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

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

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 an 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>
<thead>
<tr>
<th>System Iteration</th>
<th>Maximum Assignment Iterations</th>
<th>Relative Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>0.0006</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>0.0003</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

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:

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

Where:
- \( VC \) = V/C ratio on a link;
- \( A \) = a user-specified coefficient; and
- \( B = \frac{(2A - 1)}{(2A - 2)} \)
- \( E = 2 - B \)

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:

\[ T_c = T_0 + \min\{E - A(1-Lx) + (A(1-Lx)^2 + B^2)^{0.5}, \max(T_c)\} \]

The variables are the same as for the basic conical delay function, except:
- \( T_c = \) congested travel time
- \( T_0 = \) "free flow" travel time
- \( L = \) VC ratio factor, adjusted so that \( T_c = \pm 1.5 \) 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

<table>
<thead>
<tr>
<th>Class of Roadway</th>
<th>A</th>
<th>B</th>
<th>E</th>
<th>L</th>
<th>M</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway</td>
<td>6</td>
<td>1.1</td>
<td>0.9</td>
<td>0.88</td>
<td>10.2</td>
<td>0.0002</td>
</tr>
<tr>
<td>Highway</td>
<td>5</td>
<td>1.125</td>
<td>0.875</td>
<td>0.86</td>
<td>8.3</td>
<td>0.0002</td>
</tr>
<tr>
<td>Arterial</td>
<td>4</td>
<td>1.167</td>
<td>0.833</td>
<td>0.83</td>
<td>6.4</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

Source: SACOG 2020.
Table 3-20 Range of Congestion Factor Calculations

<table>
<thead>
<tr>
<th>Class of Roadway</th>
<th>Congestion Factor at VC =...</th>
<th>Max. @ VC=...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway</td>
<td>1.00 1.21 1.49 10.15 11+ 2.20</td>
<td></td>
</tr>
<tr>
<td>Highway</td>
<td>1.00 1.24 1.50 8.25 11+ 2.20</td>
<td></td>
</tr>
<tr>
<td>Arterial</td>
<td>1.00 1.27 1.50 6.36 7+ 2.20</td>
<td></td>
</tr>
</tbody>
</table>

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:

\[
\frac{\sum_{i=1}^{n} VMT^2}{(\sum_{i=1}^{n} VMT)^2}
\]

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**

![Ramp meter delay functions](image)

### 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)