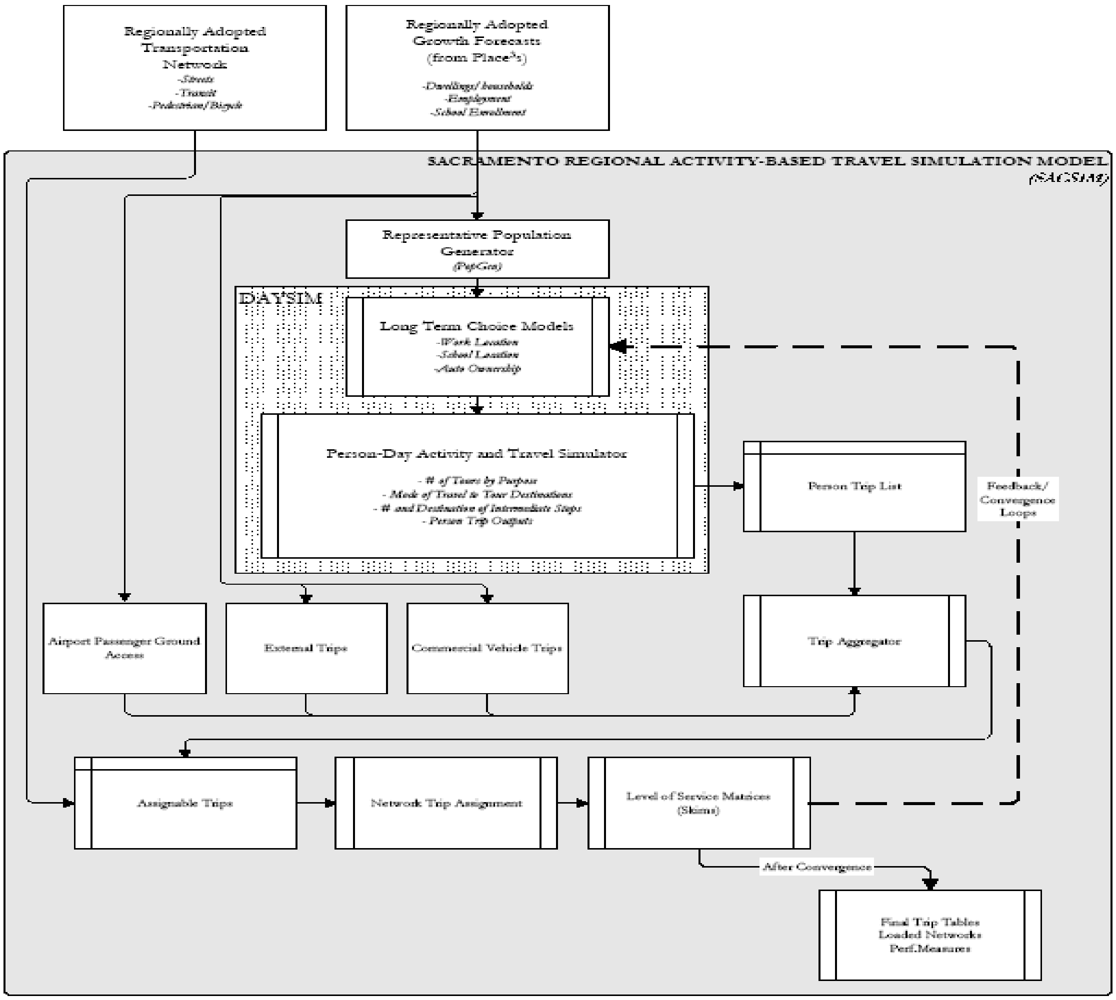
3 Model Structure

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.

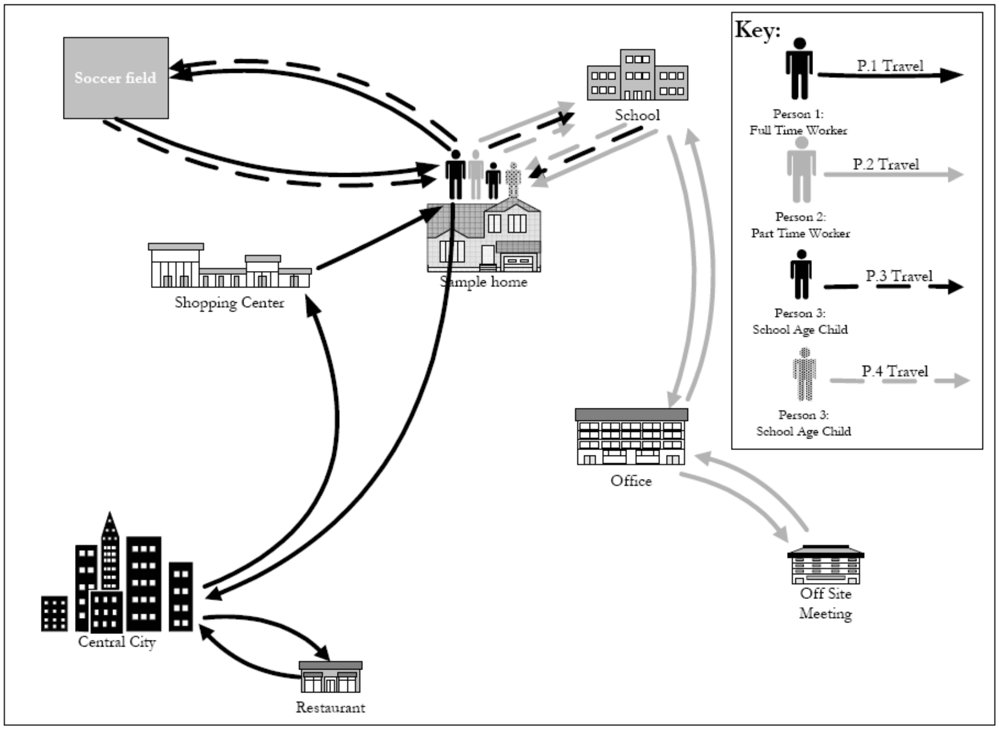
3.1.1 DAYSIM Terminology and Concepts

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

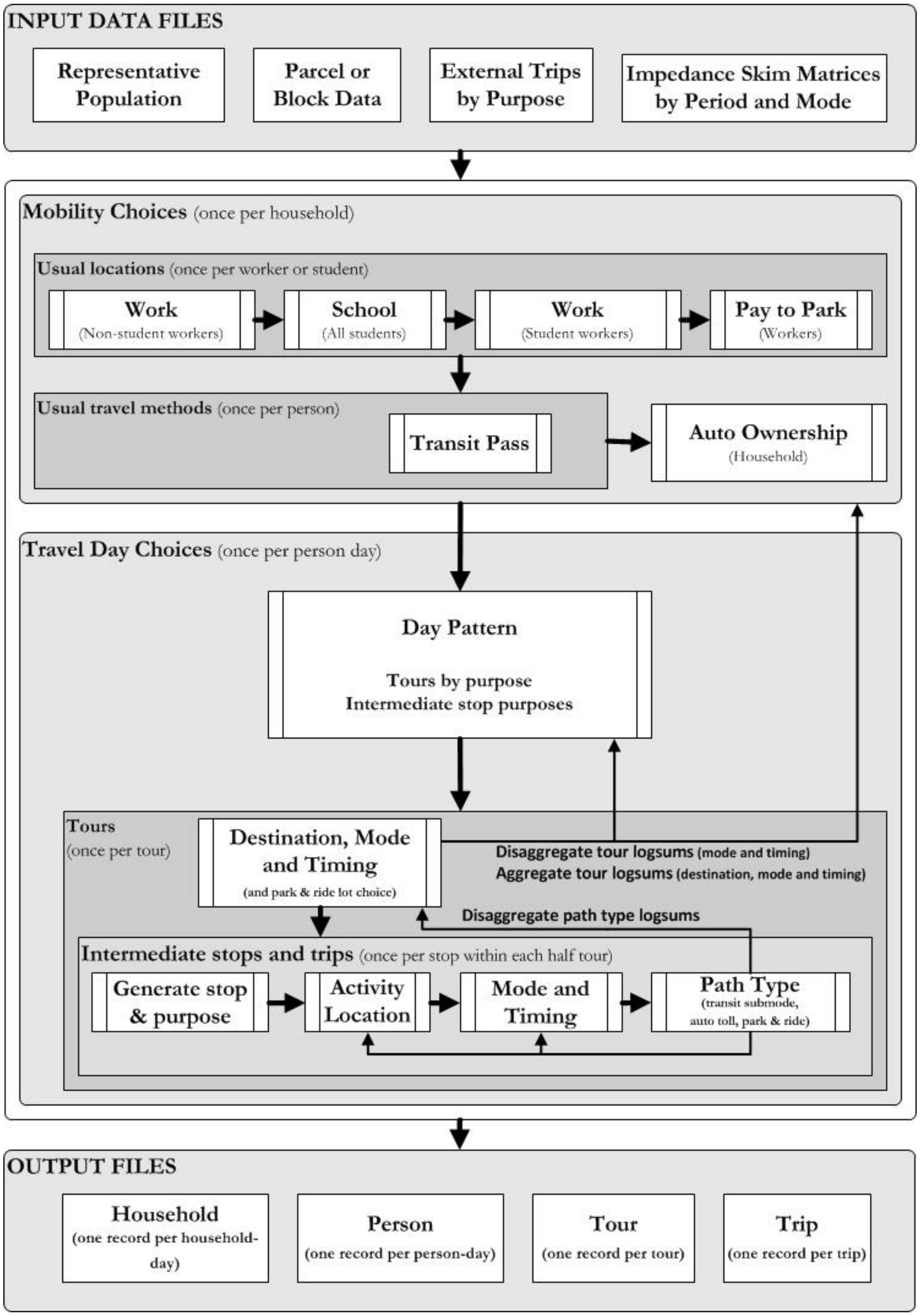


Table 3-2 Utility Function Variables in the Location Choice Models

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

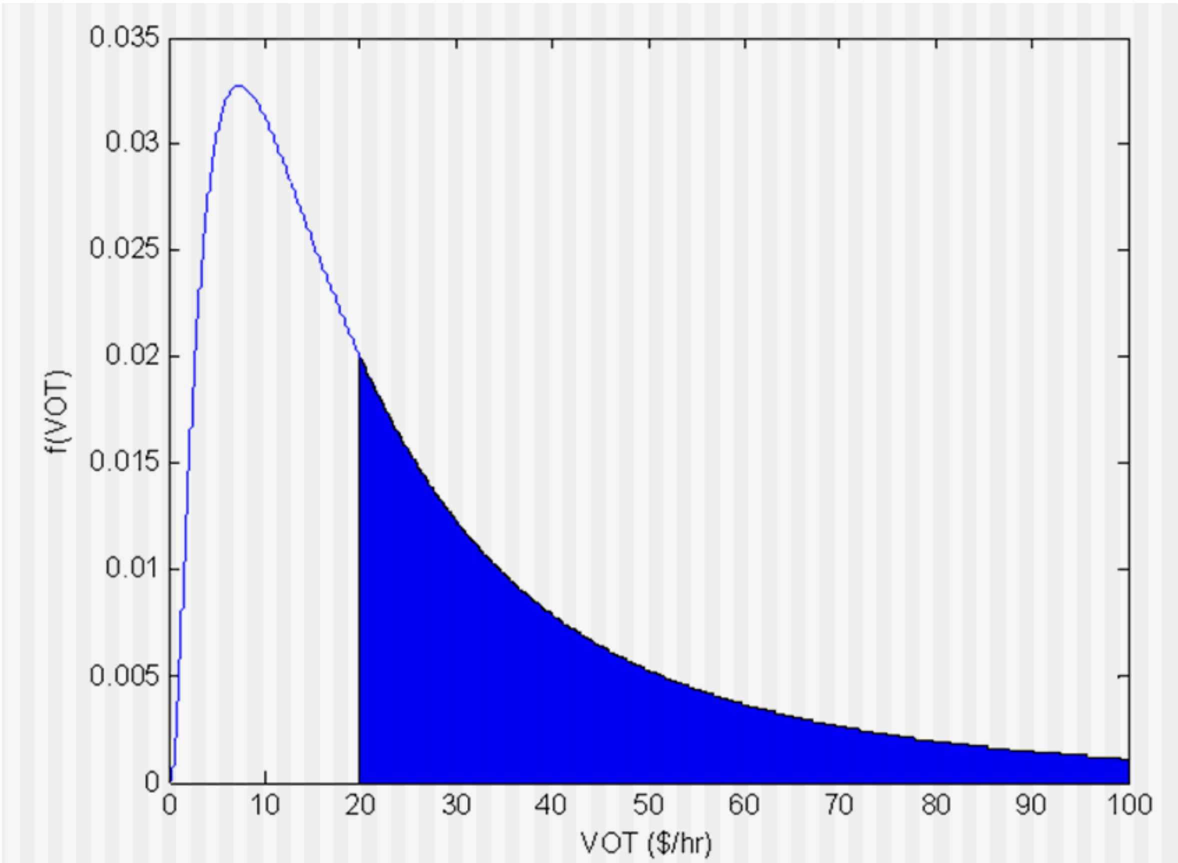
Non-work tours

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.

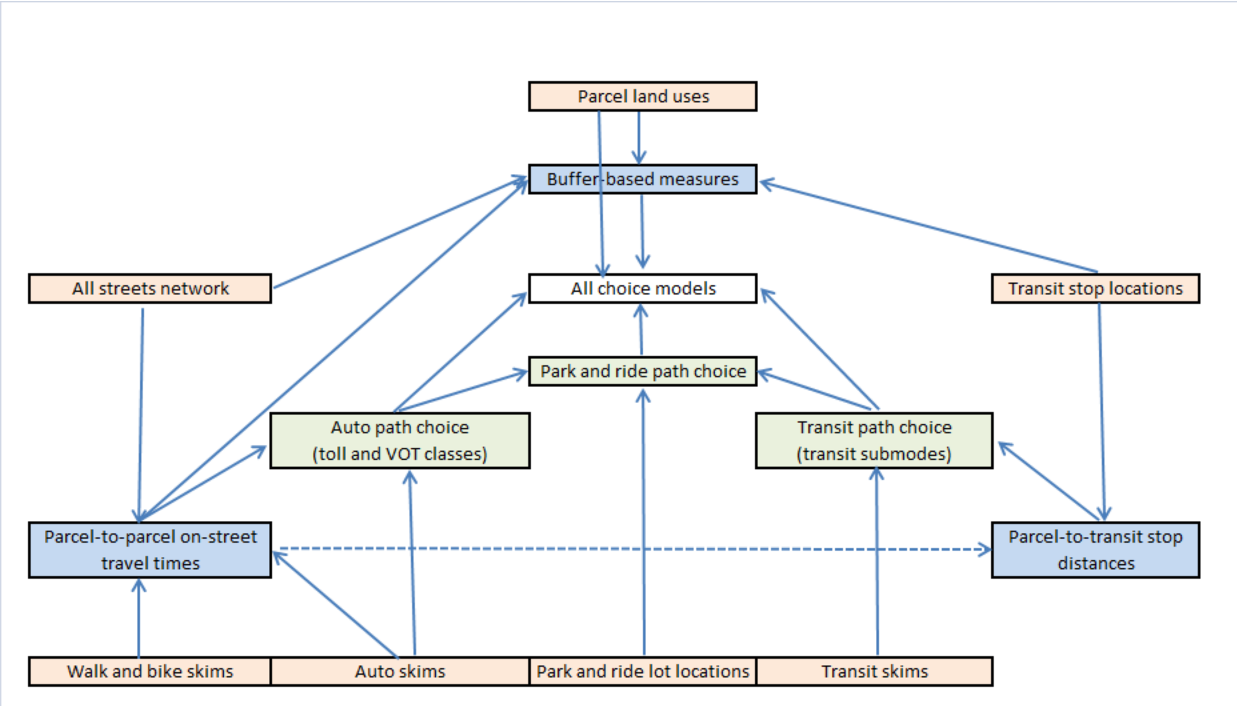
Consideration of transit fare passes and discounts: Although the transit fare values in the transit impedance skims reflect the full fare, DAYSIM no longer assumes that everyone pays that fare. Fare reduction is simulated in two ways:

- 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.