School (K12, college, university, or other education)
> - Personal Business (e.g. medical appointment)
> - Shopping
> - Meal (i.e. having a meal outside of the home)
> - Social/Recreational (e.g. going to health club, visiting a friend or family member)
> - Escort (i.e. accompanying another person to an activity they are engaging in, e.g. a parent driving a child to school)
> - Home (any activity which takes place within the home)
>
> *Tours* are series of trips which a person does from their home in order to engage in one of the above activities. A single tour is all of the activities and travel one person does between leaving home and returning home. Each person in a household may engage in one or more activities in the course of a single tour. Also, each person may make no tours (i.e. stay at home all day), or they make many tours. A tour may be very simple, consisting of as few as two trips (i.e. one trip away from home to work, for example, and a return trip home), or it may consist of many trips, with lots of intermediate stops along the way.

illustrates a typical set of activities and travel for a sample family of four. provides a tally of the trips and tours for that sample family. The sample family makes a total of 19 person trips, which are grouped into eight tours. The most complicated tour is that by Person 2, who escorted two children to school, proceeded to work, and returned to pick up children on the way home. This tour included one work-based subtour, with two trips going from work to an off-site meeting, and a return trip to work. Including the subtour, Person 2 made a total of six trips in the course of the work tour. The simplest tours include four with only two trips each, by Person 1 (escort tour for Person 3 to/from soccer), two school tours made by Persons 3 and 4, and a social/recreational tour (to/from soccer) for Person 3.

Figure 3-2 Activities and Travel for a Sample Four-Person Household



Source: SACOG 2020.

Table 3-1 Trips and Tours for Sample Four-Person Household

Trip Origin/Destination	Person Trips Person 1	Person 2	Person 3	Person 4	Description
Home to Work Work to Shopping Center Shopping Center to Home	X X X				Pers. 1: *Work Tour* with 3 trips
Work to Restaurant Restaurant to Work	X X				Pers. 1: *Work-Based Subtour* with 2 trips
Home to School School to Office Office to School School to Home		X X X X	X X	X X	Pers. 2: *Work Tour* with 4 trips Pers. 3, 4: *School Tours* with 2 trips each
Office to Off Site Meeting Off Site Meeting to Office		X X			Pers. 2: *Work-Based Subtour* with 2 trips
Home to Soccer Field Soccer Field to Home	X X		X X		Pers. 1: *Escort Tour* with 2 trips Pers. 3: *Soc/Rec Tour* with 2 trips
Person Trips Person Tours	7 3	6 2	4 2	2 1	**Household Trips: 19** **Household Tours: 8**

Key: X = Person Trip   Shaded box = Tour

Source: SACOG 2020.

DAYSIM also distinguishes *long term* and *short term* choices in representing activities and travel. Long term choices are those which are taken relatively infrequently, and are unlikely to change in the course of a few months or even a year. Short term choices are those which are made quite frequently, and may vary day-to-day for most people. Again, in reality the number and range of choices which might be *long term* or *short term* in nature for any individual or household is nearly infinite. Additionally, each household makes choices on many different timeframes, not just long or short term. DAYSIM simplifies these choices to a relatively limited number:

Long term choices:

- Household automobile availability (i.e. the number of vehicle owned and available for use by a household)
- Usual work location for each worker (i.e. the location where a worker normally reports for work, for each worker)
- Usual school location (i.e. the location where a student normally goes to school, for each student)

Short term choices:

- The number and type of tours made by each person
- The main destination of each tour
- The main mode of travel for each tour
- The arrival and departure times for each activity on each tour
- The number and purpose of intermediate stops made on each tour
- The location of each intermediate stop
- The mode of travel for each trip segment on each tour
- The arrival and departure time for each intermediate activity on each tour

DAYSIM places these choices in a hierarchy, with the highest-level choices being the long term choices, and the lowest level being the short term choices.

Other DAYSIM terms are:

Locations vs. destinations— In DAYSIM, the terms location and *destination* both refer to parcels. Usually, in DAYSIM documentation, the term *location* is associated with long term choices, like usual workplace, or to intermediate stops on tours. *Destination* usually refers to the main place that a traveler chooses on any given tour. For example, the usual workplace location is the place a worker usually reports for work. However, on any given day, that worker may report to another place for their work tour destination. For most workers, the usual work location and the work tour destination on any given day are one-in-the-same.

Tour purpose—tours are "branded" by the main activity which is engaged in during the tour. Given that multiple activities of different sorts occur during some tours, this branding requires that a hierarchy of activity purposes be established, with the tour branded by the highest-level activity engaged in on the tour. Tour purposes are keyed to the seven of the eight categories of activities defined above[2], with the following hierarchy:

- Work
- School
- Escort
- Personal Business
- Shop
- Meal
- Social/Recreational

Tour destination— the parcel selected as the destination for the main activity on the tour. If there are two or more activities along the tour with the same, highest priority tour purpose, then the location of the activity with that purpose of the longest duration is designated as the tour destination, often referred to as the "primary" destination.

Half-tour—the trips from home to the primary destination of the tour, or the trips from the primary destination of the tour to home.

Person type—in reality, the variety of activities that any person engages in, and the degree to which any single activity typifies an individual, is highly complex and variable, with practically infinite possible classifications. DAYSIM uses many person and household characteristics to capture differences in activity and travel preferences. One useful composite variable used extensively to classify persons for purposes of estimating and applying the DAYSIM models is the person type:

- Full-time worker (more than 32 hours worked)
- Part-time worker (less than 32 hours worked)
- Non-worker, aged 65 years or older
- Other non-worker, non-student adult
- College/university student (full time student)
- Grade school student aged 16 years or older (i.e. driving age)
- Grade school student aged 5-15 years
- Child aged 0-4 years

[2] "Home" activities are not used for classifying tour purpose, since every tour has a home end. Tours are classified only by the non-home activities which are engaged in by the tour-maker.

Intermediate stop—places (parcels) on a half-tour where a person stops to engage in activity other than the activity at the main destination. Examples of intermediate stops in the sample household () are the stop at the shopping center on the way from work to home by Person 1.

Day pattern— The overall number of tours made by a person, the combination of purposes of those tours, and the purposes of intermediate stops on those tours, constitutes the *day pattern* for that person. Participation in tours and intermediate stops of the seven purposes is predicted for each person. This set of predictions is referred to as the day pattern. The exact numbers of stops on tours is predicted by lower level choice models.

Random seed and Monte Carlo selection process— Choice models predict probabilities of selecting each of several options, based on the characteristics of the person choosing and the relative attractiveness of the options available to that person. Aggregate models (not DAYSIM) utilize those probabilities by splitting the choices to all members of the applicable segment of the population according to the probabilities. E.g., if a mode choice model predicted a probability of 0.20 of using transit and 0.80 of using automobile for a particular segment with 100 persons, 20 of the persons would be assigned to transit and 80 to automobile. Person level simulations (including DAYSIM) require another process to allocate individuals to particular choices at the person level. In DAYSIM this is accomplished by assigning a random seed[3] to each possible outcome for each person. Monte Carlo selections are made based on the predicted probabilities and the random seed. For example, if a person's choice probability is 0.20 for the first of two possible outcomes in a choice situation, and their random seed for that choice is 0.20 or less, then the simulator assigns the first outcome to that choice for that person. This is the source of a unique characteristic of simulation models: random variation in result for exactly the same input files and processing, arising from differences in the random seeds from one run to the next. This issue will be revisited in Chapter 11 Sensitivity Tests of this report.

[3] The random seed is a real number between 0 and 1, assigned randomly to each individual in the representative population.

3.1.2 DAYSIM Structure and Flow

DAYSIM is structured as a series of hierarchical or nested choices models. The general hierarchy places the long-term models at the top of the choice hierarchy, and the short-term models at successively lower levels in the hierarchy. The detailed hierarchy and flow through the model are illustrated in Figure 3-3. Note that the general flow is down from the long-term models to the short-term models. Moving down from top to bottom, the choices from the long-term models influence or constrain choices in lower level models. For example:

- Choices of usual locations for work and school affect the choices of work and tour destinations, since the usual locations are the most likely destinations.
- Auto ownership affects both day pattern and tour (and trip) mode choice, by generating auto ownership market segments used in the model.

In addition to these direct influences, utilities from lower level models flow upward to higher level models, too. Logsums of tour destination and tour mode affect other short-term models, as well as the upper level, long-term models. Some of the logsums from lower level models are aggregated for use in the long-term models, in order to reduce the computational load of using true logsums in such a complex nesting structure. The details of the process of utilizing logsums both “upward” and “downward” in the overall model structure is described in more detail in the DAYSIM technical memoranda[4], and in other published work[5,6]. Figure 3-3 provides more detail on the upward and downward flow of logsums and other variables in the location and destination models.

[4] Technical memoranda for DAYSIM development are available at http://www.jbowman.net/.

[5] Bowman, John L. and Bradley, Mark A., “Upward Integration of Hierarchical Activity-based models or Sensitivity to Impedance and Spatial Attributes in Activity Based Models”, January 17, 2006, available at http://www.jbowman.net/.

[6] Bowman, John L., Bradley, Mark A., and Gibb, John, “The Sacramento Activity-based Travel Demand Model: Estimation and Validation Results”, presented at the 2006 European Transport Conference, September 2006, available at http://www.jbowman.net/.

Figure 3-3 DAYSIM Structure and Flow

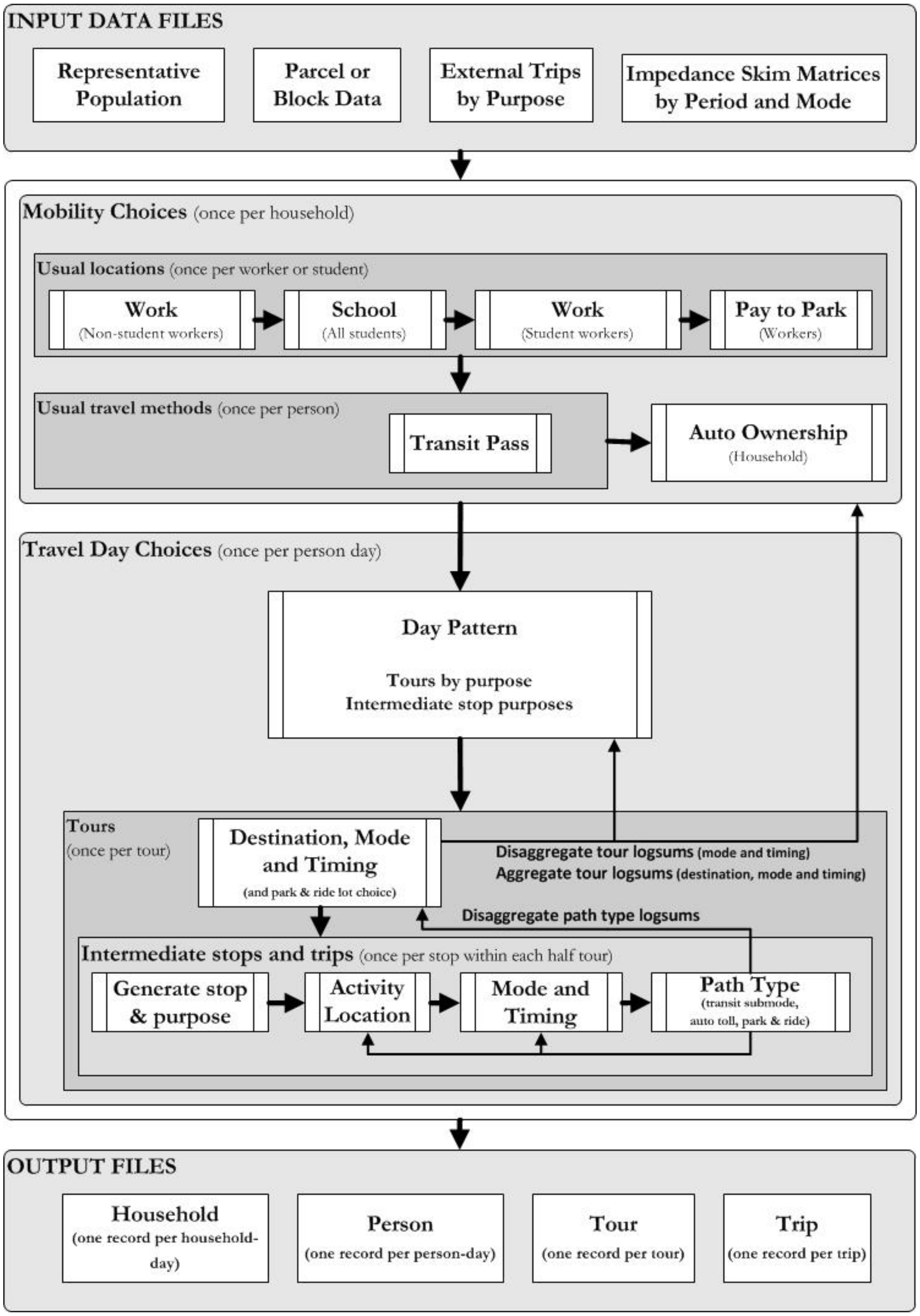


Table 3-2 Utility Function Variables in the Location Choice Models

Attributes	Models: Usual work location	Work tour destination	Usual school location	Non-work tour destination
Binary Choice				
Choice between…	…home vs. other	…usual vs. other	…home vs. other	n/a
Constants	By person type	By person type & tour type	By person type & HH size	
Disagg. Logsum For Usual Locations	Yes	Yes	Yes	
Conditional MNL choice among regular locations				
Disaggregate Mode Choice Logsum to Destination	Yes	Yes	Yes	Yes
Piecewise Linear Driving Distance Function	For full-time workers		For children under age 16	By Purpose Priority Pattern type
Natural Log of Driving Distance	For other then fulltime workers by person type & income	By person type & tour type	For persons age 16+ by person type & ??	By tour type, Income, person type & time available
Distance from Usual Work Location		Yes	For not-student-aged	
Distance from Usual School Location	For student-aged	For student-aged		Yes
Aggregate Mode+Dest Logsum at Destination	By person type	By person type	By person type	By purpose
Parking and Employment Mix	For daily parking in parcel and in TAZ	for daily parking in parcel and TAZ		For hourly parking in parcel and TAZ by car availability
Ratio of "Good"-to-Total Intersections	Yes	By car availability		By car availability
Employment, Enrollment and Households by Category	By person type & income	By person type & income	By person type	By purpose (and by 'kids-in-household' for escort tours)
Zonal density	Yes	Yes	Yes	Yes
Parcel size	Yes	Yes	Yes	Yes
Person Type Categories in the Models	Full-time worker Part-time worker Not full- or part-time worker	Full-time worker Part-time worker Not full- or part-time worker	Child under 5 Child 5 to 15 Child 16+ University student Not-student-aged	Full-time worker Part-time worker Retired adult Other adult Child under 5 Child 5 to 15 Child 16+ University student

Source: SACOG 2020.

3.1.2.1 Recent Major Improvements and Updates

Every component model of DAYSIM has been re-estimated using the 2008 parcel and skim data, and using the new DAYSIM estimation capabilities, described later. Two new pricing-related models have been added as well. Technical details of the models are provided in the Appendix A DAYSIM Users Guide. This section provides a high-level summary of the changes.

3.1.2.1.1 Changes to support the treatment of policy-based pricing

Before re-estimating the various DAYSIM models, several new features were added to DAYSIM to support the treatment of pricing effects in the models. Many of these were based on the research done as part of the SHRP 2 C04 project on model improvements to address pricing and congestion. These include:

Distributed value of time: Each tour simulated in DAYSIM has its own time/cost tradeoff, with the functions used to set the cost coefficient (c[i]) and time coefficient (t[i]) shown in Figure 3-4 below. The cost coefficient is based on an inverse power function of income and car occupancy, with the power exponents differing for work and non-work tours. The time coefficient also has different functions for work and non-work tours, and uses a log-normal distribution (see) to simulate random variation around the mean.

Note that this random variation in VOT is not used in model estimation, and can also be switched off by the user for model application, in which case the mean value is assumed. Also note that this value is for auto in-vehicle time. Relative values for other types of travel time can be specified by the user as part of the DAYSIM configuration (as can all of the parameters used in) and should be set so as to be consistent with the relative values of time assumed in the generation of the network skims. Within DaySim, the SOV cost coefficient and time coefficient are set once for each tour, and the resulting values of time for all modes (based on the just-mentioned configuration parameters) are used for all models associated with that tour. The VOT associated with each simulated trip is included in the Trip output file.

Figure 3-4 Functions from SHRP 2 C04 for Tour-Specific Value of Time

Work tours

c(i) = -0.15/$ / [((income(i) / 30,000) ^ 0.6) * (occupancy(i) ^ 0.8)]

t(i) = -0.030/min * draw from a log-normal distribution, with mean 1.0 and std. deviation 0.8

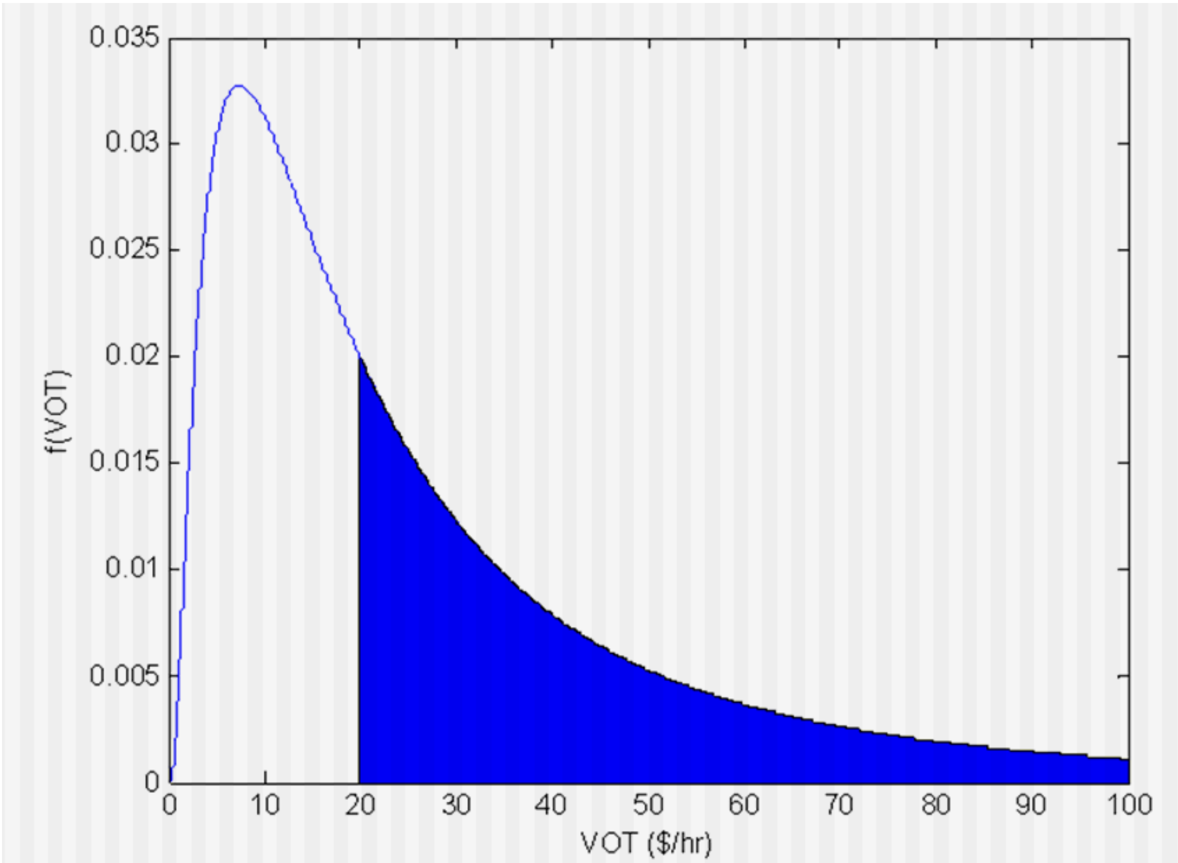
Non-work tours

c(i) = -0.15/$ / [((income(i) / 30,000) ^ 0.5) * (occupancy(i) ^ 0.7)]

t(i) = -0.015/min * draw from a log-normal distribution, with mean 1.0 and std. deviation 1.0

Source: SACOG 2020.

Figure 3-5 Shape of the log-normal probability frequency distribution



Source: SACOG 2020.

Flexibility in using impedance matrices: Another new feature of DAYSIM that supports pricing analysis is a great deal of flexibility in defining and using network impedance skim matrices. This flexibility includes:

- Matrices for a given mode can be specified for different path types. This can be used for auto (i.e. the full network versus a network that excluded tolls) and for transit (i.e. the local bus network versus a light rail network)
- Matrices for any mode can be defined to be for a specific range of VOT, allowing tours with different VOT to use different matrices reflecting differences in their "best" path. In retrieving skim values, DAYSIM uses the tour's VOT to retrieve the skim value for the correct VOT range. The endpoints of the VOT ranges are set as DAYSIM configuration parameters, and should be set to correspond consistently with the VOT assumed for each VOT-specific skim.
- Matrices can be for any minute, hour or period of the day, and these periods do not need to correspond to any fixed time periods used elsewhere in DAYSIM or in supporting trip-based models. This allows a great deal of flexibility to reflect time-of-day pricing policies.

- The same input matrix can be used to reflect multiple combinations of mode, path type, time period and VOT class, providing efficiency in memory usage and I/O.

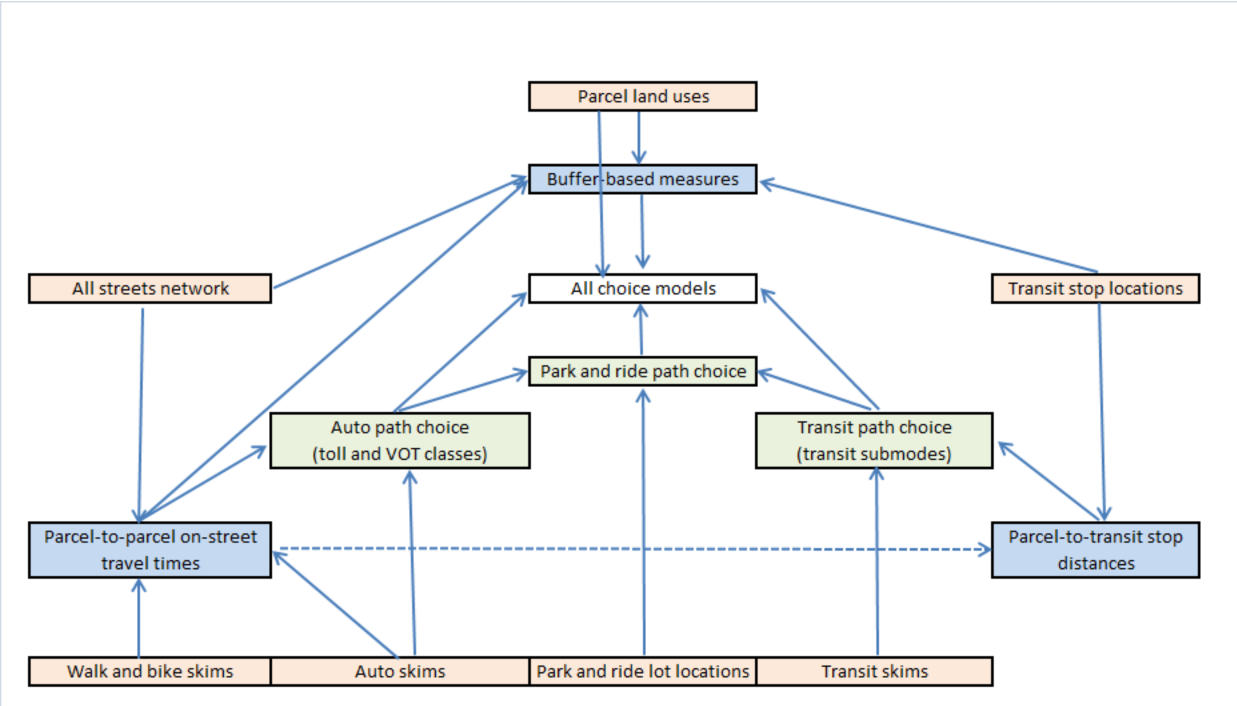
Consideration of transit fare passes and discounts: Although the transit fare values in the transit impedance skims reflect the full fare, DAYSIM no longer assumes that everyone pays that fare. Fare reduction is simulated in two ways:

- First, transit users can receive a percentage discount based on their age and student status. This is controlled via discount factors input by the user in the DAYSIM configuration.
- Also, a new Transit Pass Ownership model has been added to DaySim. This is a binary choice model predicting whether or not each person age 16+ owns a transit pass, as a function of person type, age, employment status, student status, and accessibility by transit from their home, workplace and/or school location. The user can also vary the price and price-sensitivity for transit passes via configuration inputs. If a person is predicted to own a transit pass, then their marginal fare cost for transit is 0 (100% discount factor).

The use of path type choice models for all modes: This reflects a fundamental change to how DAYSIM uses impedance information in the choice models. Figure 3-6 illustrates how all skim information works through the path type model, which performs the following functions in a consistent way:

- For a given mode/origin parcel/destination parcel/time of day, it determines if a valid path is available via one or more path types for that mode. ("Valid" meaning that there is a network path, and that the total travel time is less than a user-defined maximum.) The path can be one-way (for trip-level models) or round trip for two different times of day (for tour-level models)
- For each possible path type, a utility is determined, using the tour-specific time and cost coefficients (VOT) as well as additional time weights provided by the user.
- If one or more path types is available, a logsum across those path types is calculated and passed back for use in higher-level models such as mode choice or time of day choice.
- The travel time, cost, and distance via a chosen path type is also generated. For most uses, this is deterministic, via the path type with the best utility, although at the trip-level where the path type is predicted for the final simulated trips, a stochastic choice can be simulated instead.

Figure 3-6 Schematic of the use of path choice models to support other DAYSIM choice models



Source: SACOG 2020.

Further technical detail on the path type models is provided in the DAYSIM Users Guide. Some highlights for specific modes include:

- For bicycle, the user can define additive weights for distance on specific types of links, to calibrate the usage of different facility types.
- For auto, the user can define different VOT ranges for the skim matrices, and also specify the size of a constant term to be used for toll routes to calibrate/reflect resistance to using tolled facilities.
- For walk, bicycle, and auto, the parcel-based circuity factors are applied to get a more accurate estimate of distance and travel time for short trips, particularly intra-zonal trips for which the network skims provide little useful information.
- For transit, the user can define additive in-vehicle time weights, as well as path type-specific constants, in order to calibrate the usage of different types of transit services (as well as vary their attractiveness in higher level models such as mode choice). DAYSIM uses the tour's simulated value of time in modeling the choice of transit submode (path type).
- For transit, access and egress walk distance are determined based on parcel-specific walk distances to the nearest stops, and the user can change parameters related to the maximum walk distance and the characteristics of walking to direct paths versus paths that involve transfers.

- For park and ride, the model is similar to the transit model, but substituting drive access time for walk access at the home end. (Park and ride is always evaluated round trip, assuming the same lot on both halves of a tour.)
- For park and ride, DAYSIM will search across all park and ride lots and find the one that provides the best utility for the given O/D/mode/path type/times of day. Alternatively, the user can find the best park and ride lot node with other software outside of DAYSIM and provide a matrix of the best park and ride lot for each O/D pair.

A few more features of the path type models:

- Even if the user does not define different path types for a mode, the path type model will be used for the single, default path type in order to calculate the generalize time utility for that alternative. This ensures that the calculations are done consistently whether or not there are multiple path types available. For example, only the "full network" path type is currently available for the walk and bike modes, and this is why no "walk/bike path choice" is shown in Figure 3-6, even though those modes are also evaluated via the path type model. Furthermore, DAYSIM could be used to evaluate multiple path types even for those modes—an example would be to use completely separate bike skims for path types with and without Class 1 or 2 bike lines.
- As shown in Figure 3-6, the use of the path type model means that all DAYSIM models access and use the skim information consistently via path type choices and logsums. This also extends to the accessibility logsums used by the upper level DAYSIM models.
- The ability to do park and ride lot choice within DAYSIM is new, and more advantage of this will be taken in the future. For example, lot capacity constraint is not currently included. In future versions of DaySim, it will be possible to incorporate capacity constraint via a time of day-specific shadow-price mechanism.

3.1.2.1.2 Changes to specific DAYSIM choice models

All models were re-estimated using the new DAYSIM estimation capabilities and the new parcel data and skim data. The new model coefficients are given and annotated in the DAYSIM Users Guide. This section provides some key points for each model, starting from the "bottom" up:

Mode choice models: Mode choice models at the tour and trip levels were estimated using the logsum from the path type model for each mode as a key input. (Note: Upon first pass, this approach appears to be predicting too many long trips for walk, bike and transit, so the models will be estimated using different weights on the time component for those modes.) The use of the new parcel buffer variables also improved the land use effects on mode choice somewhat.

Time of day models: These models were also estimated (and applied) using the generalized logsums from the path type model for each time of day, rather than simply the travel time, enhancing the response to time-of-day pricing. Also, the use of time window variables and availability constraints in these models was improved to ensure that more realistic schedules are simulated.

Location choice models: The new parcel buffer variables were useful in re-estimating neighborhood effects, in combination with the size variable effects. Time window effects and availability constraints were also enhanced. Distance functions were consolidated and simplified somewhat, as recommended by the peer review panel.

Day pattern models: These include the main person-day pattern model, as well as models of the exact numbers of tours, work-based subtour generation, and intermediate stop generation. These models were re-estimated to include enhanced accessibility logsum effects via the disaggregate and aggregate logsums. Other minor changes to the specifications were carried out as well.

Vehicle availability model: The auto ownership model was re-estimated, taking advantage of new accessibility logsum variables, but otherwise the specification was not changed.

Transit pass ownership model: This is a newly-added binary choice model predicting whether or not each person age 16+ owns a transit pass, as a function of person type, age, employment status, student status, and accessibility by transit from their home, workplace and/or school location. This model was estimated using data from the Seattle (PSRC) region, since this variable was not available in the SACOG 2000 survey data.

Pay to park at workplace model: For each worker, this model predicts whether or not the person has to pay to park at/near their workplace—i.e. that they do not receive free or totally subsidized parking. It is a binary model, mainly a function of income, employment status, and the land use and parking supply around the workplace. If the model predicts that a worker does have to pay, then the parking cost at their workplace is determined by the average daily price for paid off-street parking in the (smaller) buffer around the work parcel. Otherwise, the parking cost is set at 0 (free). This model was estimated on SACOG 2000 survey data.

3.1.2.1.3 DAYSIM Software Improvements

The new software improvements have been referred to several times in the preceding sections. This final section provides a concise overview of the key improvements.

- The new code is written in C#, which is a standard language now used by software engineers for creating professional software. It is programmed in the Microsoft Visual C# integrated development environment (IDE), using 64-bit code.
- The new code was co-designed and created by RSG's top software engineers (Bryce Lovell and Leo Duran), and is maintained using state-of-the practice software version control (Subversion, with Tortoise SVN Windows interface) and project management tools (Redmine). Each revision of the code is reviewed to maintain professional standards of code legibility, efficiency, and manageability.
- The code is fully object-oriented, enhancing legibility and adaptability.
- The code uses multi-threading (parallel processing) wherever it is most efficient, making optimal use of hardware.

- The code uses advanced memory handling features, allowing most regional model systems to be run with less than 8 GB of RAM (depending mainly on the number of zones used for network skims)
- Most of the constants and parameters in the code are user-configurable, enhancing legibility of the code and avoiding the need for revising and re-compiling.
- The formats for the input and output files are now consistent, enhancing the capability to do partial runs.
- DAYSIM now includes a model estimation capability that produces data and control files that can be used "as is" to immediately estimate models using the ALOGIT software. DAYSIM also reads the coefficient files generated by ALOGIT as a result of model estimation. This has multiple advantages:
  - Ensures consistency between model estimation and application, avoiding a major source of potential bugs
  - Makes it very quick and efficient to re-estimate the models when new data becomes available or when minor changes are desired.
  - Ensures consistency across the different choice models and the way they are coded, making it easier for new users to understand different models.
- The new "skim roster" capability makes it possible (and fairly easy) to change many aspects of how the network skims are used (adding or subtracting submodes and path types, use of different VOT classes, changes in time period definitions, etc.) without needing to change or recompile the DAYSIM code.
- In addition to the above features, the new DAYSIM has maintained key distinctive features that were present in the old version:
  - The ability to work with parcel-level spatial alternatives. This is now configurable, also allowing inputs at the zone, or micro-zone (e.g. block) level.
  - A facility for synchronizing random seeds, reducing differences between runs/scenarios that is due solely to random simulation error.
  - Shadow pricing to maintain supply/demand consistency for choices of work and school locations.

3.1.2.2 Long Term Choice Models

As mentioned above, three choices are treated as long-term choice models, and are at the top level of the choice hierarchy:

- Usual work location (for workers)
- Usual school location (for students)
- Household auto availability

For persons who are both worker and student, a usual work location and a usual school location are modeled.

3.1.2.2.1 Usual Work Location Choice Model

Usual work location is the top-level model in the DAYSIM hierarchy. Except for auto ownership, logsums from lower level models influence choice; auto ownership logsum flows down to lower level models. Auto ownership is assumed to be conditioned by usual work and school locations, not the other way around. Choice sets are constrained by ratios of maximum travel times reported in the survey; alternatives which meet the time constraints are sampled for the final choice sets. In application, each choice is simulated from a sample of the available alternatives. Work-at-home utilities are determined by constants and person type.

In addition to the constraints applied to choice sets, total work location choices are constrained to TAZ-level total jobs at the work location. In application, this is accomplished by tallying the usual workplace locations to TAZ through the course of the simulation. As TAZs become "filled" they become unavailable in subsequent choices sets. This process effectively fills the equivalent of doubly constraining matrices in a gravity distribution. This accounting process is currently being replaced by a shadow price process.

Level-of-service variables are primarily home-to-work location distance, and three logsums: destination choice, mode-destination choice, and mode choice. Several parking supply and street pattern variables are included: paid, off-street parking supply (+ effect), and the "good" intersection ratio within ¼ mile (+ effect). Density variables split into two primary effects: density of service and education employment, and households (- effect); and other employment density (+ effect). Size variables enter the model at parcel level, and have similar effects by variable as density.

3.1.2.2.2 Usual School Location Choice Model

Structurally, the usual school location choice model is similar to the work location model, but with person types focused on students (K12 and college/university). Because of the strong relationship between usual school location and enrollment at the school site, and the generally shorter trip length associated with school trips, the array of land use variables is simpler compared to the work location choice model. Like work locations, alternative sampling is used in the model application.

For purposes of this model, "college/university" students are students enrolled at University of California at Davis, Sacramento State University, one of the public community colleges, or one of the private colleges or graduate schools. Students enrolled at technical or trade schools are not counted as college/university students.

3.1.2.2.3 Automobile Ownership/Availability choice model

Auto ownership here implies outright ownership, leasing, or availability of an automobile to a household for general use by other means. The submodel includes constants for ownership "choices" of no cars, one car, two cars, three cars, or four-or-more cars. Separate constants for households with one through four-plus driving age persons in the household are included. Other demographic variables relate to life cycle (e.g. presence of retired persons, school age children, or college/university students) or to household income level.

An array of accessibility and land use variables is included. Mode choice logsums to work (for workers) or to school (for students). One logsum formulation compares the mode choice logsum assuming every driver had a car, with that assuming the household owned no cars; as that difference expands (i.e. the difference between having full access to autos and no access to autos expands), the likelihood of the household owning no cars decreases. Proximity of residence to the nearest transit station or stop is included (+ for owning no cars, or for owning less than one auto per driver). The amount of accessible residential service land uses (defined as food, retail, medical, and service employment within ½ mile of the place of residence) is included (also + for owning no cars, and for owning less than one car per driver).

3.1.2.3 Short Term Choice models

Short term choice models include choices which are presumed to be more transitory in nature than usual place of work, usual school location, and auto ownership. These short term choices are: the day pattern for each person; the primary destination for each tour made; the main (but not only) mode of travel for each tour; the scheduling and timing of each activity; and subsequent choices related to the number of intermediate stops on tours, the mode of travel for each trip segment on a tour, and the timing of the trip segments. As described above, logsums from these lower level models (e.g. tour mode/destination choice, tour mode choice, etc.) are included in the upper level, long-term models. The logsums for the upper level models are also available.

3.1.2.3.1 Day Pattern and Exact Number of Tours

The day pattern consists of the number of tours of different purposes a person makes during the course of a day, plus the numbers of stops made on each tour.

The day pattern submodel consists of seven parts:

- A set of binary choices of making 0 or 1+ tours, and 0 or 1+ stops on tours, for each of the seven tour purposes.
- Constants were estimated for each of seven person types, along with additional coefficients for household composition, income, auto ownership, and land use at place of residence, and accessibility variables.
- A set of constants for predicting multiple tour+stop purpose combinations (i.e. 1 tour purpose + 1 stop purpose, 1 tour purpose + 2 stop purposes etc.).
- A set of demographic variables and accessibility variables, which affect predictions of the exact number of tour purposes and stop purposes.

- A set of constants for various combinations of multiple tour purposes and stop purposes.

The submodel shows that personal and demographic characteristics strongly influence the number and purpose of tours.

- Work tours most likely by full time workers, less likely by part-time workers, least likely by retired adults, etc.).
- Adults aged 18 to 25 are the most likely of all adults to make a school tour.
- Adults with children of school age are most likely to make escort tours, and females are more likely than males to make escort tours.
- Persons in higher income households are more likely to make tours than those in lower income households.
- Adults who are the only adult in the household are more likely to make more non-work tours.
- Accessibility variables (logsums from lower-level models like tour mode choice, and home-work intermediate stops) generally increase the likelihood of making tours.
- Mixed use density at place of residence increases the likelihood of making shop tourTour Primary Destination Submodel

Tour destination choice occurs below the usual location choices for work and school, so for workers and students (and student-workers), the usual locations of those work and school activities are already modeled. In fact, the tour destination for the majority of these persons for work and school is the usual work or school location. The work tour destination model is structured as a nested choice, with the highest level choice being the usual work location vs. other locations, with the other locations nested. No school tour destination choice submodel was estimated, since such a high percentage of students travel to the usual school location.

For non-work/non-school tour destinations, no “usual” location has been chosen at a higher level of the submodel, so tour destination choice is more complicated. The tour destination submodel includes a set of coefficients applied to logsum variables (mode choice to destination, purpose-specific aggregate mode/destination choice at destination), and other coefficients by purpose for drive distance ranges.

An array of parking supply, street pattern, and land use variables are included in the non-work/non-school submodel:

- Combination of parking and commercial employment increase the attractiveness of parcels within a TAZ.
- Street pattern (the so-called “good intersection ratio”) within one-quarter mile of a destination increases is attractiveness. The street pattern variable is computed as a proportion of the 3 or 4 leg intersections, compared to all intersections within one-quarter mile.
- A large array of density and parcel size variables by different tour purposes and density is included in the submodel. The following general patterns emerge, though:
    - Some more obvious matches between land use variables and tour purposes are captured in the submodel (e.g. higher numbers of food service employees make parcels more attractive for meal tour destinations; higher numbers of K12 enrollments make parcels more attractive for escort tour destinations; etc.).

- Higher household density and higher numbers of households on parcels reduce the attractiveness of a parcel as a destination for most purposes.

3.1.2.3.2 Tour Main Mode Submodel

Tour main mode is the predominant mode chosen for making a given tour: the actual mode chosen for each segment of the tour is modeled as “trip mode” at a lower level. The relationship between tour main mode and trip mode for trips within a single tour for a given person has an analogous relationship as that between usual work and school location, and work and tour destination—the higher level choice is highly determinative of the lower level choice. That is, the predominant mode chosen for a tour is the most likely mode for each segment within that tour. The exceptions to this general pattern will be discussed below, in the trip mode choice section.

The tour main mode submodel is structured as a multinomial logit with the following eight mode options:

- Walk
- Bicycle
- Drive Alone
- Shared Ride (2 persons)
- Shared Ride (3-or-more persons)
- Walk-to-transit
- Drive-to-transit (work tours only)
- School Bus

Non-mandatory trip purposes (personal business, shop, meal, social/recreational) were combined for the mode choice estimations. Submodels were estimated for the following trip purposes:

- Work tour
- School tour
- Non-mandatory tour
- Work-based subtours

3.1.2.3.3 Work Tour Mode Choice

The estimation included a set of four generic level-of-service variables (cost, in-vehicle time, wait time, and walk and bike time). Walk or bike time for drive-to-transit, walk-to-transit, walk and bike were split out from wait time, with coefficients estimated rather than fixed.

In addition to a mode constant, drive-to-transit variables included two auto-availability variables (- for no autos, - for autos less than workers), and a ratio of drive time to total in-vehicle time (the coefficient for which is useful for weighting drive access time in transit path building). Walk-to-transit had only a constant and a dummy variable, if the closest transit stop is an LRT station (+ for walk-to-transit).

Shared ride modes included variables on numbers of persons in the household, with likelihood of choosing shared ride declining steeply if the number of persons in the household is one (for 2 person shared ride), or less than three (for 3+ person shared ride). Shared ride is also more likely for households with school age children, with fewer cars than drivers, or households with a higher share of escort stops during the course of the day.

Drive alone included variables on auto availability (- for autos less than workers), income (- for household income less than $25,000), and share of escort stops during the course of the day (- for higher share).

Bike mode is more likely for males, younger travelers (- for age greater than 50 years), and for areas with good land use mix (+ for mixed use density at place of residence). Bike mode also includes a Davis constant (+).

Walk is less likely for males, and more likely in areas with good land use mix and density at place of residence.

3.1.2.3.4 School Tour Mode Choice

Three generic level-of-service variables are included in the estimation: cost and in-vehicle time (both constrained); and combined out-of-vehicle time).

School bus mode is less likely for very young students (- for age under 5 years), and for older students (- for age 18 years and older).

Walk-to-transit mode choice includes auto availability (+ for no cars, + for fewer cars than drivers). A constrained constant is included for children under 5 years. Walk-to-transit is more likely for older students (+ for age 16 or 17 years, + for age 18 or older). Walk-to-transit is also more likely in areas with good land use mix and density.=

Auto modes (shared ride and drive alone) include the same constellation of variables used in the work submodel.

Bike mode is more likely for male students, and students 18 years or older. A Davis constant (+) is also included.

Walk mode is more likely in areas with good street pattern (+ for higher proportions of "good" intersections).

3.1.2.3.5 Escort Tour Mode Choice

The escort tour mode choice model is relatively simple, and relies primarily on personal and family composition constants and variables. Walk mode is more likely in areas with good street pattern.

3.1.2.3.6 Work-Based Subtour Mode Choice

Work-based subtours are the only non-home-based tours in DAYSIM. Work-based subtours begin and end at the place of work, while all other tours begin and end (albeit with other destinations and stops) at home. The mode of travel used to get to work is influential in determining the mode used for work-based subtours.

3.1.2.3.7 Non-Mandatory Tour Mode Choice

This submodel predicts tour mode choice for home-based personal business, shop, meal, and social/recreational tours. The submodel includes many of the same variables at seen in the other purposes. However, the street pattern and land use density and mix variables are more prevalent and significant in this model: the street pattern variable or mixed use density variable is included in walk-to-transit, bike, and walk modes.

Each alternative in the models is characterized by three separate dimensions: arrival time, departure time, and duration of stay. Constants are included for ten arrival time blocks, departure time blocks, and activity durations per purpose. The arrival and departure blocks differ by tour purpose; for example, work arrival blocks are the shortest for the normal, morning work start times, while the time blocks for the late morning and afternoon time blocks are longer.

Activity and travel scheduling models were estimated for four trip purposes (or aggregated purposes):

- Work activities and tours
- School activities and tours
- Non-mandatory activities and tours (i.e. personal business, shop, meal and social/recreational)
- Work-based subtours

An additional scheduling submodel was estimated for intermediate stops. For intermediate stops, the departure time is fixed for stops on the outbound half tour, so those observations only contribute to the constants for arrival time and duration, and the arrival time is fixed for stops on the return half tour, so those observations only contribute to the constants for departure time and duration.

In addition to the time block constants, the submodels included various other variables, described below.

> *"Shift" variables by person type*--These variables effectively adjust the time block constants for arrival or duration by person type. For example, part time workers and student workers tend to start work activities later than full time workers—the shift constant for arrival time for part time workers is positive, indicating later arrivals. Negative-sign shift coefficients arrive earlier, or participate in the activity for a shorter duration, than other person types; positive-sign shift coefficient arrive later or participate longer.

"Shift" variables by tour complexity--Some shift variables account for complexity of tours, either by quantifying the numbers of stops for tours of different types, or the number of tours.

Income variables--Lower income workers tend to work for shorter durations, and higher income workers, longer.

Purpose specific variables--Especially for the non-mandatory purpose submodel, arrival and duration shift variables are included to differentiate the differences in each purpose.

Time pressure/constraint variables--Several variables were used to represent the constraints imposed on scheduling by inclusion of longer activities in a daily pattern, or by overall schedule complexity (number of tours, number of stops on tours):

- Duration of the adjacent empty window before period starts
- Duration of the maximum consecutive empty window before the period starts
- Total duration of all empty windows in the day before the period starts
- Duration of the adjacent empty window after the period ends
- Duration of the maximum consecutive empty window after the period ends
- Total duration of all empty windows in the day after the period ends

Level of Service and Congestion Variables--Auto and transit travel time enters the model, along with the time spent in severe congestion. Note that for purposes of the estimation, the marginal skims for the i-j TAZ interchange was used, not any actual surveyed information about the path actually taken for the trip.

Major effects captured in the models are as follows:

Work activities and tours:

- Lower income workers tend to have shorter duration activities, and higher income workers, longer activities.
- The more work-based subtours that are part of the tour, the longer the total duration of the work activity (including the subtour).
- Making more intermediate stops to/from primary destination reduces time spent at primary activity.
- Workers with 2+ tours to schedule will tend to try to leave a large consecutive block of time rather than two or more smaller blocks.
- For both AM and PM, the tendency is to move the work activity earlier as the time in very congested conditions increases.
- School activities and tours.
- Many time pressure/constraint effects are similar to work activities and tours.

Non-mandatory activities and tours:

- Relative to personal-business activities, people tend to arrive earlier for escort activities and later for shopping, meal and social/recreation activities.
- Escort and shopping activities also tend to be much shorter in duration, while social/recreation activities are much longer.

- Escort and shopping activities are likely to last less than an hour, and shopping and meal activities are likely to last 1-2 hours.
- Shopping activities are unlikely to begin before 7 AM or end after 9 PM. Meal activities are also unlikely to end after 9 PM.
- Escort activities are relatively likely to end after 9 PM.
- Time pressure/constraint effects are similar to those found for work and school tours. The main difference is that the overall time pressure effect is stronger, but the other effects are weaker, and there is evidence that people will try to space tours more evenly in the day.
- The PM peak was found to shift both earlier and later with high congestion.

Work-based activities and tours:

- Relative to work-related activities on subtours, escort, meal and shopping activities tend to start later and be of shorter duration.
- Social/recreation activities also tend to start later, while personal business activities are also of shorter duration.
- People try to leave consecutive windows both before and after the tour, meaning a tendency to “center” the subtour during the duration of the work activity.
- Intermediate stop activities and tours
- Compared to work-related activities, stops for escort, shopping, meal, and personal business activities all tend to be of shorter duration.
- Escort, shopping, social/recreation and personal business stops also tend to be somewhat later in the day. These results are very similar to those in the work-based subtour model.

Stops will tend to be shorter when there are more tours to be scheduled in the day, and also when are there more stops to be scheduled on the half tour.

3.2 Commercial Vehicle Travel

The commercial vehicle trip generation and distribution models maintain a standard "four-step" or "trip-based" model system approach. These models create trip matrices in two trip categories: 2 axle commercial vehicle trips, and 3+ axle commercial vehicle trips.

Commercial vehicle trip rates based on surveys of commercial vehicles in the Sacramento region[7], and surveys of commercial vehicle trip generation from the San Francisco Bay Area. Trip rates are shown in Table 3-3. Because of the relatively sparse data available for commercial vehicles, no "production/attraction" distinction is made.

Friction factors for 3-axle commercial vehicle trips were taken from the *Quick Response Freight Manual*[8]. For 2-axle trucks, 3+ commercial vehicle friction factors were derived from the Chicago Area Transportation Study factors, which compared reasonably well with the available local data. Friction factors are shown in Figure 3-7. Trip distribution was calculated using congested midday travel times, using a simple gravity model.

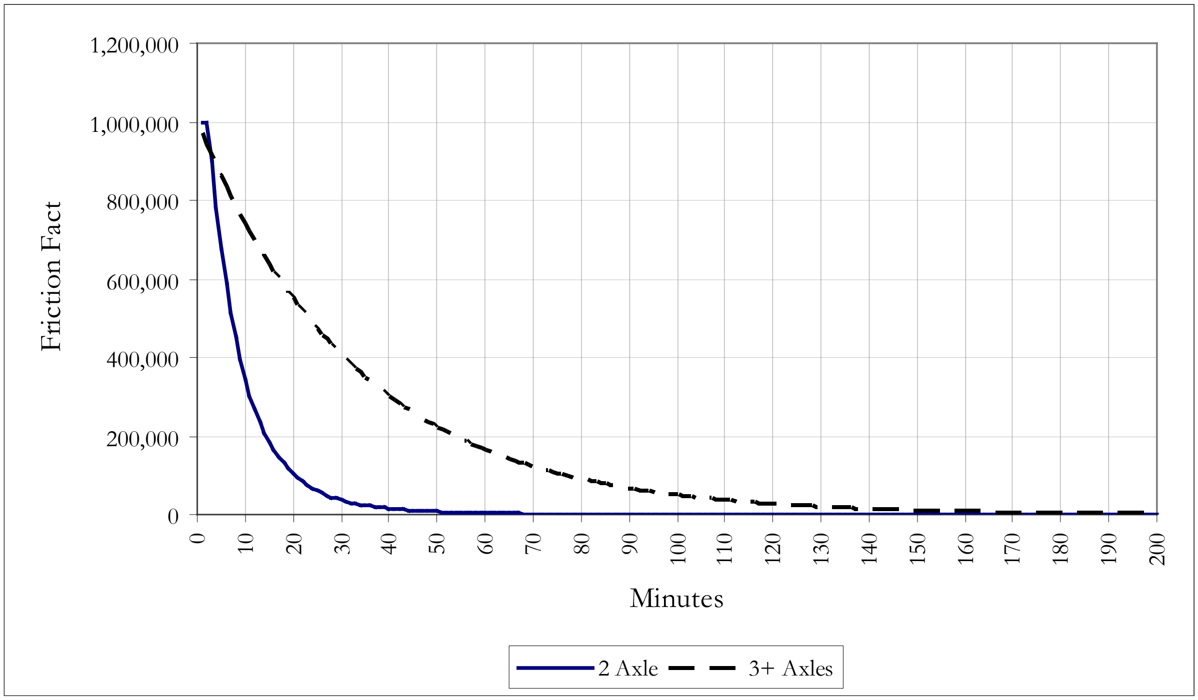
Because no "production/attraction" distinction is made in trip generation, all trip interchanges by time period are forced to be symmetrical in SACSIM, and time-of-travel proportions are applied as flat factors. Table 3-4 shows the time-of-travel factors used.

Table 3-3 Commercial Vehicle Trip Rates

Variable	2-Axles	3+ Axles
Household		
Single Family	0.28	0.003
MF 2-4	0.23	0.003
MF 5+	0.17	0.003
Employment		
Retail	0.68	0.045
Office	0.4	0.057
Medical	0.4	0.057
Education	0.4	0.057
Manufacture/Other	0.4	0.11
Source: SACOG 2020.		

[7] SACOG, "Commercial Vehicle Activity Survey Report: Phase One Project Report", July 23, 1998.
[8] FHWA (by Cambridge Systematics), "Quick Response Freight Manual", September 1996.

Figure 3-7 SACSIM Commercial Vehicle Friction Factors



Source: SACOG 2020.

Table 3-4 SACSIM Commercial Vehicle Times-of-Travel

SACSIM Time Period	2 Axle	3+ Axle
AM Hour 7:00-7:59	8%	10%
AM Hour 8:00-8:59	8%	10%
AM Hour 9:00-9:59	4%	3%
Midday (10:00-14:59)	38%	30%
PM Hour (15:00-15:59)	5%	3%
PM Hour (16:00-16:59)	5%	3%
PM Hour (17:00-17:59)	5%	3%
Evening (18:00-19:59)	9%	12%
Night (20:00-6:59)	21%	27%

Source: SACOG 2020.

3.3 External Travel

DAYSIM simulates the activities of households located within the Sacramento region, for their travel ***within the region***. The activities simulated must also be located within the region, since the simulation uses employment and travel data available only within the region. The submodels and processes described here predict the trips entering and exiting the region, which must be included for complete traffic prediction. DAYSIM also uses the predicted external trips to adjust its own predictions to account for external travel, including regional residents who may work or do other activities outside the region, as well as the effect of outside residents who take jobs within the region. These submodels and processes are based on customary aggregate trip generation and distribution models, producing person- and vehicle-trip matrices, at a traffic analysis zone (TAZ) level, not parcel.

Some definitions of common terms from traditional aggregate modeling applicable to these external models include:

- *Gateways*--TAZ's representing the areas outside of the SACOG region, connected to highways exiting or entering the region are called "gateways". Typically, each exiting highway is represented as a gateway TAZ, but some groups of highways that converge to practically the same external place share a single TAZ. Table 3-5 lists the SACSIM gateways. Important to note, SACSIM gateways representing roadways outside the region.
- *Gateway Production*--Source of travel demand located outside the SACOG region, but with travel taking it into the region. A household located outside the region, but with household members traveling to the SACOG region to work, shop, etc., would generate some number of gateway productions, which would be located at the gateway zone through which they entered or exited the region.
- *Gateway Attraction*—A location outside the SACOG region, but visited by a SACOG resident for work, shop, etc. would generate some number of gateway attractions, which would be located at the gateway through which the resident exited and re-entered the region.
- *Internal-Internal (I-I)Trips*--Describes trips which have both origin and destination within the region. All household based I-I trips are modeled by DAYSIM (for most normal household activities), and the internal passenger portion of the airport passenger ground access submodel. The commercial vehicle submodel includes the I-I truck trips.
- *Internal-External (I-X) Trips*--Describes a trip which is produced within the region, and attracted to a location outside the region, regardless of the actual direction of travel. A tour (round trip) of an area resident to San Francisco and back is considered two I-X trips. Full understanding of this concept of directionality of trip requires understanding of the difference between a "production" end of a trip, and the "attraction" end of the trip:
    - For all home-based trips, the production end of the trip is the home end. E.g., for a commute trip, the worker's home is the production end.
    - For all home-based trips, the attraction end of the trip is the non-home end. E.g., for a commute trip, the worker's place of work is the attraction end.
    - For non-home-based trips, the difference between production and attraction is somewhat arbitrary, and is assigned by convention. E.g., for work-based trips, the work end of the trip is designated the production, and the other end is the attraction.

- *External-Internal (X-I) Trips--D*escribes a trip produced outside the SACOG region, and attracted within the region, regardless of the actual direction of travel.
- *Through (X-X)Trips*--A trip entering the region through one gateway, passing through the region without stopping, and exiting through another gateway is an X-X trip.
- *Trip Purposes*--External trips are processed in five trip purposes, corresponding to the activities judged most productive of external travel: Work (or worker-flow), personal business, shopping, social-recreational, and airport passenger ground access. Other trip purposes used in DAYSIM (school, escort, and meal activities) are omitted.

All external travel is exogenous (i.e. determined outside the context of the model, and manually set by SACOG as a fixed scenario variable for both the base year and the forecast years) to some degree. I-X and X-I travel is “semi-exogenous”, in that the external gateway levels of activity are exogenously set, but the internal levels and locations of activity are modeled to some degree along with other internal activities. X-X travel is exogenous, outside of vehicle trip assignment, where the impact of through trips on capacity affect the level-of-service for internally modeled trips, and I-X and X-I trips.

Table 3-5 SACSIM Gateways

TAZ[1] No.	Gateway Roadway	Segment	Gateway Representation
1	SR-99 N	Sutter-Butte CL	Chico/Butte Co., via SR 99
2	SR-70 N	Yuba-Butte CL	Chico/Butte Co., via SR 70
3	E20/Marysville Rd NE	W. of SR 49/Yuba-Nevada CL	Nevada Co., via Marysville Rd.
4	SR-20 NE	Yuba-Nevada CL	Nevada Co., via SR 20 (from Yuba Co.)
5	SR-49 NE	Placer-Nevada CL	Nevada Co., via SR 49 (from Placer Co.)
6	I-80 NE	E. of Yuba Gap	North Lake Tahoe Basin to east of region, via I-80
7	SR 174 NE	Placer-Nevada CL	Nevada Co., via SR 174 (from Colfax)
8	SR 20 NE	Placer-Nevada CL	Nevada Co., via SR 20 (from Placer Co.)
9	Omo Ranch Road E	N. of SR-88	Amador Co., via Omo Ranch Rd (from S. Central El Dorado Co.)
10	US-50 E	Btwn. Ice House Rd & Echo Lake	South Lake Tahoe Basin, via US50
13	SR 16, 49 East	Sacramento-Amador CL	Amador Co., via SR 16 and 49
15	SR-99 S	Sacramento-San Joaquin CL	San Joaquin Co. and Central Valley, via SR 99
16	Lincoln Road S	Sacramento-San Joaquin CL	San Joaquin Co., via Lincoln Rd.
17	Franklin Road S	Sacramento-San Joaquin CL	San Joaquin Co., via Franklin Rd.
18	I-5 S	Sacramento-San Joaquin CL	San Joaquin Co. and Central Valley, via I-5
19	SR-160 S	S. of SR-12	E.Solano Co., N.Contra Costa Co., N.San Joaquin Co.
20	CR-95A	Yolo-Solano CL	N.Solano Co.
21	CR-104/Mace Blvd. SW	S. of CR-32D/Montgomery	N.Solano Co.
22	I-80 W./I-505 S.	W. of I-505	Solano Co. and Greater SF Bay Area
23	SR-128 W	Yolo-Solano CL	Solano and Napa Counties
24	Putah Creek Rd. W	W. of Winters Rd. Bridge	N.Solano Co.
25	SR-12 SE	E. of SR-160	NW.San Joaquin Co.
26	SR-12 SW	W. of SR-160	E.Solano Co.
27	SR 16	Yolo-Colusa CL	Colusa and Lake Co.
28	I-5 N	Yolo-Colusa CL	Colusa Co. and N.Sacramento Valley, Redding etc. via I-5
29	SR 45	Sutter-Colusa CL	Colusa Co.
30	SR-20 NW	Sutter-Colusa CL	Colusa Co. and N.Sacramento Valley, Redding etc., via SR 20

1. TAZs 11,12,14 are currently left blank and not used.

Source: SACOG 2020.

Trip Generation for I-X and X-I Travel

Trip generation of the gateway TAZs is an exogenous input consisting of person trips for gateway productions (i.e. trips produced outside the region, but traveling to attractions within the region) and for gateway attractions (i.e. trips produced within the region, but attracted to locations outside the region, as represented by the gateway zones). External trip purposes are:

- Work
- Personal Business
- Shopping
- Social-Recreational
- Commercial Vehicle (2 Axle)
- Commercial Vehicle (3+ Axle)
- Airport Passenger

Table 3-6 and Table 3-7 provide the exogenously set worker flow, home-based non-work and commercial vehicle trip ends. The worker flows, home-based non-work and commercial vehicle trips were based off previous version of SACSIM. The file was originated by using Census Journey-to-Work statistics (to set worker flows at each gateway), Caltrans truck volume counts (to set commercial vehicle volumes), with the other trip purposes set as "residuals" which made up the difference between the observed vehicle volumes at each gateway and that portion of the vehicle volume accounted for by worker flows and commercial vehicles. Home-based school trips, escort and meal trips are such a small part of gateway travel that they are omitted in SACSIM.

Table 3-6 SACSIM19 Year 2016 External Gateway Demand (Part 1 of 2)

Gate-way No.	Gateway Desc.	Worker Flows X-I (P's)	Worker Flows I-X (A's)	Pers.Bus. Trip Ends X-I (P's)	Pers.Bus. Trip Ends I-X (A's)	Shop Trip Ends X-I (P's)	Shop Trip Ends I-X (A's)	Soc./Rec. Trip Ends X-I (P's)	Soc./Rec. Trip Ends I-X (A's)
1	SR-99 N	1,792	2,422	2,005	1,337	2,415	1,610	2,415	1,610
2	SR-70 N	1,467	1981	1,632	1,632	1,010	1515	2,070	1,380
3	E20/Marysville Rd NE	0	0	125	125	125	125	125	125
4	SR-20 NE	0	0	1027	1,027	303	708	1,172	502
5	SR-49 NE	4,345	5,992	3,116	3,116	3,116	3,116	3,116	3,116
6	I-80 NE	1380	1,902	1,862	1,862	3,944	1,690	1,602	3,738
7	SR 174 NE	483	666	615	615	615	615	615	615
8	SR 20 NE	0	0	431	431	374	374	492	738
9	Omo Ranch Road E	0	0	255	255	255	255	255	255
10	US-50 E	690	951	1128	1,128	588	1,371	967	2,256
13	SR 16, 49 East	622	1,380	1,262	1,262	1,619	1,619	1,574	1,574
15	SR-99 S	7,200	6,986	5,242	5,242	6,889	10,334	6,028	11,195
16	Lincoln Road S	720	699	677	677	677	677	677	677
17	Franklin Road S	0	0	167	167	167	167	167	167
18	I-5 S	5,039	4,890	5,289	3,526	9,437	4,044	3,526	5,289
19	SR-160 S	1,440	1,397	985	985	985	985	985	985
20	CR-95A	0	0	76	76	58	134	78	78
21	CR-104/Mace Bl. SW	0	0	246	246	246	246	246	246
22	I-80 W	37,649	22,837	12,783	12,783	18,609	18,609	17,152	17,152
23	SR-128 W	0	0	268	268	430	107	368	859
24	Putah Creek Rd. W	0	0	28	28	28	28	43	43
25	SR-12 SE	0	0	313	580	395	734	461	461
26	SR-12 SW	768	466	1271	1271	1230	1230	1554	1554
27	SR 16	0	0	83	45	110	74	78	116
28	I-5 N	1,219	1,352	2,595	1,730	3,285	1408	1,612	1,612
29	SR 45	0	0	119	119	129	129	89	89
30	SR-20 NW	25	28	976	976	1,059	1059	728	728

Source: SACOG 2020.

Table 3-7 SACSIM19 Year 2016 External Gateway (Part 2 of 2)

RAD	Gateway No. / TAZ	Gateway Desc.	Commercial Vehicle Trip Ends	
			2 Axle	3+ Axle
97	1	SR-99 N	194	472
97	2	SR-70 N	214	382
97	3	E20/Marysville Rd NE	50	25
97	4	SR-20 NE	1260	1030
97	5	SR-49 NE	1370	835
97	6	I-80 NE	2,022	2,286
97	7	SR 174 NE	64	182
97	8	SR 20 NE	160	180
97	9	Omo Ranch Road E	168	284
97	10	US-50 E	420	310
97	13	SR 16, 49 East	438	444
97	15	SR-99 S	684	4667
97	16	Lincoln Road S	0	0
97	17	Franklin Road S	0	0
97	18	I-5 S	460	5,005
97	19	SR-160 S	252	476
97	20	CR-95A	0	0
97	21	CR-104/Mace Blvd. SW	0	0
97	22	I-80 W	3,826	2,538
97	23	SR-128 W	100	50
97	24	Putah Creek Rd. W	0	0
97	25	SR-12 SE	356	528
97	26	SR-12 SW	456	478
97	27	SR 16	24	62
97	28	I-5 N	2,688	3,419
97	29	SR 45	26	113
97	30	SR-20 NW	622	311

Source: SACOG 2020.

3.3.1 Internal Trip Generation for External Work Travel Model

The internal productions are employed residents who work outside the region. These are computed from the household marginals database, counting 1 employed resident per 1-worker household, 2 per 2-worker household, and 3.5 per household with 3 or more workers. The internal attractions are jobs held by workers residing outside the region, aggregated into zones (TAZs) from the parcel database. Both internal productions and attractions are scaled in total to balance to the external productions and attractions in the gateway file described above and shown in Table 3-8 and Table 3-9.

3.3.2 Internal Trip Generation for External Non-Work Travel Model

As discussed below, the non-work external trip distribution model only distributes I-X and X-I trips; only the gateways have "trip generation" in the customary sense. But the probability that a gateway trip is distributed to a particular internal zone is based on both its proximity to the gateway, and to a composite measure of the zone's "size". This composite measure of size is the exponentiated "size variables" coefficients, times the size function scale. Since the composite size function is not used as a number of trips or other constraint, its scale is arbitrary. The actual number of external trips distributed to any given zone is not known until external distribution, since that would depend on proximity to gateways.

3.3.3 Internal Trip Generation for Commercial and Airport Passenger Trips

Commercial vehicle trip generation (and distribution) is fundamentally different than home-based travel in SACSIM, since the submodel is entirely independent of DAYSIM. Exogenous gateway trips are appended to the internally generated trip ends, as described in the previous chapter. Airport passenger trips from the external gateways do not require internal attractions, since the airport is the sole generator of the trips.

Table 3-8 Relative Attraction Rates for External Trip Distribution

Size Variable	Measure	Personal Business	Shopping	Social-Recreational
Educational	employment	0.260	0	0.213
Restaurant	employment	0.107	0.136	0.351
Government	employment	0.286	0	0.112
Office	employment	0.324	0.022	0.146
Other	employment	0	0	0.095
Retail	employment	0.244	1.000	0.142
Service	employment	0.538	0.088	1.000
Medical	employment	1.000	0	0.467
Industrial	employment	0.063	0	0
Households	households	0.035	0	0.092
University	enrollment	0	0	0.266
K-12 School	enrollment	0.113	0	0.173

Source: Bowman and Bradley, SACSIM Technical Memo 8, Usual Location and Tour Destination Models, 2005

3.3.4 Trip Distribution for I-X and X-I Travel

SACSIM calculates a doubly-constrained zone-to-zone gravity model of worker flows, including I-I, I-X, and X-I trips (but not through trips). The I-I trips are then disregarded, and the I-X and X-I trips retained. Additionally, the I-X and X-I worker flows deduct from the parcel files (for internal attractions—jobs) and from the representative population file (for internal productions—workers).

Since DAYSIM's non-work destination choice models do not constrain the numbers of trips attracted to activities, a singly-constrained distribution model is applicable for external trips. For I-X trips, the gateway attractions are constrained, since they are derived from gateway traffic counts or forecasts and any available interregional travel surveys. There is no constraint on the amount or percentage of trips produced by internal zones to go to external attractions. For X-I trips, the gateway productions are constrained, and there is no constraint on the internal zones' trips that go external. For each trip purpose, I-X and X-I trips are distributed separately. Attraction rates for this process are shown in Table 3-8.

3.3.5 Friction Factors and Deterrence for Work Trips

The deterrence function for worker flows was estimated by iteratively fitting trip length frequency of observed home-based work trips in the 2000 household survey. After applying the gravity model with a previous estimate of the deterrence function, a new one is first numerically estimated by multiplying values at each trip length increment by the ratio of observed to modeled trip frequency. Then the parameters of a rational function (quotient of two polynomials) are estimated to best fit the numerical function to a log-likelihood objective (analogous to that used to fit logit choice models). After iterating this fitting procedure until reasonable convergence, this function is obtained:

$$f(t) = \exp\left(\frac{-0.00421t^3 - 0.106t^2 + 0.201t}{1 + 0.0425t^2} \right)$$

This function is applied as a lookup table in file “sacfftpp.txt,” rather than coded algebraically.

3.3.6 Friction Factors and Deterrence for Non-Work Purposes

The deterrence function for non-work trips is a composite from parameters in the tour-destination and mode choice models, as listed below in Table 3-9 and Table 3-10.

The deterrence function is the exponential of a parameter times the travel time, in the manner of a logit choice model. The composite parameters are calculated from the above parameters (and an assumption of 50 mph speed). The deterrence function is shown in Table 3-10.

Table 3-9 DAYSIM Factors Utilized for External Trip Deterrence

Parameter	Personal Business	Shop	Social-Recreation
Non-Work Non-School Tour Destination			
Mode Choice Logsum	1	1	1
1-way drive distance, 10+ miles (10s of mi)	-0.7635	-0.8238	-0.4468
Aggregate mode-dest. LogSum at dest.	0.0206	0.1892	n/a
Home-Based Other Tour Mode Choice			
In-vehicle time (min)	-0.025	-0.025	-0.025
Mode nesting parameter	0.73	0.73	0.73
Simplified Mode Choice for Calculating Aggregate Logsums			
In-vehicle time (min)	-0.02	-0.025	n/a

Source: SACOG 2020.
Based on Bowman, John L. and Bradley, Mark A. "Technical Memorandum Number 8: Usual Location and Tour Destination Models", October 28, 2005, and on draft documentation provided by DKS Associates.

Table 3-10 Computation of External Deterrence Factors

Personal Business: -0.0823 = -0.025*0.73 + -0.7635/10mi * 50mi/60min + -0.020*0.0206
Shop -0.0916 = -0.025*0.73 + -0.8238/10mi * 50mi/60min + -0.025*0.1892
Social-Recreational -0.0555 = -0.025*0.73 + -0.4468/10mi * 50mi/60min
Source: SACOG 2020. Based on draft documentation provided by DKS Associates.

3.3.7 Trip Distribution for I-X and X-I Commercial Vehicle and Airport Trips

Commercial vehicle trips are generated and distributed independent of DAYSIM. Trip distribution for all trips is treated through a gravity model as described in the previous chapter. Airport trip distribution is trivial, because of all external airport passenger trips that are to or from the airport.

3.3.8 Mode Split and Time-of-Travel for I-X and X-I Travel

External trips are allocated to vehicle trip modes using flat person-to-vehicle trip factors. The factors are shown in Table 3-11.

Time-of-travel for I-X and X-I trips were also allocated to the nice time periods using fixed factors. Table 3-12 shows the factors used.

Table 3-11 Mode Split Factors for I-X and X-I Travel

Purpose	Mode			
Household-Generated Travel[1]				
	Drive Alone	2 Person Carpool	3+ Person Carpool	Total
Work	89.0%	8.5%	2.5%	100.0%
Personal Business	54.0%	29.0%	17.0%	100.0%
Shop	45.0%	40.0%	15.0%	100.0%
Social Recreational	29.0%	31.0%	40.0%	100.0%
Airport Passenger Ground Access[2]				
	Drive/Park	Drop Off	Van/Shuttle	Total
Airport	50.3%	43.9%	5.8%	100.0%

Source: SACOG 2020.

[1] Based on 2000 SACOG Household Survey data, adapted to SACSIM11 external trip purposed by DKS Associates.

[2] Based on 2002 airport passenger survey, adapted to external passengers by SACOG.

Table 3-12 Time-of-Travel for I-X and X-I Travel

	Purpose									
	Production > Attraction					Attraction > Production				
Demand Time Period	Pers. Bus.	Shopping	Soc./ Rec.	Work	Airport	Pers. Bus.	Shopping	Soc./ Rec.	Work	Airport
AM 7-8	4.2%	2.0%	2.8%	13.8%	3.0%	0.2%	0.1%	0.2%	0.2%	0.3%
AM 8-9	6.6%	2.0%	3.3%	7.8%	2.7%	0.1%	0.3%	0.1%	0.3%	2.0%
AM 9-10	7.8%	4.0%	2.5%	2.9%	4.7%	0.7%	0.3%	0.6%	0.3%	3.0%
MD 10-15	24.6%	19.5%	14.0%	3.7%	15.6%	12.9%	12.4%	6.1%	2.8%	16.1%
PM 15-16	2.3%	3.7%	2.9%	0.4%	2.7%	3.5%	7.9%	2.2%	3.3%	2.7%
PM 16-17	2.3%	3.6%	3.0%	0.5%	3.0%	5.0%	7.2%	3.7%	5.9%	2.7%
PM 17-18	2.7%	3.6%	5.4%	0.5%	2.4%	5.5%	8.2%	4.2%	12.9%	3.4%
EV 18-20	2.0%	2.0%	10.3%	0.4%	5.1%	7.8%	12.5%	7.8%	19.4%	6.0%
NI 20-6	3.9%	2.6%	5.4%	18.3%	10.9%	7.9%	8.0%	25.6%	6.5%	14.0%

Source: SACOG 2020.

3.3.9 Through Trips for X-X Travel

Through trips are a completely exogenous model input, which are read in directly from a prepared through trips file. A portion of gateway trips are assigned to though travel, meaning vehicles that start from and end outside of the SACOG region (XX). Caltrans 2016 3+ Axle and 2+ Axle truck volumes, total vehicle traffic counts at each gateway, and CTPP county to county worker flows are all used to estimate both the passenger vehicle and commercial vehicle through travel model input file.

3.4 Airport Passenger Ground Access Model

3.4.1 Introduction

The airport passenger ground access model is actually a system of models of trip generation, trip distribution, and mode choice, which forecasts auto, transit, taxi, and shuttle van travel of air travel passengers using Sacramento International Airport, as well as return trips for picked-up and dropped-off passengers. The model also includes as an exogenous input estimates of passengers traveling to the airport from origins outside the SACOG region. The model does not include travel by employees of the airport, or airport-using or airport-serving businesses, which are represented by DAYSIM and commercial vehicle models.

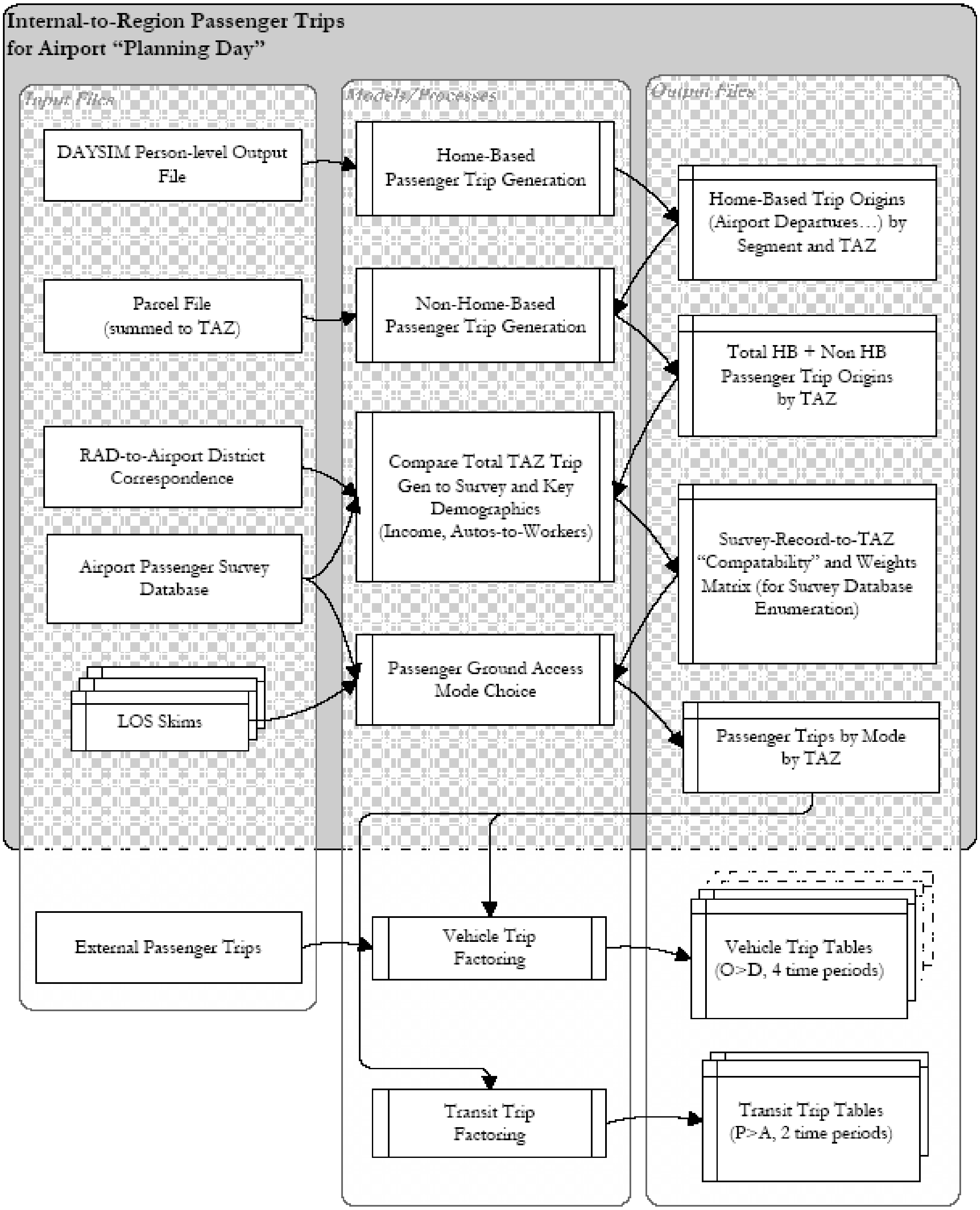
This airport trip model application consists of five main components:

- Trip generation for SACOG (internal) passengers;
- Association of generated trips to representative survey trips, for use in computing survey expansion factors for internal passengers;
- Mode choice for internal passengers;
- Direct estimate of external (i.e. outside SACOG) passengers;
- Time-of-travel and vehicle trip factoring for auto mode trips; and
- Time-of-travel and person trip factoring for transit trips.

The airport passenger ground access model is calibrated to represent activity for a “planning day” at the airport, which is defined as an average day from the peak month of passenger activity at the airport[9]. Figure 3-8 illustrates the major model components and flow.

[9] PB Aviation, “Sacramento International Airport Master Plan Study”, March 8, 2001.

Figure 3-8 Airport Passenger Ground Access Model



Source: SACOG 2020, based on work by DKS Associates (2008).

3.4.2 Trip Generation for Internal Passengers

SACSIM airport internal passenger trip generation was initially built from findings from the Downtown-Natomas Airport Study, 2003 (DNA). The DNA corridor analysis did not directly use trip generation by each model zone (TAZ). Instead, it used survey observation data, with each record's weight factor "grown" proportionally to the aggregate trip generation in its RAD (Regional Analysis District, of which there are approximately 58 in the Sacramento region). This approach was modified for use in SACSIM, to allow for "on-the-fly" enumeration of the survey based on the population and employment in each TAZ.

This application uses the same trip generation factors for non-home-based trips: 0.006 per non-retail employee, except the Downtown Sacramento RAD, with 0.010 per non-retail employee.

But for home-based trips, trip generation factors are applied to household segmentations by income as shown in Table 3-13:

Table 3-13 Home-Based Airport Trip Generation based on Household Income (Enplaning Airport Passengers)

Household Income (c.2000 dollars)	Estimated Enplaning Passengers per Household
Under $15k	0.0060
$15k to 35k	0.0068
$35k to 50k	0.0133
$50k to 75k	0.0156
$75k or more	0.0269

Source: SACOG 2020.

Home-based trip generation rates apply to five household income strata as described above. These generated trips are then saved in four household categories used by the mode choice model, which can be considered a two-dimensional array of (1) whether the household income is over $50,000, and (2) whether there are as many autos available as persons in the household.

A concurrent process adjusts the survey records' expansion factors factored to match the respective grand totals of home-based and non-home-based trips. The Tripgen program is ideally suited to do this concurrently, treating each survey record's expansion factors as "attractions" flagged into either "purpose 1" or "purpose 2," respectively. Normally the "control totals" of these two purposes are determined by zonal trip generation, and naturally grow when forecasting with regional growth.

3.4.3 External Passenger Generation Rates from Population

To forecast SMF passenger demand outside the SACOG region within the SACSIM models, the full demographic detail used within the region is neither necessary nor appropriate. It would be appropriate and pragmatic to have simpler and more readily-forecast independent variables than income-stratified households and non-retail employment.

County populations were checked and found to be reasonably proportional to the preceding passenger demand estimates from detailed demographics. Non-retail employment is likewise reasonably proportional to county population. Proportionalities with respect to county population are significantly closer than to total households in county. Consequently, only one independent variable, population, is chosen for application of external airport passenger demand.

Table 3-14 shows airport passenger generation rates for external (non-SACOG) areas. Table 3-14's rates count both arrivals and departures, unlike above tables that count departures only. Table 3-14 shows passenger generation rates split into the demographic strata needed by the airport access mode choice model, obtained by dividing the generation calculated for each particular stratum, by population.

Table 3-14 Two-Way SMF External Passenger Generation Rates

Trip Category	Income	Cars per Person	2-Way Rate per Population
Home-Based	Less than $50k	As many or more	0.00090
Home-Based	Less than $50k	Fewer	0.00039
Home-Based	More than $50k	As many or more	0.00179
Home-Based	More than $50k	Fewer	0.00022
Non Home-Based			0.00095

Source: SACOG 2020. For External Areas Only

3.4.4 Enumeration of Passenger Survey Database

This model application phase calculates appropriate weights for passenger survey observations to represent a given zone's generated trips for the sake of mode choice, so that the mode choice model can be applied as a modified sample enumeration procedure. Conversely, this phase can be considered to split or spread each survey record across several zones, instead of its one observed zone. (This phase is analogous to trip distribution, although, strictly speaking, the airport trip generation described above is also trip distribution, since the trips are attracted to one zone, the airport.) The general objective is that each zone's generated trips would be represented by "compatible" survey records, that is, compatible in demographics and geography, as well as matching in being home-based or non-home-based. (This phase was not needed in the DNA Corridor Study, in which survey records "stayed in their zones" and were growth-factored for forecasting.)

This association is represented as two matrices, one for home-based and the other for non-home-based trips; rows represent actual TAZs and columns represent survey records. The cells are zero if not "compatible," and have a spread weight value otherwise. The row-sums for home-based trips must match the zonal home-based trip generation, and likewise the row-sums for non-home-based trips must match non-home-based trip generation. Column-sums are proportional to the base year expansion factor of the respective survey observation, but are scaled to the same grand total as the trip generation.

Ideally there would be several survey observations, of each demographic cross-classified category (persons by income by autos), that could be associated with each demographic category in each RAD. But there aren't enough survey cases to do this. Instead, we must combine RADs into yet larger districts just to provide home-based and non-home-based survey observations to all zones. Some cross-classified cells have few or no cases at all in the survey. Therefore, the more demographic variables of the modeled households we wish to match to representative survey records, the larger the districts must be for the computation to be possible.

For home-based trips, the present application chooses survey records for each trip in the same one of 8 regional districts, matching whether household income is less than $50,000 (a mode choice dummy variable), and whether there is a shortage of autos per person (as defined for another mode choice dummy variable). This could be conversely be thought of as spreading each survey record across all zones in the same of 8 districts, proportionally to the airport trip generation by households of the same of two income classes and two autos-per-person classes. This particular compatibility scheme is subject to change as validation and forecasting issues are considered.

For non-home-based trips, this application chooses all survey records in the same one of the 8 regional districts.

The actual mechanism to achieve these associations or spreads, subject to row and column constraints, is iterative proportional factoring, implemented in the TP+ Fratar program. The constraint vectors are the trip generation results (home-based and non-home-based zonal demand as productions, factored survey weights as attractions). The input matrix to the home-based process is the compatible-class trip generation of the zone; the input matrix for the non-home-based process is simply a 1 if in the same of 8 districts, and a 0 otherwise. The result matrices are the number of trips generated by the *i* zone, associated with survey record number *j* (or conversely, the number of trips of survey record *j* spread to zone *i*.)

3.4.5 Ground Access Mode Choice for Internal Passengers

The mode choice model used a two-by-two segmentation of air passengers: resident vs. non-resident, and business vs. other. The model was based on highway and transit network level-of-service measures obtained from a regional travel demand model. The model is applied by enumerating (i.e. expanding) the airport survey dataset according to residential growth (for home- or residence- based trips) or non-retail employment (for non-home-based trips).

The mode choice model is taken directly from an application spreadsheet used in the DNA Corridor Study. It is multinomial logit, with these seven alternatives:

- Auto Drop-Off
- Drive-and-park at airport (for residents)
- Return rental car at airport (for visitors)
- Taxi
- Van
- Transit Walk-Access
- Transit Drive-Access
- Transit Drop-Off Access

Table 3-15 shows the coefficients of this logit model. This paper does not report the numerous details in the definitions of the variables. Demographic variables only apply to home-based trips by residents.

This model is applied to the matrix of weighted trips computed in the preceding phase, in which the *i* zone is the zone of trip generation, and the *j* zone is the survey record number. It is thus a modified form of sample enumeration, with the survey records "spread" among numerous zones, instead of kept in their original zones. The actual output result of this application is the row sums of the seven modal matrices, that is, the aggregation of them by zone, collapsing all survey records. Reports aggregating modal trips by the segment (travelers, resident business, resident leisure, visitor business, and visitor leisure) are also provided; reports aggregating by any survey data variable can be generated.

Table 3-15 Airport Ground Access Mode Choice Logit Model Coefficients

		Passenger Market Segment			
Coeff No.	Variable	1 Resident/ Business	2 Resident/ Leisure	3 Visitor/ Business	4 Visitor Leisure
Mode Constants					
1	Auto Drop-Off	0	0	0	0
2	Auto-Park(Res)/Return Rental(Vis)	0.5303	0.5303	0.106	-1.1104
3	Taxi	-1.5858	-2.1639	-0.3116	-1.8789
4	Van	-1.0737	-0.5921	-0.4271	-1.2767
5	Transit-Walk Access	0.5281	0.5281	0.705	0.705
6	Transit-Drive Access	0.1097	0.1097	-0.5949	-0.5949
7	Transit-Drop-Off Access	-0.2191	-0.2191	0.3275	0.3275
Demographic Variables					
8	Autos<Persons	-0.2494	-0.2494	0	0
12	1 Persons	-0.3995	0	0	0
13	3+ Persons	0	0.6422	0	0
14	Income<$50K	0	0.7416	0	0
Cost Variables					
15	Parking Cost	-0.0155	-0.0155	0	0
16	Van/Taxi Cost	-0.0191	-0.0003	-0.0191	-0.0003
17	Transit Cost	-0.0422	-0.0422	-0.0422	-0.0422
Travel Time/Level-of-Service Variables					
18	Main Mode Time	-0.0095	-0.0095	-0.0095	-0.0095
19	Walk and Transfer Time	-0.0518	-0.0518	-0.0518	-0.0518
20	Drive Access Time	-0.0079	-0.0079	-0.0079	-0.0079
21	Chauffer Time	-0.0055	-0.0003	-0.0055	-0.0003
22	First Transfer	0	0	0	0
23	Second+ Transfer	-0.845	-0.845	-0.845	-0.845
Airport Egress Variables					
24	Walk Egress Time	-0.0183	-0.0183	-0.0183	-0.0183
25	Walk Egress Dummy	-0.0916	-0.0916	-0.0916	-0.0916
26	Shuttle Egeress Time	-0.0053	-0.0053	-0.0053	-0.0053
27	Shuttle Egress Dummy	-0.0526	-0.0526	-0.0526	-0.0526
Other Variables					
28	Scale Factor for Utility	1.865	1.865	3.0869	3.0869

Source: SACOG 2020. Using values from November 2008.
Based on technical memorandum by Bowman, John L., Bradley, Mark A., and Griesenbeck, Bruce "Sacramento RT DNA Transit Access Mode Choice Model", July 3, 2002.

3.4.6 Updated Time-of-Day Distribution of Airport Access

No surveys or counts of trips entering or exiting the airport have been available that would yield time-of-day distributions of airport passenger arrivals or departures, either at the flight gate or on the road. An alternative basis is the time of day of aircraft arrivals and departures, assuming most flights are nearly full, and different-sized aircraft are scheduled consistently across the day.

Table 3-16 presents the approximate (shifted) distribution of passenger ground travel, in the nine time periods used in the updated SACSIM model system. (Arriving and departing percentages are both normalized to 50%.)

Table 3-16 Estimated Time-of-Day Distribution of Ground Access of SMF Airport Passengers

SACSIM Time Period	Percent Departing	Percent Arriving
AM Hour 7:00-7:59	3.0%	0.3%
AM Hour 8:00-8:59	2.7%	2.0%
AM Hour 9:00-9:59	4.7%	3.0%
Midday (10:00-14:59)	15.6%	16.1%
PM Hour (15:00-15:59)	2.7%	2.7%
PM Hour (16:00-16:59)	3.0%	2.7%
PM Hour (17:00-17:59)	2.4%	3.4%
Evening (18:00-19:59)	5.1%	6.0%
Night (20:00-6:59)	10.9%	14.0%

Source: SACOG 2020.

3.5 Vehicle Trip Table

3.5.1 Vehicle Trip Table Preparation and Assignment

This chapter documents the process of taking the various estimates of person trips and vehicle in different formats, creating origin-to-destination vehicle or passenger trip tables, and assigning those tables to highway or transit networks. The generic estimates of trips are:

- DAYSIM person trip segments, which includes person trip segments in origin-to-destination format, with one record per person trip, with mode and time of travel information on each trip record.
- Commercial vehicle trips which are daily, total flow of vehicle trips, split into number-of-axle classifications (2 axle and 3+ axle vehicles). The trips are in origin-to-destination form, with assumed symmetry of flows to and from origins and destinations.
- Airport passenger person trips, which are predicted as "half-round-trips" in production-to-attraction format, with the airport end being the attraction. The half-round-trip, P-to-A matrix is converted to a daily, both direction flow by transposing the P-to-A half-round trips, with symmetry of round trips assumed.
- IX and XI daily person trips, in production-to-attraction format.
- XX vehicle trips, in daily, both-direction, origin-destination format, with three tables: private autos and commercial vehicles (2 axle and 3+ axle combined).

Trip assignment to highway networks is made for nine demand periods using a conventional, TAZ-to-TAZ, origin-destination, static equilibrium assignment using Citilabs® TP+/HWYLOAD software.:

- 7-8 AM,
- 8-9 AM,
- 9-10 AM,
- Midday 10 AM-3 PM,
- 3-4 PM,
- 4-5PM,
- 5-6PM,
- Evening 6-8PM,
- Night Time 8PM-7AM

Transit passenger trips are assigned using Citilabs® Public Transport software, with trips in origin-to-destination format. Five demand periods are assigned:

- Period 1, spanning from 5:00am until 9:00am
- Period 2, from 9:00am until 3:00pm
- Period 3, from 3:00pm until 6:00pm
- Period 4, from 6:00pm until 8:00pm
- Period 5, from 8:00pm until 11:00pm

3.5.2 Trip Table Preparation

This process combines trips from DAYSIM, and the models of external, airport, and commercial vehicle trips into time periods for assignment to highway and transit networks. SACSIM19 is broken into nine time periods, for simplicity, performance, and establish unit-hour period durations for the entire day. Previous version of SACSIM broke out the two peak periods each cover three-hour periods. SACSIM19 separates these out into individual hours for a total of six separate trip tables during the peak periods. The midday period is five hours, Evening is two hours, and Night time (late evening/early morning) period is eleven hours.

Table 3-17 SACSIM Demand Period Definition

Time Period	Begin	End	Hours
7am	7:00	7:59	1
8am	8:00	8:59	1
9am	9:00	9:59	1
Mid-Day	10:00	14:59	5
3pm	15:00	15:59	1
4pm	16:00	16:59	1
5pm	17:00	17:59	1
Evening	18:00	19:59	2
Late Evening / Early Morning	20:00	6:59	3

3.5.2.1 DAYSIM Person Trip Segments

For highway assignable trip tables, DAYSIM auto person-trips are aggregated into TAZ-to-TAZ flows, stratified by mode, 3 person values-of-time (VOT) bins, and time period. This file is generated in O-to-D format, with arrival and departure time on each trip record, so none of the ordinary directionality conversion from P-to-A, or from daily to the demand period, is required.

Auto person-trips are already stratified by occupancy (drive alone, 2 person shared ride, and 3+ person shared ride) and VOT bins (high, medium, low), and each record is converted to a vehicle trip equivalent using the inverse of the average occupancy (i.e. 1.0 for drive alone, 0.5 for 2 person shared ride, and 0.3 for 3+ person shared ride). The values of time bins were updated to reflect latest traveler preference survey in the SACOG region conducted by RSG consultants. More information on actual threshold price points, distribution curves, and data collection can be found in *Appendix B, RSG Travel Demand Model Toll Enhancement Technical Memorandum, September 2018*.

In the DAYSIM trip output file, transit person-trips are distinguished by walk-access and drive-access, and the drive-access trips are distinguished by direction (drive-transit-walk versus walk-transit-drive). The transit drive-access trips from DAYSIM are generated in O-to-D format, without explicit reference to the location of the transition the between transit and auto. The Origin-to-Destination

(O-D) person trips were split and converted to Production-to-Attraction (P-A) format, then split into the two transit service periods.

A simple park-and-ride (also including kiss-and-ride) lot choice model in SACSIM19 splits these trips into separate auto and transit segments. The auto portion of the trip (e.g. from home to the park-and-ride lot, or from the park-and-ride lot home) is included with other vehicle trips in the highway assignment; the transit and walk from the last transit stop to the final destination (e.g. at the work end of a work tour), or the walk from the primary tour destination to the first transit stop on the return half-tour, is assigned as a passenger trip in the transit assignment. This process for transit drive-access trips will be discussed in greater detail below.

3.5.2.2 External Trips

The external models create partial matrices of daily person-trips between the gateways and the internal zones in P-to-A format. These are converted to vehicle trips split by occupancy and time of day to be included in the vehicle trip assignments. The auto mode split, directionality, and time-of-travel factors were presented earlier. No external transit, walk, or bike trips are predicted. Conversion of auto person-trips to vehicle trips is made using the same vehicle trip equivalent factors discussed above.

3.5.2.3 Commercial Vehicle Trips

Commercial vehicle, and exogenous through-trip matrices are also split by time of day for the vehicle trip assignments using the time-of-travel factors presented in Section 3.2. Commercial vehicle and through trips do not have any orientation of production and attraction defined, so they are split equally in both directions and split by time of day using the non-directional factors in presented in Section 3.2.

3.5.2.4 Airport Ground-Access Trips

Airport passenger trips are converted to vehicle trips, including the extra "return" trip required for pick-ups and drop-offs, within the airport mode choice computation module, because the traveling party-size is available then as a survey variable. Assumptions used in this process include the following rules:

- *Auto Drop*--One vehicle trip for pick-up or drop-off, plus the vehicle trip of the air traveler. If the air travel party size is 1 or 2, then it is assumed that 80% of such travelers are picked up or dropped off by one person, and 20% are by two persons. For larger air travel party sizes, this changes to 90% by one person, 10% by two. These assumptions are judgments, for lack of survey data. The pick-up or drop-off vehicle trip is stratified by occupancy (number of meeting persons), and the air-travelers' vehicle trip is stratified by its occupancy (number of meeting persons plus air travel party size).
- *Auto Park*--One vehicle trip per traveler, stratified by party size.

- *Taxi*--One and a half vehicle trips per traveler, one with the traveler, plus a judgmental assumption that half of such trips involve a "deadhead" taxi trip without a passenger. The "deadhead" trip is assumed single-occupant (the driver alone), and the regular trip's occupancy is the party size plus the driver.
- *Van*--One tenth of a vehicle trip per traveler.
- *Transit Drive and Transit Drop*--The same auto trip making and occupancy assumptions apply as with Auto Park and Auto Drop, including pick-up and drop-off trips. These trips are saved stratified into three matrices of daily auto trips as if to the airport, to be later "relocated" to a park-and-ride lot, and split by time and directionality. The transit part of each trip is also relocated to travel from the park-and-ride lot to the airport.

Time-of-travel factors presented in Section 3.5 were used to split the vehicle trips into the four demand periods for highway assignment. Transit passenger trips were converted to P-to-A format and split into the two transit demand periods (peak and off-peak) for assignment with the other transit passenger trips. Transit-drive access airport passenger trips are split into the drive portion (e.g. from home to park-and-ride, or from park-and-ride to home), and the transit portion in the same manner as non-airport transit-drive access trips, which will be discussed in greater detail below.

3.5.3 Vehicle Trip Assignment

Vehicle trip assignment in this model system uses a standard deterministic user equilibrium algorithm which iterates the Dijkstra tree-building "shortest paths" algorithm and a form of Frank-Wolfe or "conditional gradient" direction step size choice to blend the iteration volumes progressively closer to equilibrium. Ideal equilibrium achieves Wardrop's criterion, that no traveler can reduce travel time by shifting to another route. Each vehicle trip assignment solves the conditional equilibrium *for the given trips* during any iteration of the SACSIM19 system-equilibrium solution.

This application is a simultaneous multi-class assignment like past versions of SACSIM. However, SACSIM19 differs from past versions by expanding assignment routing classifications by path impedances by vehicle type/occupancy and VOT to determine preferences of path choice by class. A total of 15 combinations of VOT, vehicle type, and vehicle occupancy are grouped into the following 12 classes:

- Class 1: "LOW" VOT Single Occupancy Vehicle (SOV) & "LOW" VOT 2 Axle Commercial Vehicles (CV2)
- Class 2: "LOW" VOT 3+ Axle Commercial Vehicles (CV3+)
- Class 3: "LOW" VOT 2 Passenger Shared Occupancy Vehicle (S2)
- Class 4: "LOW" VOT 3+ Passenger Shared Occupancy Vehicle (S3+)
- Class 5: "MEDIUM" VOT Single Occupancy Vehicle (SOV) & "MEDIUM" VOT 2 Axle Commercial Vehicles (CV2)
- Class 6: "MEDIUM" VOT 3+ Axle Commercial Vehicles (CV3+)
- Class 7: "MEDIUM" VOT 2 Passenger Shared Occupancy Vehicle (S2)
- Class 8: "MEDIUM" VOT 3+ Passenger Shared Occupancy Vehicle (S3+)

- Class 9: “HIGH” VOT Single Occupancy Vehicle (SOV) & “HIGH” VOT 2 Axle Commercial Vehicles (CV2)
- Class 10: “HIGH” VOT 3+ Axle Commercial Vehicles (CV3+)
- Class 11: “HIGH” VOT 2 Passenger Shared Occupancy Vehicle (S2)
- Class 12: “HIGH” VOT 3+ Passenger Shared Occupancy Vehicle (S3+)

Previous SACSIM iterations also included a percentage of “Violators” and exempt SOV vehicles to use HOV lanes and a percentage of HOV prefer general purpose lanes. Since implementing the VOT bins already increases the class, thus significant assignment runtime, and is required for implanting roadway and mileage-based pricing functionality; violator HOV choice classifications were removed from SACSIM19 vehicle path choice.

Controls for the equilibrium assignment are set to and increasing number of maximum assignment iterations, and a decreasing relative gap. The “maximum assignment iterations” are a limit placed on the vehicle/highway assignment process for each time period assignment. “Relative gap” is a measure of the degree of closure or the decreasing difference in target measures for additional assignment iterations. In combination, maximum assignment iterations and relative gap function as an “either/or” criteria for ending a given time period assignment. The assignment ends if either the relative gap closure criteria is met (i.e. if the difference between the current assignment iteration and the last iteration is less than the relative gap criteria), or if the number of iterations reaches the maximum. “System iterations” are iterations of the entire model system, also known as “feedback loops”—system iteration and convergence is discussed in the following chapter. The settings for the equilibrium assignment criteria are shown in Table 3-18

Table 3-18 Equilibrium Assignment Closure Criteria

System Iteration	Maximum Assignment Iterations	Relative Gap
1	300	0.0006
2	300	0.0003
3	300	0.0002

Source: SACOG 2020.

3.5.3.1 Congestion Delay Functions

3.5.3.1.1 Conical Delay

SACSIM19 uses computed speed-flow curves, which are based on the conical delay function. Conical delay function has the form:

$$f(x) = E - A(1\text{-}VC) + (A(1\text{-}VC)^{2} + B^{2})^{0.5}$$

Where:

- VC = V/C ratio on a link;
- A = a user-specified coefficient; and
- B = (2A -1)/(2A -2)
- E = 2 - B

The attributes of this function which make it desirable for applications in travel demand model assignments are:

- *f*(x) is strictly increasing. This is necessary for convergence to a unique solution;
- *f*(0) = 1 and f(1) = 2. This ensures that free-flow travel times are uncongested, and congestion at capacity (i.e. V/C ratio = 1) doubles travel time for the link.
- The function does not require exponentiation, which results in computation time savings.

A modified form of the conical delay function was used for SACSIM:

$$T_C = T_O * \min\{E - A(1\text{-}Lx) + (A^2(1\text{-}Lx)^{2} + B^2)^{0.5}, \max(T_C)\}$$

The variables are the same as for the basic conical delay function, except:

- T_C =congested travel time
- T_O =”free flow” travel time
- L= VC ratio factor, adjusted so that TC=+/- 1.5 when VC=1.0
- $Max(T_C)$=M + N(VC)

3.5.3.1.2 Passenger Car Equivalents Conversion

Commercial vehicles are converted into passenger equivalent vehicles by for the delay function to more accurately reflect vehicle size impacts on congestion and delay estimations. Vehicles are used for the to calculate volume to capacity ration by:

- Passenger vehicles = 1

- Smaller commercial vehicles = 1.5
- Larger or 3+ axle commercial vehicles = 2.0

For this reason, V_1 or V_1T are considered passenger equivalent total volume and not recommend to be used to report total vehicle volumes. The subtotals volume classes after the assignment has been completed should be used to report to total vehicle volumes totals.

3.5.3.1.3 SACSIM Delay Formula Variables

Table 3-19 reports the variable values utilized for SACSIM. The A and B values were calibrated to allow for "softening" of the basic form. As mentioned above, the function itself was created to return a congestion factor of 2 when VC ratios equal 1. In test assignments, this resulted in erratic assignments with high link error. The optimal results were achieved when congestion factors were about 1.5 when VC ratios equal 1. A "soft ceiling" maximum was included in the function, to reasonably constrain the time factors, while still providing some positive slope to the curve. Table 3-20 provides a comparison of the current speed-flow functions

Table 3-19 Congestion Factor Variables and Values

	Variable					
	A	B	E	L	M	N
Class of Roadway	User Specified Conical Delay Coeff.	User Specified Conical Delay Coeff.	User Specified Conical Delay Coeff.	VC factor	Maximum constant at 2.2 V/C	Maximum coeff.
Freeway	6	1.1	0.9	0.88	9.1	0.5
Highway	5	1.125	0.875	0.86	8.3	0.0002
Arterial	4	1.167	0.833	0.83	6.4	0.0002

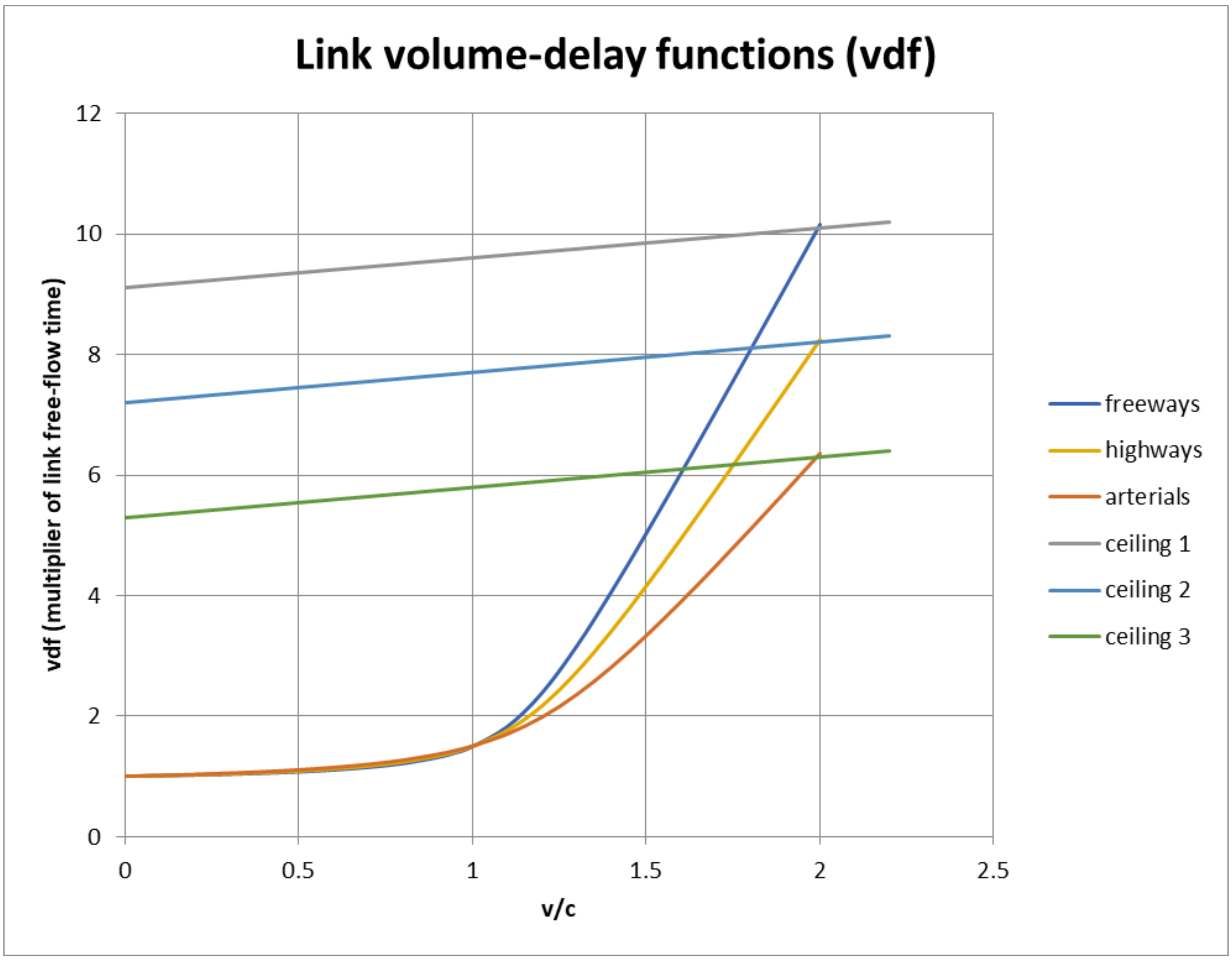
Source: SACOG 2020.

Table 3-20 Range of Congestion Factor Calculations

	Congestion Factor at VC =…					
Class of Roadway	**0.00**	**0.80**	**1.00**	**2.00**	**Max TF**	**Max. @ VC=…**
Freeway	1.00	1.21	1.49	10.15	11+	2.20
Highway	1.00	1.24	1.50	8.25	11+	2.20
Arterial	1.00	1.27	1.50	6.36	7+	2.20

Source: SACOG 2020.

Figure 3-9 SACSIM19 Link volume delay function



Source: SACOG 2020.

3.5.3.2 Traffic Flow Intensity Factors

The time periods of traffic assignment depend on vehicle trip tables factored by the directional time-of-day factors. Also needed is a factor, for each assignment period, relating the volume of traffic in that period, to the average flow rate in vehicles per hour. The "time-mean" definition of such an average is simply one divided by the number of hours. Instead of that, however, an average was preferred that represents the average intensity of traffic as experienced by the drivers, what may be termed a "vehicle-mean." Vehicle-mean traffic intensity rates were calculated using a summary, from the household travel survey, of vehicle-miles traveled grouped by 15-minute increments of the whole day. This formula estimated the "vehicle-mean" traffic intensity for AM and PM 3-hour periods and the off-peak period, summing for all 15-minute periods within the 3-hour periods:

$$\frac{\sum_1^n VMT^2}{(\sum_1^n VMT)^2}$$

Where *n* is the number of 15-minute periods within the multi-hour AM/PM peaks.

3.5.3.3 Metered On-Ramps

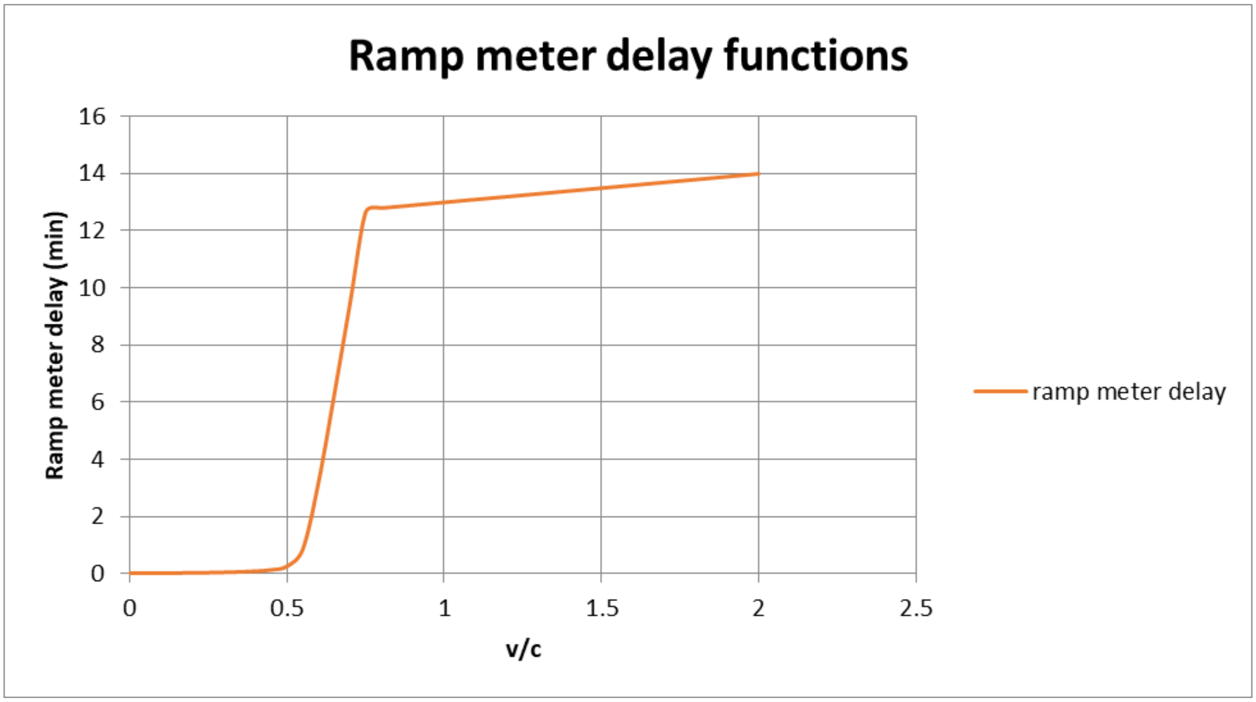
Migrating the traffic assignments to TP+ required a new way to operationalize HOV lanes and metered on-ramps. In the highway network, DELCURV identifies on-ramp links that restrict or "meter" flow entering a freeway at certain times of the day using special traffic signal systems at the on-ramp. Values of this code are:

- 0 = not a metered on-ramp (most links in the network)
- 1 = metered in the AM peak period (3 hours)
- 2 = metered in the PM peak period (3 hours)
- 3 = metered in both AM ad PM peak period (6 hours)
- 4 = metered in AM, Mid-Day, PM
- 5 = metered all 24 hours

The presence of ramp metering on freeway entrance ramps can significantly add to vehicular travel time for trips which utilize metered ramps, particularly when demand is near or exceeds ramp capacity. Therefore, a delay function was developed which estimates vehicular delay at metered ramps as a function of the volume-to-capacity (v/c) ratio.

The two key input factors are the distribution of demand over time and the vehicle discharge rate. For the assignment periods during the three hour peak AM and PM periods modeled, the relative distribution of demand was initially derived from the Caltrans/SACOG household travel surveys and travel time testing. The vehicle discharge rate was assumed to be 900 vehicles per lane per hour. By proportionally changing the three-hour demand, total delay over a three hour period was calculated as a function of three-hour v/c ratio. The delay curve was represented as a piecewise linear equation. Overriding this derived curve was a “soft ceiling” delay of 15 minutes, and a constantly increasing delay with respect to v/c ratio. Figure 3-10 shows the meter delay curve.

Figure 3-10 Ramp Meter Delay



3.5.3.4 Bypass Lanes for HOVs at Metered On-Ramps

At some metered on-ramps in the Sacramento region, special lanes for high-occupancy vehicles have been designated. These lanes are not controlled or otherwise delayed by the ramp-meter signal. The model network representation of these lanes consists of longitudinally-connected pairs of links parallel to the metered on-ramp link. (Two links instead of one are required because the network software permits only one link in a direction between the same pair of nodes.) The effect is that HOVs (and any other eligible vehicles) are not delayed by the ramp meter delays. The following codes are required on HOV links that bypass metered on-ramps:

- DELCURV = 0 (0 for all links except metered on-ramps)
- USECLASS 2 or 3 (for ramp meter bypass links, specify minimum occupancy requirement to use bypass)

3.6 Transit Assignment

3.6.1 Transit Path Building and Assignment

Transit path-building and assignment is performed in five time periods:

- Morning peak (start of service to 10:00AM)
- Midday period (10:00AM to 3:00PM)
- Afternoon peak (3:00PM to 6:00PM)
- Early Evening (6:00PM to 8:00PM)
- Night period (8:00PM to end of service)

Additionally, transit path-building and assignment is done in an origin-to-destination, direction format. SACSIM19 accomplishes this O-D assignment format by splitting the drive portion of drive access trips from the transit assignment, and assigning all trips as “walk-transit-walk”. The drive portion of path-building and assignment, between home and the park-and-ride lot, is accomplished through HWYLOAD and matrix processing, outside of PT.

3.6.2 Transit Background Network

The SACSIM19 PT implementation builds routes using transit lines and walk access links connecting them to each other and zone centroids. A background network is created on which transit lines run, and walk access is found. The background network is created from:

- Loaded highway networks corresponding to the five transit service periods, including centroid connectors, minus any dummy placeholder links used in different scenarios. This is the source of walking distance and traffic speeds.
- Reverse directions of one-way links in the highway network, for (1) walk access, and (2) enable two-way transit lines to use one-way streets without run failure.
- Exclusive transit links, given in a file manually prepared transit links file (“transit_links.csv”), for light rail and other transit-only links.
- Walk access links connecting the highway network to light rail stops (and other services on exclusive ROW), given in in a manually-prepared station links file (“station_links.csv”).
- A manually prepared park-and-ride file (“_pnr.dbf”) with lot sizes and connections to transit stops from, to provide a shorter walk distance from park-and-ride zone than the centroid connector.

Before PT builds complete routes via transit, it prepares walk access links using the shortest path between nodes on the compiled background network. In output files, however, these links appear as direct connections between nodes, skipping the intermediate nodes.

3.6.3 Transit System Coding Structure

The SACSIM19 PT implementation uses three "system" files:

- A fare file ("PTfare.txt") which specifies initial boarding fares, and operator-to-operator transfer fares.
- A system file ("PTsystem.txt") which specifies transit modes, operators, and various wait time curves.
- A factor file ("PTfactor.txt") which specifies parameters affecting path-building.

The PT system file declares the coding conventions for transit lines, transit access links, and operators. It also declares a set of wait curves (discussed later). Each transit line has a mode and an operator. PT generates additional links for access, egress, and transfer, with their own modes. Modes are shown in Table 3-21. Operators and fare groups area shown in Table 3-22.

Table 3-21 SACSIM19 Transit Modes

Mode	Description
1	Light rail (and other local guideway)
2	Commuter bus and rail
3	Local bus
12	Transfer links generated by PT
13	Access and egress links generated by PT
14 (not used)	(reserved for separate egress links, if needed)
15 (not used)	(reserved for separate park-and-ride access links, if needed)

Source: SACOG 2020.

Table 3-22 SACSIM19 Transit Operators

Operator / Fare Group Number	Description
1	RT light rail lines
2	RT fixed-route bus lines
3	Yolobus commuter/express lines
4	Yolobus local fixed route bus lines
5	Roseville commuter bus lines
6	Roseville local fixed route bus lines
7	Yuba-Sutter Transit commuter lines
8	Yuba-Sutter local fixed route bus lines
9	El Dorado Transit commuter bus lines
10	El Dorado Transit local fixed route bus lines
11	Placer County Transit commuter lines
12	Placer County Transit local fixed route bus lines
13	Unitrans local fixed route bus lines; CSUS Hornet shuttle lines
14	Heavy rail (currently Sacramento region stops for Capitol Corridor)
15	South County Transit (SCT Link)
16	E-Tran commuter lines
17	E-Tran local bus lines
18	Future Neighborhood Shuttle
19	Future Streetcar
20	Folsom Stage Line

Source: SACOG 2020.

The PT factors file declares:

- Parameters for path building
  - Maxima on numbers of boardings, etc.
  - Relative weights for costs and out-of-vehicle times compared to in-vehicle, in determining generalized cost of paths
  - Multi-path choice parameters
- Additional coding convention information
- Associates fare-systems with operators
- Time-transfer nodes declaring special wait curves for particular nodes.

3.6.4 Transit network

Details of transit network coding are provided in Chapter 7. For purposes of path building and assignment, travel speeds of buses on highway links are related to the background traffic speeds in the respective period of the day, multiplied by a time factor that represents delays from stopping, loading and unloading, acceleration and deceleration. Time factors are specified for each line but can vary along different segments of the same line. Each operator has an initial boarding fare, and transfer fares from an operator-to-operator matrix. There are no zone- or distance-based fares in the model.

Timed-transfer stations are coded with alternatives to the global or default maxima on wait time specified in the PT factors file. These alternatives are specified by station or stop node. Each refers to an “xwaitcurve” code which must be present in PT system file. Code 105 represents a 5-minute maximum wait (or “pulse” period), 107 is a 7-minute maximum wait, and 110 a 10-minute maximum wait.

3.6.5 Routing

For drive-access transit travel, the PT application processes only the walk-transit-walk portion. Park-and-ride lot choice is a separate model applied outside of PT, using auto and transit skims, and the auto and transit trip-legs separated for assignment. The auto portion uses the highway network to or from any zone having capacity in the “_pnr.dbf” file, and the transit portion uses the transit network to or from the respective park-and-ride zone.

Generalized time (or “perceived time” used to evaluate routes) derives from times, distances, and costs according to parameters specified in the PT factors file. Perception of first-wait time is a piecewise-linear function fitted to the logarithm of randomly-distributed exponentiated utility, coded as the “wait curve” in the Factors file. This gives a high sensitivity to short headways, and a lesser sensitivity to long headways (infrequent service) without the total loss of sensitivity that a truncation would impose.

PT applies a multi-path routing model. Waiting at a stop, travelers are routed among all acceptable lines with probability proportional to frequency, from the premise that a traveler will board whichever service arrives there first among those that efficiently reach his/her destination. PT also provides a multinomial logit choice at decision points to wait at one node or another. Its parameters are the “spread” parameters in the “PTfactors.txt” file, specified close to the program defaults.

3.6.5.1 Skimming

DAYSIM uses TAZ-to-TAZ skim components rather than total perceived time. DAYSIM does not use the skimmed walk time, but instead estimates it parcel-to-parcel. (Composite time among walk branches is available but not used, although multiple used lines picking up at a node get the combined frequencies. For future improvement, consider adding "value of choice" to utility)

3.6.6 Transit Assignment

Transit assignment is performed at the end of the model, since it is not needed in feedback. It uses the same routing criteria as skimming.

Within SACSIM19, DAYSIM uses 5 discrete period skims, but outputs trips in continuous time, therefore it is not always certain by which skim period SACSIM19 created a transit trip prior to settling the person's full itinerary. As a result, some trips are placed into a period having no transit service, so they are unassignable. Many of the unassignable trips occur in the evening period. To minimize unassignable trips, special rules are applied for transit trips in their placement into periods of the day for assignment.

- All trips earlier than the normal AM 4-hour period are placed in AM,
- If a trip begins in one period and ends in another, but one of these periods lacks transit service (as evident from lacking a transit skim), it is placed into the period that has service,
- If a trip occurs in the evening period, but has no service, it is placed into the PM period if it has service.

3.6.7 Drive Access to Transit

Park-and-ride travel is modeled in much the same way as described in *Sacramento Activity-Based Travel Simulation Model (SACSIM11): Model Reference Report* (SACOG, Feb 2012). For each individual park-and-ride trip pair (drive-transit-walk and walk-transit-drive), the park-and-ride lot of minimum generalized time is chosen, among those not already full at the time of the trip's outbound departure (beginning of the drive-transit-walk leg). Skims are a probability-weighted average across the period, of the time-dependent best choice.

To provide a more realistically short walk access between the park-and-ride zone and light rail stops, the model script was changed so the short link between them connects directly to the light rail stop, instead of a nearby node on the highway network.

PT, and this model's park-and-ride model, allow but do not require the "funnel link" system at light rail stops as in the SACSIM11/TRNBUILD model. It is sufficient to provide one link (or a few as needed) connecting an adjacent node in the highway network to each light-rail stop node. Conversion to PT retained all the funnel links from the SACSIM11/TRNBUILD model, in the interest of preserving access that was provided before, and to expedite conversion.

3.6.8 Park-and-Ride Lot Assignment

Some park-and-ride lot choice approaches were proposed for use in this model system that take advantage of TP+'s capabilities. These models include:

- Multinomial logit with shadow cost solution;
- All-or-nothing choice of the least generalized cost;
- All-or-nothing least generalized cost choice, but with maximum drive times solved for each full lot so that demand does not exceed capacity. (A maximum drive time can be considered a catchment area radius, but with catchment areas of different lots freely overlapping; and
- Simulate filling of parking lots over time, making each lot that fills up unavailable to later trips.

The first approach, (multi-nomial logit + shadow cost) was not explored due to lack of data, and budget and time constraints. The second approach (AON assignment based on generalized least cost) was rejected, simply because it lacked any capacity constraint. The third approach (varying drive-to-park-and-ride-lot sheds to match observed loadings) was rejected, because any correlation between drive shed size and lot capacity was weak, and lacked any behavioral relationship. The fourth approach (simulated lot filling, based on generalized least cost), which simulated lot choice, was tested and implemented.

The selected approach has appeal as a simple simulation of a familiar process of parking lots available to those who arrive before they fill up and closed to those who come late. Such a mechanism is reasonable since transit park-and-ride lots mostly serve commuters to work in the morning, and most vehicles stay parked through the day until the evening commute period. Its run-time is quite fast when applied to disaggregate trips such as from DAYSIM.

3.6.8.1 Implementation

There are two interrelated parts to the implementation of the park-and-ride lot choice model: the actual parking lot choice for each trip, and level of service (skim) measurement of the auto-access transit mode for each origin-destination pair.

The park-and-ride lot choice model is applied to each disaggregate trip record predicted by DAYSIM with the auto-transit-walk mode (mode 1). For each, this model selects one zone for this trip to park. Only zones having available parking capacity are allowed. With this selection, the trip is split into an auto trip from the origin to the parking zone, and a transit trip from the parking zone to the destination.

Each trip is linked to the same person's return trip (mode 2), and the return trip is split into a transit and an auto trip through the same parking zone. (The return trip may have a different origin than the original d-t-w trip's destination, and/or a different destination than the original trip's origin.)

The resulting auto and transit trips are then aggregated into trip matrices by time period for inclusion in the auto and transit assignments. This trip processing model is applied after DAYSIM (since DAYSIM trip predictions are input), and before auto assignment (since the auto portions of trips are included in the assignments).

The parking lot choice model makes a single choice for each d-t-w trip of the parking zone, among those available for parking and not filled up, having the least generalized cost combined from the auto and transit portions of travel parking at that zone. The generalized costs are as follows, for origin zone *i* and parking zone *k*:

$GC(auto)_{ik}$ = {3*Auto $Time_{ik}$ + 2*(TermTime $_i$+ TermTime $_k$) + 2*(AutoDist $_{ik}$ * 12 cents/mile + $ParkCost_k$ /2) * 0.0558 minutes equivalent/cent } / 1.28 persons per vehicle

Where:

- GC(auto) = generalized cost for auto portion of transit-drive access trip, per person trip
- Auto $Time_{ik}$ = auto travel time from i-zone to park-and-ride lot k-zone (minutes)
- TermTime = terminal travel time at i-zone and k-zone (minutes)
- AutoDist = i-to-k zone auto driving distance (miles)

$GC(transit)_{kj}$= InVehTime + 2*WalkTime + 1.5*InitWaitTime + 2*TransfTime + (2*Fare * 0.0558 minutes equivalent/cent)

Costs are in year 2000 cents, consistent with SACSIM. The factors on costs are taken from the SACSIM model's middle stratum of cost factors for work trips. Parking cost is specific to park-and-ride activity, being taken from the park-and-ride capacity database file, not the zonal land use or parcel data.

Ideally, the park-and-ride zones would be special zones coded at the actual locations of the parking lots. However, presently they are in ordinary zones, and some of their centroids are some distance away from the parking and the transit station. The ordinary walk-access transit skims would include walk time from the parking zone centroid to the transit stops, which is excessive in some zones. TP+ is not able to isolate or exclude walk time from the origin to the first boarding, which would solve this problem. The current solution to transit skimming for park-and-ride is to actually run customary drive-to-transit skimming, with the requirement that all park-and-ride zones be coded in their own catchment areas. This approach does not appear to introduce conflicts, because the parking lot choice calculations ignore all the transit skims except those beginning at the parking lot zones (i.e. the zones with parking capacities).

This model processes AM trips in chronological order, according to the predicted time-of-day of each trip. Because the trip start-times from DAYSIM occur at a limited number of unique times, a random number breaks ties to settle the order in which trips are processed and given priority at parking lots. One parking zone is chosen for each DAYSIM drive-transit trip, which has the least total generalized cost from its auto and transit legs. The remaining capacity of the chosen zone is decreased by 1 vehicle; if that was the zone's last available parking space, then the zone is unavailable to all later trips.

In addition to the trip pairs labeled with the parking lot choice, the AM drive-transit trip processor also outputs the schedule of when each parking zone fills up, expressed as a fractional number from 0 to 1, representing the cumulative fraction of AM period trips that have been processed.

For the midday period, all lots that fill up in the AM period are unavailable. For PM and evening, all lots are available for drive-to-transit trips. Airport transit-drive trips are not disaggregate and are few in number, so all parking lots are considered available to them.