Application of an Activity-Based Travel Model of the Sacramento Region (SacSim)

Draft 9/21/06

Introduction

This report documents a travel demand model system, SacSim, which applies an activity-based travel model developed for the Sacramento Area Council of Governments. The activity-based travel model itself, DaySim, is described in separate documents. SacSim consists of DaySim plus auxiliary models predicting external trips, airport ground access trips, and commercial vehicle trips, along with the processes that provide network-based data to DaySim and the auxiliary models, and load trips from DaySim and the auxiliary models onto networks. SacSim is command script for TP+ or Voyager, and launches the stand-alone DaySim program at specified points in the process. SacSim runs in iterations with a modified form of the "method of successive averages" enabling it to approximate system equilibrium. This report describes the auxiliary models and the processes of SacSim outside of DaySim.

Overview

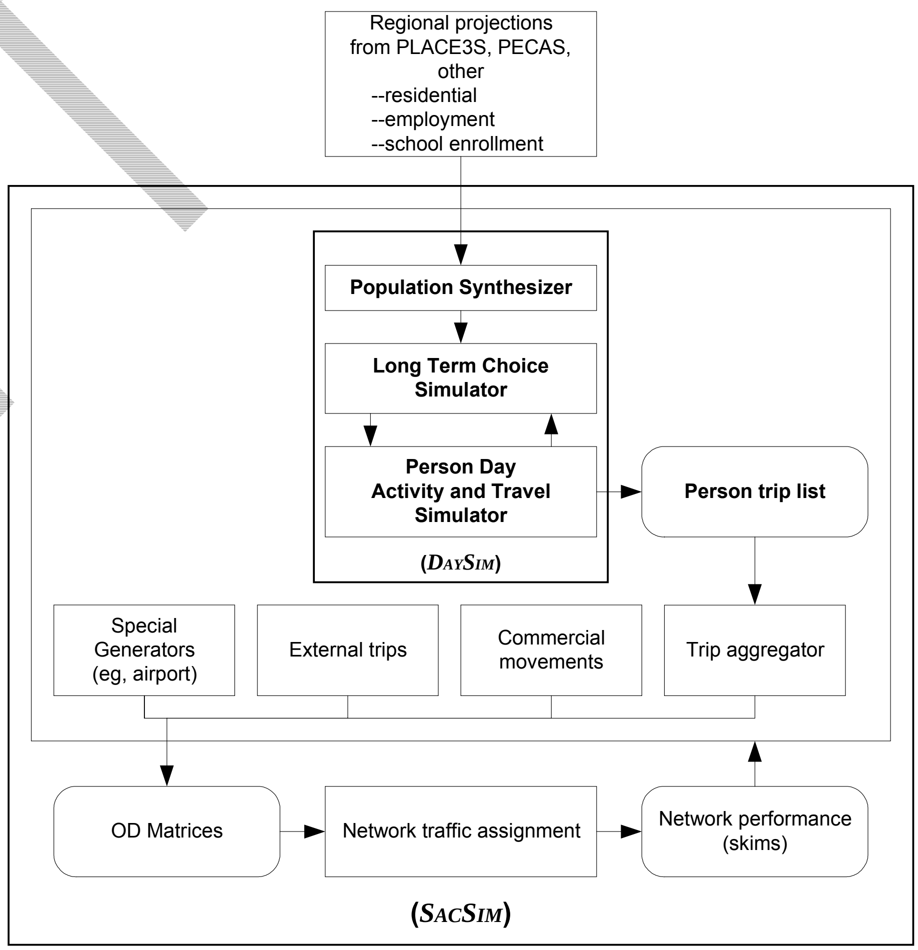
DaySim is an activity-based travel model developed by Mark Bradley and John Bowman for the Sacramento Area Council of Governments (SACOG). DaySim's PopSyn component creates a synthetic population of the Sacramento region consistent with regional residential, employment, and school enrollment forecasts; for each member of this population, DaySim then simulates a one-day activity and travel schedule, including a list of each person's tours and trips on each tour. Bradley and Bowman have produced a series of technical memos describing the development of DaySim (Bradley and Bowman 2006).

As part of this work program, DKS Associates developed a regional travel forecasting system incorporating DaySim. This system is known as SacSim. SacSim is written in scripting language for Citilabs TP+/Voyager modeling software, version 4.0 or higher. These scripts specify runs of DaySim at certain points. Certain components of SacSim are based on the corresponding components of the SACMET model, the Sacramento regional four-step model system maintained by SACOG (DKS Associates 2002).

Figure 1 shows the major components of this travel forecasting system. SacSim has auxiliary models predicting external trips (entering and exiting the region), airport passenger ground-access trips, and commercial vehicles. SacSim aggregates the trips from DaySim, and combines them with trips from the auxiliary models, into time- and mode-specific matrices. Network traffic assignment models load the trips onto the network. Network performance, measured as "skim" times and costs, are updated for use in a subsequent iteration of DaySim. The system is run in an iterative convergence process to approximate system equilibrium, that is, consistency between the network performance input to DaySim and the auxiliary trip models, and the network performance resulting from assignment of those trips.

The population synthesizer has been incorporated into the DaySim program as a runtime option. SacSim specifies population synthesis during its first run of DaySim; all runs thereafter use members of that same population.

Figure 1: SACOG Regional Travel Forecasting Model System



DaySim uses coding conventions of mode and activity as in Table 1 below. Each trip has a mode, and two activities, one at each end. Other sections of this report refer to these modes and activities.

Table 1
Coding Conventions for Mode of Travel and Activity

Number	Mode of Travel
1	drive-transit-walk
2	walk-transit-drive
3	walk-transit-walk
4	school bus
5	car-shared ride 3+
6	car-shared ride 2
7	car-drive alone
8	bike
9	walk
10	other mode

Number	Activity
1	work
2	school
3	escort
4	personal business
5	shopping
6	meal
7	social/recreational
8	at home

Network Performance Measures

Auto Level of Service

DaySim and the auxiliary models use matrices of zone-to-zone travel time and other level of service attributes. These are computed for the four periods of the day (AM and PM 3-hours, mid-day, and evening). In the peak periods, all measures are determined separately for single-occupant and multiple-occupant vehicles. In the first iteration, free-flow link times apply. Afterwards, congested times are taken from the most recent auto assignment.

The variables measured are:

1) Auto travel time, along the shortest-time route,
2) Auto travel distance, along the shortest-time route.
3) Excess travel time due to congestion beyond 1.2 x free-flow time,
4) Excess travel time due to congestion beyond 1.5 x free-flow time.

Special traffic congestion measures are calculated for time-of-day choice models in DaySim and for post-run analyses. These measure the amount of excess travel time for a trip compared to what the travel time would be if no link had more than a certain limit to congestion. This is computed with two limits: link time truncated to 1.2 times free-flow time, and link time truncated to 1.5 times free-flow. (The latter is the time at capacity, according to the speed-flow relationship used in the traffic assignment model.)

It would be easy to compute these measures by accumulating the excess time difference along the links in the shortest path. However, this measure could vary substantially among other paths that are nearly equal in travel time (which might be exactly equal if the assignment were able to achieve precise equilibrium). A path-independent measure is used instead: the difference between the path-sum of truncated time on the least truncated-time path, and the path-sum of assignment time on the least assignment-time path. Truncated time is the lesser of assignment time, and {1.2 or 1.5} x free-flow time. In other words, these measures are differences between skims, not skims of link-time differences.

A placeholder for tolls is provided in the data file format for time and cost differences, although no tolls are presently coded or involved in the computations.

Transit Level of Service

Transit level of service for the walk-to-transit mode are based on the methodology in the Sacmet model system, except weights on travel time components set to “good practice” values.

Transit lines are coded with reference to the nodes and links of the highway network, and most derive their traversal times from the highway network. Traversal times are typically the underlying highway link’s congested time (AM for peak, mid-day for off-peak), multiplied by a time factor (specified in the line coding) to account for stops, acceleration and deceleration delays, etc.

Transit line data include identifying information, the headways for the peak and off-peak periods, a line mode used to compute fares and determine transfer rules, plus the sequence of nodes. In the sequence of nodes may be changes of the time factor or any special traversal time rule, and whether the transit vehicle actually stops or not at each node.

Transit coding includes a supplemental “supply link” file which specifies underlying links for off-highway transit, such as light rail and bus-only roadways. This file also codes special “funnel” links at light rail stations and certain other transit stops.

Park and ride level of service uses a new method described in detail in the next section.

Park-and-Ride Transit Level of Service and Trip Processing

SacSim applies a new model of park-and-ride lot choice for drive-to-transit trips that accounts for parking lot capacities, and splits the trips into their respective auto and transit parts for separate assignment. This model replaces the drive-to-transit methodology provided in TP+. It provides coordinated modules for splitting trips into the auto and transit parts, and calculating level-of-service matrices. First the general methodology is described, then its application in calculating performance measure skims (before DaySim) and trip processing (after DaySim and before auto trip assignment).

Background and Selection of Park-and-Ride Lot Choice Model

SACMET uses the standard methodology provided in TP+ for generating drive-to-transit level-of-service matrices, and transit assignment. But TP+ does not provide for assignment of the auto-access vehicle trips to the highway network, so a custom program calculates auto-access vehicle trips from the drive-to-transit trip matrices, so they can be added to the assignment vehicle trips. The standard methodology in TP+ for drive-to-transit handling requires the user to code a "catchment area" list of all zones (TAZs) that are given access to each park-and-ride lot. (This is much the same as the original MINUTP application, but without the memory limitations.) In transit studies, these zone lists can be difficult to code and maintain, and are subject to the judgment and technique of the analyst. If the model overloads a park-and-ride lot beyond its capacity (actual or foreseeable), the only recourse is to remove zones from association with the lot, and associate them to other lots, and run the model again. Capacity-constraint adjustments are judgmental, and require time-consuming trial-and-error. Consequently, an alternative methodology was sought for SacSim (and possibly for Sacmet) that avoids user-coded catchment areas or similar judgmental inputs, avoids special programs, and automatically satisfies parking capacity limits.

Since at least 1994, users of the competing travel model software EMME/2 have been applying models of park-and-ride choice that calculate with "convolutions" - explicit loops through each possible intermediate zone between each origin and destination zone (Blain, 1994). EMME/2 does not build drive-to-transit paths in its transit assignment module, so this mode must be handled by matrix processes. These processes include a skimming stage, and a trip-splitting stage which converts the transit-drive trips into separate drive trips (for inclusion in auto assignment) and transit trips (for inclusion in transit assignment).

Many of these models, including Blain's, are multinomial logit choice among all accessible zones designated for transit-access parking. Consequently, drive-to-transit trips from any origin to any destination are split in some amount to all accessible park-and-ride lots. Estimated or calibrated coefficients of these models commonly weight the drive access time between three and six times compared to transit in-vehicle time.

Soon afterwards, parking lot capacity restraint methodologies were added to these models (Spiess, 1996). An additional "shadow cost" imposed on potentially each parking lot is iteratively solved, so that every park-and-ride lot satisfies the rule that either its demand matches capacity, or it has no shadow cost and demand is less than capacity.

TP+ permits explicit and versatile user-coded loop control and matrix cell addressing capabilities in its matrix processing program, unlike those in MINUTP and most other modeling software, which basically process matrices sequentially cell-by-cell. These capabilities are more general than EMME/2's "matrix convolutions," and permit TP+ to apply these and a wide range of other possible park-and-ride models.

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

(1) Multinomial logit with shadow cost solution,
(2) All-or-nothing choice of the least generalized cost,
(3) 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.)
(4) Simulate filling of parking lots over time, making each lot that fills up unavailable to later trips.

Model (1) was not developed or tested in TP+ for this effort. Model (2) is the basis of the other models, and remains the method of park-and-ride lot choice in the first iteration of the model system, when all times are free-flow. Model (3) has appeal as an analytical non-judgment-based alternative to the common practice of user-coded catchment areas, although its simulation or behavioral basis is unclear. Preliminary tests found its run-times slower than satisfactory. (It must run iteratively through all trips, although the number of iterations might be reduced by starting with a previous run's solution. The existence and uniqueness of solution has not been established.)

Model (4) 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. (Travelers too late to use a lot are modeled as having this knowledge: none drive to a lot, find it full, then drive on to another, etc.) Such a mechanism is reasonable since transit park-and-ride lots mostly serve regular 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. This is the park-and-ride lot choice model implemented in the present SacSim system.

A shadow of doubt to any parking capacity constraint model for the Sacramento region is that no transit park-and-ride lots in this region are observed to regularly fill up completely, raising a question of whether their usage is presently influenced by capacity. More complex behaviors may explain this, perhaps with "risk management" against driving to a lot and finding it full. But no practical modeling approach besides parking capacity constraint is presently available to avoid overfilling parking lots.

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.

Implementation on Trips

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 $Time_{ik}$ (minutes)
+ 2*(Terminal $Time_{i}$ + Terminal $Time_{k}$)
+ 2*(Auto $Distance_{ik}$ * 5 cents/mile + Parking $Cost_{k}$ /2) * 0.0558 minutes equivalent/cent / 1.28 persons per vehicle

$GC(transit)_{kj}$ = In-Vehicle Time (minutes)
+ 2*Walk Time
+ 1.5*First Wait Time
+ 2*Transfer Time
+ 2*Fare * 0.0558 minutes equivalent/cent

Costs are in 1990 cents, consistent with Sacmet data. (The U.S. Bureau of Labor Statistics reports that $1.00 in 1990 is equivalent to $1.49 in 2005 and $1.55 in 2006.) The factors on costs are taken from the Sacmet model's middle stratum of cost factors for work trips, and imply a value of time of $5.38/hour. 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. (Not all had been in the Sacmet data.) 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.

Implementation on Level of Service Measurements

DaySim uses zone-to-zone measurements of times and costs for auto-access transit among its inputs. These must be provided for all zone-to-zone movements having access to this mode, not just those having trips.

The AM transit-drive skimming module, which is run separately after auto assignment, uses the loading schedule to compute weighted-average skims for the next model system iteration. (In the first iteration of SacSim, when times are free-flow, no lots are filled, so this schedule is empty.) This schedule is expressed as a cumulative fraction of AM d-t-w trips processed when each zone fills up (rather than clock time). The loading schedule, in effect, partitions the AM period into a number of time increments, each of which has a certain set of parking zones available. This implementation takes advantage of the fact that each time increment has one parking zone less than the previous, which is the zone that filled up at the start of the increment.

For each origin-destination pair and each time increment, level-of-service measures are computed by choosing the yet-unfilled parking zone yielding the least combined generalized-cost, according to the same criteria described above for trips. From all the increments, a weighted average is combined for each measure, which is saved to level-of-service matrices.

In the special case of the first iteration through the SacSim system, level of service measures are needed before there are any trips to fill parking lots. All parking zones are considered available for this case.

For the mid-day period, two level-of-service matrix sets are made. One has all parking zones that filled in the AM period unavailable, for use by DaySim for the off-peak periods. The other has all parking zones available, for use by the airport mode choice model (which includes an explicit transit drop-off mode). PM and evening transit skim matrices are not made. Instead, DaySim uses the opposite direction of AM skims for the PM period, and the opposite direction of mid-day for the evening.

External Trip Model

DaySim simulates the activities of households located within the Sacramento 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 model (or actually, set of models) 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, and outside residents who take jobs within the region.

These models are based on customary aggregate trip generation and distribution models, producing person- and vehicle-trip matrices.

Definitions

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

Gateway: TAZs outside of the modeled internal region, connected to highways exiting the region. 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.

Production: Source or location of demand for travel or activity participation, typically homes.

Attraction: Location visited to satisfy demand for travel or activity participation, typically at workplaces, businesses, and other places people visit to do things.

II (Internal-Internal) describes a trip both produced and attracted internally to the region, that is, an entirely internal trip.

IX (Internal-External) describes a trip produced internally and attracted externally, regardless of the actual direction of travel. A tour (round trip) of an area resident to San Francisco and back is considered two IX trips.

XI (External-Internal) describes a trip produced externally and attracted internally, again, regardless of the actual direction of travel.

Through-trip (or XX): a trip entering the region through one gateway, passing through the region without stopping, and exiting through another gateway. Through trips are an exogenous input matrix to SacSim.

Trip Purposes: External trips are processed in four trip purposes, corresponding to the four activities judged most productive of external travel: Work (or worker-flow), personal business, shopping, and social-recreational. (School, escort, and meal activities are omitted.)

External Trip Generation for External Travel Models

Trip generation of the gateway TAZs is an exogenous input consisting of person trips for productions and for attractions in each trip purpose. The present source for this information is the Sacmet model's gateway trip generation.

Sacmet's gateway trip generation is expressed in production person-trips and attraction person-trips, in each of the Sacmet system's own trip purposes:

Home-Based Work
Home-Based Shop
Home-Based School
Home-Based Other
Work-Other

Other-Other
Commercial Vehicle, 2 Axles
Commercial Vehicle, 3+ Axles

The external trip models developed for SacSim are in different trip purposes, for compatibility with the activity types in DaySim:

Worker Flow
Personal Business
Shopping
Social-Recreational

Home-based school trips are such a small part of gateway travel that they are neglected in SacSim. The two commercial vehicle trip purposes are adapted directly from Sacmet, including the gateway trip generation in these trip purposes. All further discussion of commercial vehicle trips is in their own section of this document.

Worker flow is estimated as Home-Based Work trips / 1.7, for both productions and attractions.

Work-Other and Other-Other trips are first prorated to Home-Based Shop and Home-Based Other trips. Specifically, the "Other" end of Work-Other, coded as Work-Other productions, is spread proportionally to HB-Shop and HB-Other. Then, both productions and attractions of Other-Other are spread likewise. Finally, the HB-Other trips with their spread trips from Work-Other and Other-Other are split among Personal Business and Social-Recreational according to assumed splits. Expressed as formulas, where all trip variables on the right side are from Sacmet:

$$P(Shop) = P(HBShop) + (P(OO) + A(WO))\frac{P(HBShop)}{P(HBShop) + P(HBOther)}$$

$$A(Shop) = A(HBShop) + (A(OO) + P(WO))\frac{A(HBShop)}{A(HBShop) + A(HBOther)}$$

$$P(SocRec) = Split(SocRecP)\left[P(HBO) + (P(OO) + A(WO))\frac{P(HBOther)}{P(HBShop) + P(HBOther)}\right]$$

$$A(SocRec) = Split(SocRecA)\left[A(HBO) + (A(OO) + P(WO))\frac{A(HBOther)}{A(HBShop) + A(HBOther)}\right]$$

$$P(PersBus) = [1 - Split(SocRecP)]\left[P(HBO) + \left(P(OO) + A(WO)\right)\frac{P(HBOther)}{P(HBShop) + P(HBOther)}\right]$$

$$A(PersBus) = [1 - Split(SocRecA)]\left[A(HBO) + \left(A(OO) + P(WO)\right)\frac{A(HBOther)}{A(HBShop) + A(HBOther)}\right]$$

The reverse orientation of productions and attractions for Work-Other associates the "work" end with productions and the "other" end with attractions to the intended activity.

Table #X1 shows the Sacmet and converted SacSim gateway trip generation. The assumed splits are included that broke home-based other and prorated non home-based into social-recreational and personal business. Most are constant, except the attractions are weighted more toward recreation on major gateways toward the Lake Tahoe and San Francisco Bay areas.

Table #X1

Gateway Trip Generation Conversion from Sacmet to SacSim																			
Gateway	Sacmet HB-Work		Sacmet HB-Shop		Sacmet HB-Other		Sacmet Work-Other		Sacmet Other-Other		Assumed Split Factors between Soc-Rec and Pers Bus.		SacSim Personal Business		SacSim Shopping		SacSim Social-Recreational	
Zone	Prod	Attr	Prod	Attr	Prod	Attr	Prod	Attr	Prod	Attr	Soc-Rec P	Soc-Rec A	Prod	Attr	Prod	Attr	Prod	Attr
1	2290	1128	2431	216	3856	764	2084	363	2014	1940	0.6	0.77	2143	885	3377	1087	3214	2962
2	1873	923	2012	256	3195	2525	1214	352	1898	2089	0.6	0.4	1662	3687	2617	623	2494	2458
3	0	0	210	26	334	265	128	37	199	218	0.6	0.4	174	387	274	63	261	258
4	0	0	977	125	1550	1223	589	172	921	1012	0.6	0.4	807	1786	1271	304	1210	1191
5	9983	3464	2692	619	4274	3488	2004	1065	2544	2563	0.6	0.4	2463	4695	3878	1389	3694	3130
6	777	1541	1198	1374	1902	9102	1338	2494	3077	3146	0.6	0.7	1701	4353	2679	2190	2552	10156
7	1110	385	634	143	1006	799	472	243	591	595	0.6	0.4	578	1083	910	323	867	722
8	0	0	617	130	1008	735	462	225	569	569	0.6	0.7	574	511	878	301	860	1191
9	0	0	191	57	306	402	134	67	163	172	0.6	0.4	172	417	268	99	258	278
10	128	302	618	971	978	6205	576	1585	1364	1396	0.6	0.7	921	2577	1455	1344	1381	6014
11	0	0	0	0	0	0	0	0	0	0	0.6	0.4	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0.6	0.4	0	0	0	0	0	0
13	2409	1519	1350	396	2142	2835	738	781	1207	1287	0.6	0.6	1230	2009	1937	702	1844	3014
14	0	0	0	0	0	0	0	0	0	0	0.6	0.4	0	0	0	0	0	0
15	5981	7531	4709	2253	7473	8697	3397	4404	5718	5665	0.6	0.4	4903	10643	7725	4595	7355	7095
16	598	753	468	164	741	635	336	321	480	475	0.6	0.4	457	836	722	360	686	558
17	0	0	170	62	271	236	123	120	176	175	0.6	0.4	168	308	264	135	252	206
18	4186	5272	2710	1427	4299	5506	1954	2789	3485	3453	0.6	0.5	2883	5508	4544	2855	4325	5508
19	1196	1506	578	155	916	1002	498	483	550	577	0.6	0.4	607	1187	958	306	910	791
20	0	0	94	22	149	147	81	73	87	90	0.6	0.4	97	181	154	45	146	120
21	0	0	350	85	552	555	302	270	319	329	0.6	0.4	361	670	572	171	541	447
22	15759	22649	3619	3740	21832	24109	11892	11657	13292	13733	0.6	0.63	16813	17577	6968	7369	25219	29928
23	0	0	368	101	582	648	320	313	351	373	0.6	0.6	388	510	613	199	582	765
24	0	0	0	0	0	0	0	0	0	0	0.6	0.4	0	0	0	0	0	0
25	0	0	65	26	103	100	47	51	72	71	0.6	0.4	65	128	103	56	98	85
26	322	462	204	60	323	383	176	185	205	212	0.6	0.4	218	446	344	116	327	297
27	0	0	149	0	239	86	108	21	153	155	0.6	0.6	127	158	199	0	191	236
28	1300	1190	1815	0	2880	1089	1306	267	1999	1830	0.6	0.6	1538	1967	2423	0	2307	2951
29	0	0	98	0	156	56	71	15	98	101	0.6	0.4	84	153	131	0	125	102
30	27	24	1091	98	1730	343	936	162	904	871	0.6	0.4	961	1034	1516	492	1442	689

Internal Trip Generation for External Work Travel Model

The internal productions are employed residents, 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 employees, aggregated into zones (TAZs) from the parcel database.

Internal Trip Generation for External Non-Work Travel Model

As discussed below, the non-work external trip distribution model only distributes IX and XI 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 summarized in Table #X2#. It is determined from the exponentiated "size variables" coefficients, times the size function scale, in Table 6 of Technical Memo 8, Usual Location and Tour Destination Models. 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.

Table #X2#
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

Trip Distribution for External Travel

Trip distribution estimates a matrix of daily trips (or worker flows) produced at one TAZ "*i*" and attracted to another (or the same) TAZ "*j*". Trips may need to be constrained by rows, that is, the total number of trips in row *i* must match the trip productions in TAZ *i*. Trips may also need to be constrained by columns, so the total number of trips in column *j* must match the number of attractions in TAZ *j*. Finally, a trip distribution model favors short trips against long trips in terms of a deterrence function of the trip length, $f(t)$. The trip distribution model is $T_{ij} = R_i S_j f(t_{ij})$, where *R* is a vector of values that solve the row constraints of productions $\sum_i T_{ij} = P_i$ for all *i*, or is implicitly all ones if there is no row constraint, and *S* is a vector of values that solve the column constraints of attractions $\sum_j T_{ij} = A_j$ for all *j*, or is implicitly all ones if there is no column constraint. If both rows and columns are constrained (the model is doubly constrained), then **R** and **S** are solved iteratively with a procedure similar to iterative proportional factoring, such as a gravity model or a Fratar procedure. For a singly-constrained model (on either rows or columns), a simple prorating procedure is used. Normally after solution, the trips are output and the **R** or **S** vectors discarded.

SacSim calculates a doubly-constrained zone-to-zone gravity model of worker flows, including II, IX, and XI trips (but not through trips). The II trips are then disregarded, and the IX and XI trips retained.

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 IX 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 XI trips, the gateway productions are constrained, and there is no constraint on the internal zones' trips that go external. For each trip purpose, IX and XI trips are distributed separately.

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 was 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.

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

Table #XPAR#
Source Parameters for Non-Work Deterrence Functions

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-destination 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

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) thus:

Personal Business $-0.0823 = -0.025*0.73 + -0.7635/10\text{mi} * 50\text{mi}/60\text{min} + -0.020*0.0206$
Shop $-0.0916 = -0.025*0.73 + -0.8238/10\text{mi} * 50\text{mi}/60\text{min} + -0.025*0.1892$
Social-Recreational $-0.0555 = -0.025*0.73 + -0.4468/10\text{mi} * 50\text{mi}/60\text{min}$

Through Trips

Through trips traverse the regional model's coverage area by entering one gateway and exiting another, without explicitly stopping at any zone within the area. Through trips enter the model system as exogenous vehicle trip matrices, one for auto trips and another for heavy trucks. SacSim uses the same through trip matrices as SACOG's trip-based Sacmet model system. The various trip distributing models in SacSim are prevented from creating any additional through trips.

Mode Choice of External Trips

External trips are stratified by mode by means of simple factors. This system considers only the automobile modes, classified by occupancy.

External (IX & XI) work trips are taken from the external worker-flow matrix, times a factor of 1.7 to convert to person-trips.

External person trips (IX & XI) are split by auto occupancy by means of the factors on Table #XOD#. The resulting trips are still person-trips, which are then converted to vehicle trips by dividing by the number of persons per vehicle. (3 or more persons are divided by 3.5.) Through trips are already vehicle trips, so the split factors in the table are already expressed in terms of vehicle trips. The factors for through trips are a judgmental average of the other factors after re-expressing them in vehicle-trip terms.

The actual code for this factoring is combined with time-of-day factoring, in a single system phase that compiles all modeled trips into the applicable vehicle trips for the auto assignments.

Table #XOD#
Occupancy Distributions of External Person Trips

Persons per Vehicle	Person-Trips				Through Vehicle-Trips
	Work	Personal Business	Shopping	Social-Recreational	
1	89%	54%	45%	29%	60%
2	8.5%	29%	40%	31%	25%
3 or more	2.5%	17%	15%	40%	15%
Total	100%	100%	100%	100%	100%

Sources: SACOG 2000 Regional Household Survey (for person trips)

Airport Ground Access Trip Model

The airport 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. This model does not include travel by employees of the airport, or airport-using or airport-serving businesses, which are assumed to be represented by SacSim's activity and commercial vehicle models.

As part of a planning study for future transit service in the Downtown-Natomas-Airport (DNA) corridor, Sacramento Regional Transit District (RT) commissioned a survey of passengers at the Sacramento International Airport (SMF), and the estimation and application of a model of mode choice and potential transit usage of ground access to/from this airport using that survey. A memorandum by Bowman, Bradley, and Griesenbeck (July 3, 2002) describes the model development procedure and application methodology.

The mode choice model used four segments of travelers, resident business, resident leisure, visitor business, and visitor leisure, and numerous other traveler attributes, including whether the local trip was to/from a home (home-based or non-home-based). It also uses highway and transit network level-of-service measures obtained from a regional travel demand model. Application for forecasting used the sample enumeration approach with the survey cases "expanded" proportionally to forecasts of households and non-retail employment (for home-based and non-home-based cases respectively) in the "Regional Analysis District" (RAD) of the case's local origin or destination.

The Sacramento airport passenger access model was applied in spreadsheets, using imports of auto and transit travel times from the Sacramento regional travel demand system (SACMET), a copy of the survey data, expansion factors, and calculation formulas. Results summarized and compared for various transit alternatives included transit boardings by various geographical and access categories, and the Federal Transit Adminstration's (FTA's) SUMMIT analysis method of user benefit.

As part of a significant regional model development effort, the Sacramento Area Council of Governments (SACOG) has chosen to incorporate this airport passenger access model as a component. Instead of a spreadsheet application, this component is to run without user interventions (such as data imports and exports) in the Citilabs TP+ and Voyager modeling software. This application was first developed for use with the Sacmet model system, and was since adapted to SacSim.

While the original sample enumeration application was appropriate for forecasting aggregate transit ridership to/from the airport, and comparing aggregate user benefits, its sample size makes it "lumpy" for transit or highway traffic assignment. Furthermore, persons interviewed in the survey whose local origin or destination were outside the practical "RT-reachable" area were not interviewed any further, since they would not be relevant to transit forecasts to the airport. Thus excluded were respondents to or from many parts of Yolo and El Dorado Counties.

SacSim applies a new model of airport trip generation, and a modified sample enumeration method designed to generalize this airport access model to parts of the greater Sacramento area not covered in the survey and to potential urban growth areas, and to provide "smooth" highway and transit network assignments of modeled airport access ground travel. Post-mode-choice application, including diurnal factors for highway assignment, are covered in the later section on trip aggregating and processing.

Application Structure

This airport trip model application consists of three main phases:

1) Trip Generation,
2) Association of generated trips to representative survey trips, and
3) Mode Choice.

Each is described below in turn.

Additional calculations split auto and transit trips into time periods of the day, so they may be included in trip assignments onto the network. These are described in the later section on trip aggregating and processing.

Trip Generation

The spreadsheet application for 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). The airport trip generation rates used in this application were:

Home-based trips: 0.007 per household;

Non-home-based trips: 0.003 per non-retail employee, except the Downtown Sacramento RAD, with 0.010 per non-retail employee.

SacSim uses the same trip generation factors for non-home-based trips. But for home-based trips, improved trip generation methods accounting for zonal demographics were examined.

Table #AP1 compares the regional distribution of circa 2000 household size (number of persons) to the weighted distribution of household size of home-based trip survey respondents (499 cases). The implied trip generation rates are computed as the overall average rate times the ratio of the category's survey distribution percentage to the regional distribution. One-person households are relatively less frequent in the survey than in the region, implying a less-than-average trip generation rate; two- and three-person households are slightly more frequent, implying an above-average rate, while the rate goes back down to average for four-or-more-person households.

Table #AP1
Home-Based Airport Trip Generation based on Persons per Household

Persons per Household	Regional Distribution	Survey (HB) Distribution	Implied Trip Generation Rate per Household
1	23%	17%	0.0056
2	34%	36%	0.0079
3	18%	21%	0.0088
4+	26%	26%	0.0073

Table #AP2 makes a similar comparison based on autos owned in the household. The difference in distributions is quite distinct, implying a sharply increasing relationship of more trips from households with more autos. There is wide uncertainty, however, with the zero-auto category, having only 6 survey records.

Table #AP2
Home-Based Airport Trip Generation based on Autos in Household

Autos in Household	Regional Distribution	Survey (HB) Distribution	Implied Trip Generation Rate per Household
0	7%	1%	0.0013
1	31%	20%	0.0049
2	41%	42%	0.0077
3+	22%	36%	0.0121

Table #AP3 makes a comparison likewise on household income categories. There were 437 survey cases reporting an identifiable income category. A relationship is clearly discerned of increasing airport trip frequency with increasing income.

Table #AP3
Home-Based Airport Trip Generation based on Household Income

Household Income	Regional Distribution	Survey (HB) Distribution	Implied Trip Generation Rate per Household
Under $15k	13%	5%	0.0030
$15 to 35k	24%	11%	0.0034
$35 to 50k	17%	15%	0.0066
$50k to 75k	21%	22%	0.0078
$75k or more	26%	47%	0.0135

The rates based on household income categories are the tentative home-based trip generation model. But in the SACMET model's income categories, the second boundary ($35k) may be actually closer to $25k, so the second rate may be lowered and the third raised slightly.

The original airport trip generation application uses input data and procedures available in SACMET models, and the ?aox.txt and ?zbas.txt files. The first step uses classgen.bas, a program SACMET uses for cross-classified household trip generation. It uses the rates by income category from Table 3, and aggregates the trips into the demographic categories chosen for the next process (association). The next step uses the Tripgen program in TP+ to combine the household trip generation for each zone as "purpose 1 productions", and calculate the non-home-based trip generation, as "purpose 2 productions."

The SacSim application of the airport model replaces the SACMET cross-classification system with a direct use of households simulated by DaySim. Each household's number of persons, vehicles, and income is taken from person number 1's simulation output. 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. It is simple to modify the model code to provide control totals exogenously when desired.

Association of generated trips to representative survey trips

This model application phase seeks to choose which survey observations 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. (An option can be provided to pre-specify the control totals, and scale the trip generation to those totals.)

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*.)

Mode Choice

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
Auto Park at Airport
Taxi
Van
Transit Walk-Access
Transit Drive-Access
Transit Drop-Off Access

Table #AP4 lists 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 association-weight 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.

The mode choice model was verified using a modified application in which each survey record was kept in its own zone, and the mode choice results tallied by survey record instead of by zone. Debugging the TP+ mode choice application used record-by-record comparisons with a DNA Corridor Analysis spreadsheet. Aside from errors found in a few records of the spreadsheet, no substantial differences occur in mode shares between the spreadsheet and TP+ versions.

Table #AP4
Airport Ground Access Mode Choice Logit Model Coefficients

Num.	Variable	Resident Business	Resident Leisure	Visitor Business	Visitor Leisure
1	Segment Number	1	2	3	4
2	Auto Drop Const	0	0	0	0
3	Auto Park Const	0.5303	0.5303	0.106	-1.1104
4	Taxi Const	-1.5858	-2.1639	-0.3116	-1.8789
5	Van Const	-1.0737	-0.5921	-0.4271	-1.2767
6	Walk Access Const	0.5281	0.5281	0.705	0.705
7	Drive Access Const	0.1097	0.1097	-0.5949	-0.5949
8	Drop Access Const	-0.2191	-0.2191	0.3275	0.3275
12	Autos<Persons	-0.2494	-0.2494	0	0
13	1 Persons	-0.3995	0	0	0
14	3+ Persons	0	0.6422	0	0
15	Income<$50K	0	0.7416	0	0
16	Parking Cost	-0.0155	-0.0155	0	0
17	Van/Taxi Cost	-0.0191	-0.0003	-0.0191	-0.0003
18	Transit Cost	-0.0422	-0.0422	-0.0422	-0.0422
19	Main Mode Time	-0.0095	-0.0095	-0.0095	-0.0095
20	Walk and Transfer Time	-0.0518	-0.0518	-0.0518	-0.0518
21	Drive Access Time	-0.0079	-0.0079	-0.0079	-0.0079
22	Chauffer Time	-0.0055	-0.0003	-0.0055	-0.0003
23	First Transfer	0	0	0	0
24	Second+ Transfer	-0.845	-0.845	-0.845	-0.845
25	Walk Egress Time	-0.0183	-0.0183	-0.0183	-0.0183
26	Walk Egress Dummy	-0.0916	-0.0916	-0.0916	-0.0916
27	Shuttle Egeress Time	-0.0053	-0.0053	-0.0053	-0.0053
28	Shuttle Egress Dummy	-0.0526	-0.0526	-0.0526	-0.0526
29	Scale Factor for Utility	1.865	1.865	3.0869	3.0869

Airport trips by mode are converted to vehicle trips and split by time of day according to factors described below in the section on trip aggregating and processing.

Commercial Vehicle Trips

The commercial vehicle trip generation and distribution models were adapted directly from the current Sacmet model system. These models create trip matrices in two trip categories: 2-axle commercial vehicle trips, and 3+-axle commercial vehicle trips.

Generation and distribution include II, IX and XI together in each of the two trip categories.

The exogenous through-trips data include a matrix of 3+-axle commercial vehicle trips.

Time of day factors are tabulated in the next section.

Trip Aggregation and Processing

This process combines trips from DaySim, and the models of external, airport, and commercial vehicle trips.

The 24-hour day is divided into the four time periods as listed in Table #TP#. Supplemental time periods may be optionally extracted after the system model run, such as peak hours, after the equilibrium process is ended.

Table #TP#
Time Periods of the Day

Time Period	Begin	End
AM 3-hour	6:30	9:29
Mid-Day	9:30	14:44
PM 3-hour	14:45	17:44
Evening	17:45	6:29

DaySim Trip Segments

DaySim's "trip segments" weighted output is aggregated into zone-to-zone flows, stratified by mode and time period. Auto person-trips are already stratified by occupancy (see table 1 on mode code conventions), so they are easily converted to vehicle trips. Transit 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 specified from origin to destination without the location of the change of mode between transit and auto; the park-and-ride lot choice model in SacSim splits these trips into separate auto and transit segments.

External and Commercial Vehicle Trips

External (IX & XI) work, personal business, shopping, and social-recreational trips are expressed in zonal matrices of daily trips oriented from production to attraction. These are converted to vehicle trips stratified by occupancy, according to the factors in the above section on Mode Choice of External Trips. Concurrently, they are then converted to vehicle trips in the actual direction of travel in the respective time periods by means of the factors in Table #XTOD#. These factors were estimated from the travel-activity records in the 2000 regional household activity survey conducted by NuStats for SACOG, for trips reported as 30 or more minutes in length. (Survey records of trips beginning at a particular non-home activity represent the attraction-to-production direction; those ending at the activity represent the production-to-attraction direction.)

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 Table #XTOD#. These factors are adapted from the current Sacmet model system.

Table #XTOD#
Time-Of-Day Distributions Used for External Trips

	Work		Personal Business		Shopping		Social-Recreational	
Period	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod	Prod-Attr	Attr-Prod
AM (3 hours)	29.5%	1.8%	8.8%	3.7%	2.8%	2.7%	6.0%	2.9%
Mid-Day	10.1%	9.8%	26.4%	22.6%	23.1%	21.7%	17.3%	14.9%
PM (3 hours)	3.5%	30.0%	11.2%	16.5%	18.1%	17.8%	14.7%	11.7%
Evening	6.9%	8.4%	3.6%	7.2%	6.0%	7.8%	12.0%	20.5%

Source: SACOG NuStats 2000 Regional Household Survey, trips 30 or minutes long.

	Through	Comm. Veh. 2-Axle	Comm. Veh. 3+ Axle
Period	each direction	each direction	each direction
AM (3 hours)	18%	18.2%	18.2%
Mid-Day	36%	28.8%	32.5%
PM (3 hours)	18%	23.5%	14.4%
Evening	28%	29.5%	34.9%

Source: Sacmet Regional Model version 2001 et al.

Airport Ground-Access Trips by Mode

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.

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.

Airport Access Trips by Time of Day

The airport passenger survey that the airport mode choice model was based did not ask or record the time of day. No surveys of auto trips entering or exiting the airport were available that would yield time-of-day factors. The alternative basis is the time of day of air traffic. Southwest Airlines serves a large portion of Sacramento International Airport passengers, and publishes an extensive flight schedule list (downloaded 1/24/2006 from http://www.southwest.com/cgi-bin/retrieveSchedule). Since Southwest is reputed to practically fill all flights, its flight schedule time-of-day profile at Sacramento is assumed as representative of air travelers there in general. Counting only the weekday non-stop flights gives the time profiles of air operations at Sacramento. Shifting these profiles earlier for departures and later for arrivals approximates the times of the traveler going to or from the airport, which are summarized in Table #FLT#.

Table #FLT#
Time-Of-Day of Weekday Flights in Southwest Airlines Published Schedule for Sacramento
(for a period of early 2006)

Adjusted*	Number of Flights		
Hour	Depart	Arrive	Total
5	6	0	6
6	7	0	7
7	6	2	8
8	5	5	10
9	4	6	10
10	4	3	7
11	4	5	9
12	6	3	9
13	3	6	9
14	6	3	9
15	3	6	9
16	6	3	9
17	3	7	10
18	5	4	9
19	5	4	9
20	6	5	11
21	0	6	6
22	0	6	6
23	0	5	5
Grand Total	79	79	158

* Departures adjusted one hour earlier, Arrivals adjusted 20 minutes later, to approximate time of ground trip.

When these data are summarized by modeled time period (likewise adjusted for ground trip time), the profile in Table #ATOD# results. The percent of flights by period are used in the model application.

Table #ATOD#

Number of Flights				Percent of Flights		
Period*	Depart	Arrive	Total	Depart	Arrive	Total
AM	16	8	24	10%	5%	15%
Mid-Day	25	25	50	16%	16%	32%
PM	10	14	24	6%	9%	15%
Evening	28	32	60	18%	20%	38%
Grand Total	79	79	158	50%	50%	100%

* Departures adjusted one hour earlier, Arrivals adjusted 20 minutes later, to approximate time of ground trip.

Airport Park-and-Ride Trips

The airport travel demand and mode choice models include two modes of predicted park-and-ride trips: transit-drop and transit-park. These trips have the airport zone as the attraction, and the other zone (home or business) as the production. A parking zone is then chosen for each airport park-and-ride trip, so the resulting auto and transit trips can be added to the demand matrices and assigned to the respective networks. The section above titled “Park-and-Ride Transit Level of Service and Trip Processing” describes this process for DaySim trips as well as airport trips. Special provisions of the process for airport trips include:

1) There is no “pairing” of trip records as with DaySim trips. Instead, the time of day factors (Table #ATOD#) split half of the trips in the day as traveling toward the airport (for a departure) and half from the airport (from an arrival).
2) The trips are stratified by party size, a variable in the airport survey. The number of auto trips is obtained by divided by the traveling party size (up to a maximum of 4). The transit portion of the trips is kept in person trips. (It is not appropriate to factor up the person trips by the party size, since the model’s and survey’s unit of analysis is person trips, not parties.)
3) For each transit-drop auto trip, a reverse-direction auto trip is added, treating the auto chauffeur’s trip as a round trip.
4) In vehicle trip stratifications by occupancy, both air-travelers and chauffeurs are included. (In the return legs of transit-drop auto trips, only the chauffeurs are present.)
5) For transit-drop trips with traveling party sizes of 1 or 2, 80% are assumed to have one person as chauffeur, and 20% have an additional non-air-traveling person with the chauffeur. For party sizes of 3 or more, 90% are assumed to have one chauffeur, and 10% with a second non-air-traveling person. The chauffer and additional persons are not generated as person-trips per se in any models, they exist only implicitly in the stratifications of auto trips. These chauffeuring group profiles are judgmental assumptions, for lack of any applicable survey data.
6) All park-and-ride lots are considered available to airport park-and-ride access; the parking lot capacity restraint is disregarded.

Auto Assignment

Auto assignment is the accumulation of vehicle trips (in zonal matrices) onto links in the highway network that are in each trip's shortest set of paths.

Within the equilibrium solution process, the four periods of the day (AM 3-hour, mid-day, PM 3-hour, and evening, in Table #TP#) are each assigned separately. Daily traffic volumes are the sums of volumes from these four periods.

Auto assignment in SacSim is based on assignment in the SACMET model system, and uses the same network file as a comparable SACMET model. The SACMET network coding conventions are described in that model's documentation (DKS, 2002), including link classification systems for capacity and volume-delay relations, HOV links, pedestrian links, etc. Some network coding conventions may be revised shortly before or after release of SacSim, along with documentation of them.

This application is a simultaneous multi-class assignment. The classes are (1) single-occupant vehicles, including commercial vehicles, (2) a portion of the multi-occupant vehicles designated to have all HOV facilities available, and (3) the remainder of the multi-occupant vehicles that are kept off from freeway median HOV lanes but allowed though ramp meter bypass lanes. Studies have found a significant share of HOVs on such freeways are not always actually in the HOV lane. Models of this behavior have been developed, and applied in corridor studies (DKS 1994, Long, Gibb, Garry 1994), but are difficult to apply in practice throughout the region. This implementation splits HOVs like SACMET: 70 percent are enabled to use all HOV facilities including median lanes, and 30 percent are prevented from using median HOV lanes.

SacSim apples the same "conical" volume-delay functions (Spiess, 1990) as the SACMET model system (DKS Associates 2002). These functions specify a factor upon the traversal time of each link, relative to free-flow time; the argument of the functions is the volume-to-capacity ratio (*v/c*) of flows on the link. To ensure uniqueness and solvability of assignment equilibrium, these functions are strictly increasing for all positive *v/c* ratios, and asymptotically approach linearity at extremely high *v/c*.

Conversion of hourly link capacities to period capacities accounts for varying traffic flow intensities within each assignment period. If traffic flow were uniform in a period, its capacity factor would simply be the number of hours. But because it is not, the effective capacity factors are less than the number of hours in the period. Table #ASN2# shows the effective capacity conversion factors for each period, which were taken from SACMET.

Table #ASN2#
Effective capacity factors

Period	Effective Capacity Factor (relative to hourly capacities)
AM 3-hour	2.77
Mid-Day	5.00
PM 3-hour	2.77
Evening	6.25

Auto assignment in this model system (and SACMET) uses a standard deterministic user equilibrium algorithm using the Frank-Wolfe iteration system. For each iteration within assignment, a tree-building algorithm forms paths on currently shortest routes, and a step size is chosen to determine to what extent to divert trips to the new paths so as to progress closer to equilibrium. Ideal equilibrium achieves Wardrop's criterion, that no traveler can reduce travel time by shifting to another route. Each auto assignment approximates this equilibrium for the trips being presently assigned during any iteration of the SacSim system-equilibrium solution. As such the assignment algorithm's iterations are nested within the SacSim system's iterations; the assigner determines the step sizes for its own iterations independently of SacSim's overall iteration structure.

The assigner in TP+ offers several options of stopping criteria, to automatically decide whether as assignment is sufficiently close to equilibrium to stop iterating. The chosen criterion is the "relative gap." The total gap is the total vehicle-time that can be saved by each trip unilaterally switching to the shortest route; the relative gap criterion in TP+ is the ratio of total gap to total vehicle-time traveled. (Some other software packages, such as EMME/2, define this differently.) This measure is particularly pertinent in a system equilibrium context: skim times, which are measured on the final shortest route, should be consistent with times on the actual routes used; the relative gap measures this consistency. Also, while the relative gap does not strictly decrease from one assignment iteration to the next, this measure is greater than or equal to a quantity that does. Alternative measures, such as fractional change in vehicle-time, vary erratically between assignment iterations, and frequently cause premature stopping.

Between early iterations of the model system, the zone-to-zone travel times fluctuate, so it seems that a "loose" assignment stopping criterion, preferably within the margins of the zone-to-zone time fluctuation, is appropriate. As the system converges, the assignment stopping criterion should become correspondingly tighter. Work is ongoing to determine just how to balance the stopping criterion with the convergence of travel times, but meanwhile, satisfactory results are achieved using a relative gap criterion of 0.002 in the first system iteration, gradually decreasing it to 0.0002 in the final 4 or 5 system iterations.

Transit Assignment

Transit assignment is the accumulation of transit trips aggregated into zonal matrices onto links in the transit network that are in each trip's shortest set of paths. Transit assignment calculations use the same program, methodology, highway network and transit line data as transit skim time calculations, just different input and output options.

Transit assignment is performed in two periods, peak and off-peak. The peak period is the combination of the AM and PM 3-hour periods used in auto assignment; the off-peak period is the combination of mid-day and evening. PM and evening trips are assigned in the reverse direction, to approximate a production-to-attraction orientation, and because most peak-only services run the opposite way in the PM as in the AM. (This means actual boardings at a station should be taken as half the sum of modeled "boardings" and modeled "alightings.") Transit assignment is not subject to congestion delays due to transit passenger volumes, so it does not need to be calculated during the system equilibrium process. It is a post-run option.

Walk-access transit trips are assigned from zonal matrices aggregated from DaySim trip output into the two time periods. Each pair of auto-access transit trips (leaving and returning to the car) is first assigned a parking zone by the park-and-ride lot choice model described above. Then the transit portions of those trips are aggregated into their respective time periods, with both trips oriented from the parking zone to the other zone(s) in keeping with production-to-attraction orientation.

System Equilibrium

In the overall system design of SacSim, Figure 1 shows a cyclical relationship between network performance and trips: DaySim and the auxiliary trip models use network performance measures to model person-trips, which are then loaded to the network, determining congestion and network performance for the next iteration. The model system is in equilibrium when the network performance used as input to DaySim and the other trip models matches the network performance resulting from assignment of the resulting trips. Network performance for this purpose is times, distances, and costs measured zone-to-zone along the least-time paths (or more specifically, the paths of least generalized cost).

Trip-based model systems with this same requirement have existed for at least thirty years (Evans, 1976), and the theory of system equilibrium for them is well developed now. A wide range of trip-based models have a fixed point solution for all zone-to-zone and link flows, which can be solved with proper algorithms. These have been rare in practice until the 1990s, which saw development of many convergent model systems. Unfortunately, many four-step models have been applied with naïve "feedback" schemes that do not reliably converge.

Almost all convergent trip-based models, at some stage in an iteration process, use the method of convex combinations. This is to update the current best solution of flows (zone-to-zone matrices and/or link volumes) with a weighted average of the previous best solution of those flows ($\mathbf{x}_{i\text{-}1}$), and an alternative set of flows calculated by the new iteration ($\mathbf{y}_i$): $\mathbf{x}_i = (1-\lambda)\mathbf{x}_{i-1} + \lambda \mathbf{y}_i$, where the step size λ must satisfy $0 < \lambda \leq 1$. (In the first iteration, there is no $\mathbf{x}_{i\text{-}1}$, so λ must be 1. The first iteration normally uses network performance skim matrices based on free-flow link times.) When flows are combined in this manner, the result meets the same conservation-of-flow constraints as the iteration matrices.

Several trip-based model systems are defined so that the step size can be chosen at each iteration to optimize an objective function, or approach the solution to a variational inequality. But most models in practice do not satisfy those models' specific requirements, so the step size must be predetermined. The classic reliable workhorse is the Method of Successive Averages (MSA). This reliably converges for a wide range of models for which there is no determination of an iteration's optimal λ. This method chooses $\lambda = 1/i$, so that, in effect, after any iteration *n*, the solution approximation is the average of all the iteration-result vectors computed so far: $\mathbf{x}_i = \frac{\mathbf{y}_1 + \mathbf{y}_2 + \ldots + \mathbf{y}_i}{i}$. Some trip-based models converge reliable and more efficiently with a fixed step size (Bar Gera and Boyce, 2006), though care must be taken in the choice of that step size, which depends on the problem. (Sacmet uses a fixed step size, originally because of software limitations.)

Equilibrium theory of trip-based models has unfortunately not been extended into activity-based models. In these, zone-to-zone flows are only an indirect result of more complex behavior models which cannot be reduced to the terms of the established equilibrium trip-based models. Activity models also have excessively vast choice sets to be able to split travel among all alternatives in proportion to their probability. Consequently, most, such as DaySim, are applied as Monte Carlo processes, randomly generating one outcome (household trip diary) per unit of analysis (household or person).

Fortunately, trips from DaySim can be subjected to convex combination methods such as the method of successive averages, or with fixed step sizes.

With the unit of analysis being households instead of origin-destination pairs, come options not normally available to trip-based models. DaySim need not simulate the entire synthetic population in an iteration; it is able to run a selected sample of the population. Since its runtimes are long but proportional to the number of households modeled, early system-iterations can be sped up by simulating small samples. DaySim's sample processing scheme partitions the households, so successive iterations may run successive partitions. Coordinating this approach with MSA enables the modeled flows to be constituted from the entire population with each member represented with equal weight. Preserving equal weights is not required, but it minimizes the random variance of trip flows. An example of this approach with MSA is:

Iteration 1: Simulate households numbered 1, 11, 21,… All have expansion weight of 10, to scale the trips to the scale of the whole population.

Iteration 2: Simulate households 2, 12, 22,… The expansion weight is still 10. MSA combines flows to 1/2(Iteration 1 flows) + 1/2(Iteration flows). Now 2 out of 10 households are present, each with an effective expansion factor of 5.

Iteration 3: Simulate households 3, 13, 23,… with expansion factor 10. MSA combines flows to 2/3(Iteration 2's MSA flows) + 1/3(Iteration 3 flows). Now 3 out of 10 households are present, each with an effective expansion factor of 3.3333.

When iteration 10 is performed and combined by MSA, trips from all the households are present, each with a weight of 1.

This method, if enough iterations are specified, can converge flows and travel times within the range of random uncertainty.

Since the unit of analysis is individual households and their members, post-model analysis may examine their individual choices and travel costs incurred. A conflict between the MSA method and post-hoc analysis of the simulated trips is that households in the early iterations incur significantly different travel costs than the converged costs, and make their choices based on these. Three solutions are:

1) After completing all households by MSA, resimulate all the households' activity and travel based on the final MSA result's travel times, and/or
2) Cut the MSA process short after reasonable early convergence, and start it over, beginning with the latest travel times, and running it though to completion.
3) Rerun the system with more iterations and a proportionately lower sampling rate.

Solution 1 ought to give the "cleanest" post-analysis of all individuals, since all input travel times are consistent, and all simulation data records are in single files rather than split among several. Note that the travel times resulting from assignment of the final total simulation will still not exactly match those used to perform that simulation, because the final simulation yields randomly different trips than those accumulated in the MSA process. Solution 2 is valid for some post-analyses of the individuals that don't depend on all individuals having exactly equal travel times. It is also a potential strategy to reach the neighborhood of equilibrium with less simulation effort, and may be combined with solution 1. Solution 3 reduces the number of households simulated during early iterations.

Equilibrium Solution Procedure

The equilibration procedure employs equilibrium assignment iteration loops (a-iterations) nested within iterations between the demand and assignment models (da-iterations). This is similar to the nested iteration in many trip-based model systems.

Assignment is run for four time periods, and each one employs multi-class equilibrium assignment, with classes composed of SOV, HOVs not using median HOV lanes, and HOVs using them. A convex combinations algorithm is used, with the step size α determined automatically by the TP+ software, and closure criteria determined by the user: maximum number of iterations (N_i), and relative gap as defined by TP+ (g_i). Iterations stop when one of the closure criteria is satisfied.

There are a number of points in the model stream where it is possible to apply the convex combinations as a "blending" of trips and/or volumes. The following are prevalent in the literature for convergent models:

(1) "Pre-assignment blending" - Blend the trip demand matrices from the system-iteration's demand model, with the previous system-iteration's blended trips, into a weighted average. (Boyce et al. 1994) Then assign these new blended trips in equilibrium.
(2) "Post-assignment blending" - assign the new iteration trips alone in equilibrium, and afterwards blend those volumes with the previous system-iteration's blended link volumes. (Boyce, Zhang, Lupa 1994.)
(3) Assign each iteration's trips in an all-or-nothing assignment on the same paths used to derive the skims. (e.g. Evans 1976) Most modeling software, and the several whole-matrix processes in the SacSim system (and most trip-based models) conspire against the practicality of such an approach. Consequently, the Evans model and numerous generalizations (Miller 1997) are rarely used in practice.

An alternative blending method during assignment was studied and found to reduce run-times considerably. In this method, the step-size fraction of the new demand is assigned while the complementary proportion of the previous system-iteration's final volumes is kept as a preloading. Link time calculations always include this blended volume. In effect, preloaded traffic (from previous system iterations) is fixed on its route choices, while the iteration's demand trips are allowed to change routes until optimal, accounting for the preloaded traffic. Several tests indicate this method yields assignments that compare reasonably (though not identical) to assignments of blended trip matrices, but converge with far fewer assignment iterations.

In the *i-th* da-iteration, DaySim is run on a subset of the synthetic population, consisting of the fraction $1/s_i$ (i.e. $100/s_i$ percent) of the households, starting with the m_i-th household and proceeding uniformly every s_i households. The user determines s_i and m_i. DaySim scales up the synthesized trips by the factor s_i before they are combined with the estimated external, airport and commercial trips in mode-specific OD matrices for the four assignment time periods. During the *n-th* a-iteration within the *i-th* da-iteration, link volumes are estimated for the iteration i OD matrices, and combined in a convex combination with link volumes from the prior da-iteration, using a user-specified combination factor (or step-size) λ_i. This is the preloading method intended to prevent link volume oscillation between da-iterations. The resulting estimated volumes are then combined with link volumes from the prior a-iteration using the TP+-determined step size α as described in the previous paragraph. This is intended to prevent link volume oscillation between a-iterations.

The above description corresponds with the following algorithm:

0. Set starting link times $\{t_a^1\}$ using free flow times.
1. Calculate shortest paths and skim OD matrices *C*, with elements $C_{krs}^i(\{t_a^i\})$, where *k* indexes skim variables, and *r* and *s* index origin and destination zones.
2. Run DaySim and trip-based demand models, generating OD flow matrices *f*, with elements $f_{rs}^i(C)$.
3. Run multi-class user equilibrium assignment:

3.0. Set $t_a^{i,0} = t_a^{i-1}$ for all links *a*, the final link time from iteration *i*-1, or freeflow if *i*=1. Set *n*=1.

3.1. Perform all or nothing assignment based on the current link travel times, yielding this a-iteration's shortest-path link volumes $\tilde{y}_a^{i,n}(\{t_a^{i,n-1}\},\{f_{rs}^i\})$ for all links *a*.

3.2. Adjust this a-iteration's new link volumes by blending with link volumes from the previous da-iteration, $y_a^{in} = \lambda_i \tilde{y}_a^{in} + (1-\lambda_i)x_a^{(i-1)}$ for all *a*. (Notes: This step is intended to prevent link flow oscillation between da-iterations. λ_1 must be set to 1 if there are no previous da-iteration link volumes. $x_a^{(i-1)}$ refers to the values at the final *n* during the prior *i*.)

3.3. Solve for α for which $\sum_a t_a((1-\alpha)x_a^{i,n-1} + \alpha y_a^{i,n})(y_a^{i,n} - x_a^{i,n-1}) \approx 0$. ($\alpha = 1$ in a-iteration 1.) Set new a-iteration's link volumes by blending this a-iteration's new link volumes with the a-iteration's link volumes: $x_a^{i,n} = (1-\alpha)x_a^{i,n-1} + \alpha y_a^{in}$ for all *a*. Compute new link times from those volumes, $t_a^{i,n}(x_a^{i,n})$. (This step is intended to prevent link flow oscillation between a-iterations.)

3.4. Check that the closure test statistic, "relative gap" = $\dfrac{\sum_a (t_a^{i,n-1}x_a^{i,n-1} - t_a^{i,n-1}y_a^{in})}{\sum_a t_a^{i,n-1}x_a^{i,n-1}}$, is less than a user-specified tolerance criterion.
IF fail, THEN increment *n* and go to step 3.1
ELSE IF *i*<*I* THEN increment *i* and go to step 1
ELSE DONE and final values of link volume, link time, zone-to-zone travel costs, and zone-to-zone flow are $\{x_a^i\},\{t_a^i(\{x_a^i\}\},\{C_{krs}^i(t_a^{i-1})\},\{f_{rs}^i\}$. (Note: final link volumes and times come from last d-a iteration's assignment, but final OD flows come from prior iteration's link times.)

As implemented, the equilibration procedure runs for a user-determined number (*I*) of da-iterations. Within each iteration, the user controls the synthetic population subset used by DaySim (via s_i and m_i), their weight (λ_i) given during assignment to the link volumes associated with this iteration's simulated trips, and the assignment closure criteria (N_i and g_i).

Note that, with the above algorithm, although a specified level of convergence (relative gap) is automatically met for assignment within each da-iteration, there is no assurance that a corresponding level of convergence will be met across the da-iterations (da-convergence). Indeed, the algorithm does not yet specify a formal measure for testing the level of da-convergence that has been achieved when it terminates. Work will continue to define such a measure and to also identify appropriate parameter settings to hasten da-convergence. The next section discusses parameter schedules that have been considered, and it is followed by a section of experimental findings related to parameter settings and da-convergence.

Selections for Iteration Parameters

The iteration parameters specifying the household sampling for DaySim s_i, m_i, and the da-iteration step size λ_i are specified in advance of a SacSim run, due to the lack of a reliable basis on which to choose these automatically while a run progresses. Experimental runs have provided experience from which to choose these parameters, as is discussed below.

Basic MSA with *I* iterations is specified using $s_i \equiv I$, $m_i = i$, and $\lambda_i = 1/i$. This method samples an equal number (within 1) of households in each iteration, and when complete, each household has been simulated exactly once, and each household's trips contribute equally to the overall demand.

A variation is "staged MSA." This starts over the MSA procedure at some iteration; this iteration keeps the latest skims but does not average in the old trips and volumes. Staging is specified with $\lambda_i = 1$ for a start-over iteration, then choosing s_i, m_i, and λ_i afterwards as if the start-over iteration is iteration 1. An empirical test-run series is described below using only the first four iterations of a 30-iteration MSA schedule, then starting over with a complete 8-iteration MSA schedule, then one final pass through the complete population specified with all three parameters = 1. Table X (below in Experimental Study) details the specifics of a family of test models with the staged MSA design.

An iteration schedule with a constant step size of one-half was also tested. Experience with this constant step size has been generally favorable with trip-based models. A parameter schedule for a pass through the population in *I* iterations is shown in Table #W#:

Table #W#
Constant Step Size Iteration Schedule,

General Form for *I* Iterations

i	s_i	m_i	λ_i
1	2^{I-1}	2^{I-1}	1
2	2^{I-1}	2^{I-2}	0.5
3	2^{I-2}	2^{I-3}	0.5
4	2^{I-3}	2^{I-4}	0.5
…	…	…	…
I	2	1	0.5

This iteration schedule provides that the sampling rates double with each iteration (except the first and second are equal), and that, when complete, each household will have been simulated exactly once, and each household's trips contribute equally to the overall demand. A final pass through the complete population may be specified afterwards, to give a complete, consistent simulation database. Some potential advantages of this method over regular MSA is that early iterations are sped through at low sample rates, their residual results comprise a small fraction of the final results, and experience indicates it converges in fewer iterations than MSA.

Both the MSA and constant step size test-models preserve each sampled simulation's relative weight, that is, they ensure that each simulation of a household's trips contribute equally to the overall demand. This is accomplished by choosing $\lambda_i = \dfrac{\frac{1}{s_i}}{\sum_{j=1}^{i} \frac{1}{s_j}}$. While not necessarily required to achieve equilibrium, coordinating the sampling rate and the step size in this manner minimizes the random variance of the blended trip demands due to the Monte Carlo process that creates them. This is because the variance of t trips arising from sampling rate s is st (i.e. t/s independent events have variance t/s, scaled by s^2), so a weighted average of trips t_1 at sampling rate s_1, and trips t_2 at sampling rate s_2, has variance $(1-\lambda)^2 s_1 t_1 + \lambda^2 s_2 t_2$, which is minimized at $\lambda = \dfrac{\frac{t_2}{s_2}}{\frac{t_1}{s_1} + \frac{t_2}{s_2}} \approx \dfrac{\frac{1}{s_2}}{\frac{1}{s_1} + \frac{1}{s_2}}$.

(This principle should probably not be rigidly upheld on a model that takes several iterations to approach equilibrium. Poor convergence is also a source of error. Such determinations are problem-specific.)

For both the MSA and constant step size methods investigated here, the household sampling schemes select households for simulation in a predetermined manner such that in a fixed set of iterations, each household is simulated once, within one of the iterations. This specification is also not strictly required for equilibrium if any subsample chosen on intervals of the household ID number is unbiased. But to draw each sample once should minimize Monte Carlo randomness compared to an equal number of draws that skip some households, sample some once, some twice, etc. (i.e. draws with replacement). To satisfy this specification and the former on preserving relative weights, using DaySim's procedure to draw samples, requires the iteration procedure to use certain qualitative forms, the two most obvious of which are investigated here.

Either of these iteration parameter schedules is predetermined. The test applications discussed in this report examine approximations to system equilibrium that can be achieved using these schedules with one simulation per household (or slightly more). If, for a given application, a higher precision in zone-to-zone times or other system output is needed, an enhanced schedule can be implemented. Several options exist for improving convergence precision and/or reducing variation caused by Monte Carlo simulation. These include the following, alone or in combination:

1) tightening the assignment's relative gap closure criterion, especially in later system iterations
2) adding more system iterations with smaller step sizes and/or smaller first sample
3) adding more system iterations that simulate schedules for the entire synthetic population
4) running the entire model system multiple times and averaging the results
5) coordinating random number seeds across policy scenarios and measuring differences
6) running the model system with a synthetic sample significantly larger than the actual population, and rescaling each iteration's resultant trip matrices accordingly before assignment

Options 1-3 adjust the iteration schedule to improve convergence, but cannot reduce or eliminate the effects of random simulation error. Options 4 and 5 reduce the effects of random simulation error but do not affect convergence of a single run. Option 6 does both. Further experimental and theoretical study is needed to determine the interactions of equilibrium precision and trip demand precision. That is, what kind and amount of equilibrium tolerance is sufficient to ensure a trip demand quantity's random error is close to what is expected at its sampling rate? This experimental study should hopefully lead to further efforts to answer these questions.

Experimental Study

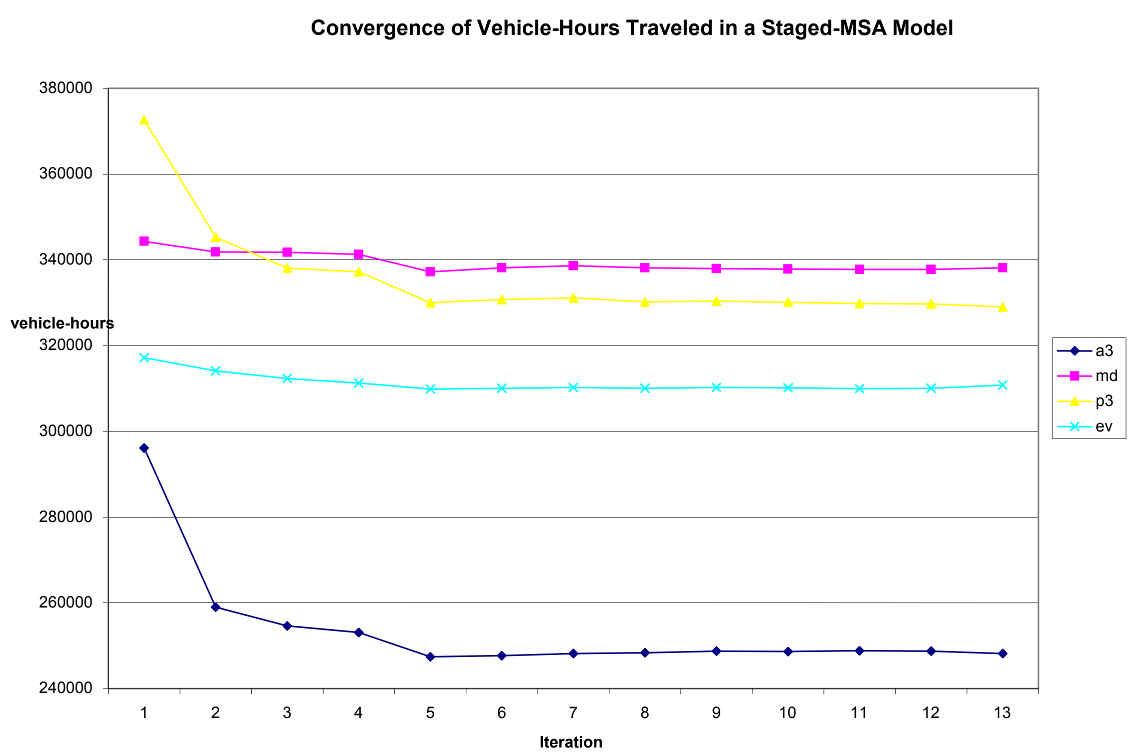
After a variety of early experiments to test and refine various details of the model system, an MSA schedule in two stages was coded and run several times, identically except for the random-number seed in DaySim. (To reduce randomness, the same synthetic population was used in all test runs, rather than regenerated as in the standard procedure.) This schedule is the staged-MSA example described above. This staging was devised to (1) eliminate residual effects of the first iterations, when the times and volumes fluctuate the most, faster than MSA alone will, and (2) accomplish these early iterations with a lower sampling rate, reducing run times. A final stage passes through all the households, to generate a complete, consistent database of a simulation for post-hoc analysis. Table #X1 lists these iteration parameters.

Table #X1
Experimental Staged MSA Iteration Schedule

i	s_i	m_i	λ_i	households sampled (index)
1	30	1	1.0000	1, 31, 61…
2	30	2	0.5000	2, 32, 62…
3	30	3	0.3333	3, 33, 63…
4	30	4	0.2500	4, 34, 64…
5	8	1	1.0000	1, 9, 17… (start over)
6	8	2	0.5000	2, 10, 18…
7	8	3	0.3333	3, 11, 19…
8	8	4	0.2500	4, 12, 20…
9	8	5	0.2000	5, 13, 21…
10	8	6	0.1667	6, 14, 22…
11	8	7	0.1429	7, 15, 23…
12	8	8	0.1250	8, 16, 24… (completes all HH)
13	1	1	1.0000	1, 2, 3, 4… (final full pass)

The SacSim model thus specified was run with year 2000 existing conditions demographic, employment, and network data, using a fairly complete DaySim (including the time-of-day models), but not the final coefficients. Figure A shows convergence of vehicle-hours traveled (VHT) for the four time periods of the day, in one typical run.

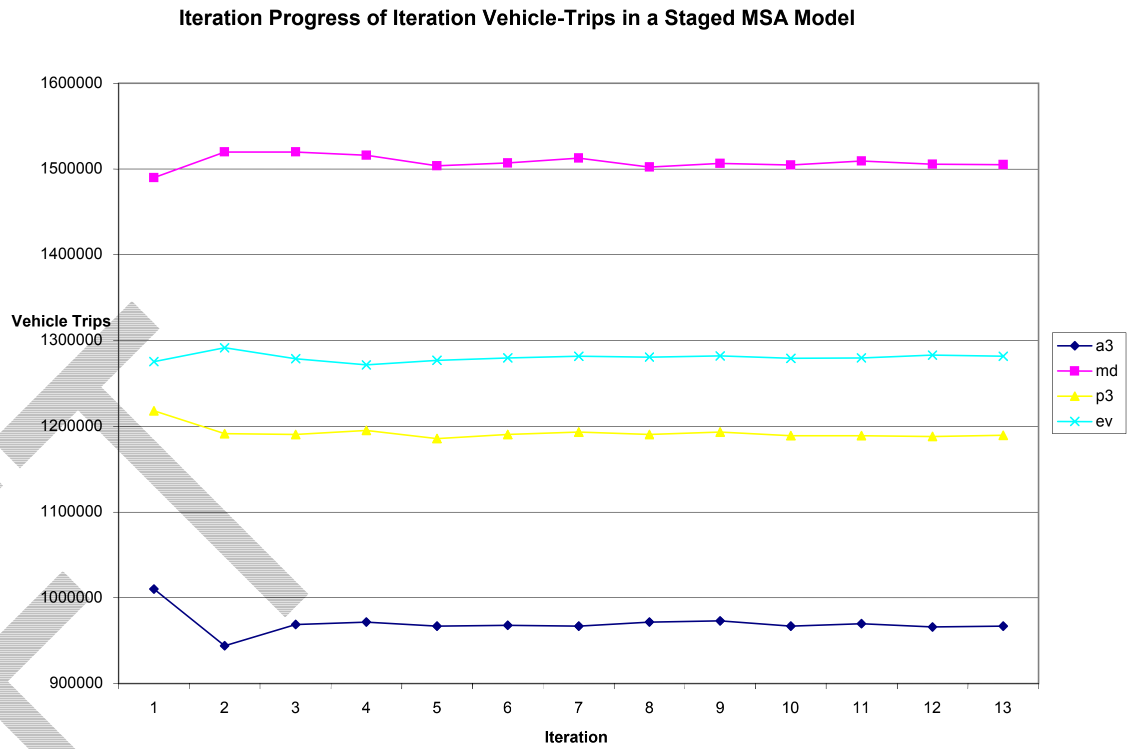
Figure A



The peak period vehicle-hours drop rapidly from the first to the second iteration, because the demand in iteration 1 is based on free-flow conditions, while the demand from iteration 2 is the average of the iteration 1 demand and the first estimate of congested conditions. Some of this is due to demand shifting from peak to off-peak time periods, some is due to shortening of trip length, and some might be from changes in the number of trips. Vehicle-hours change more slowly afterwards, partly due to convergence of demand, and partly due to the decreasing step size dampening the fluctuations in the system. Iteration 5 is a start-over, so it is not dampened by step size averaging. That iteration 5 jumps to near the final values after three iterations of gradual progress is evidence that the MSA step sizes get too small too soon. But this also shows that a few iterations across a small sample are sufficient to reach the neighborhood of a converged solution, and serve as a good starting point for a group of iterations that collectively process the whole population. Some random movement is expected for iteration 13, since it starts over with a new simulation and does not average it with the previous. (In early runs with a lax and improperly specified assignment closure criterion, iteration 13's VHTs usually jumped up a small but significant amount compared to late-iteration fluctuations.)

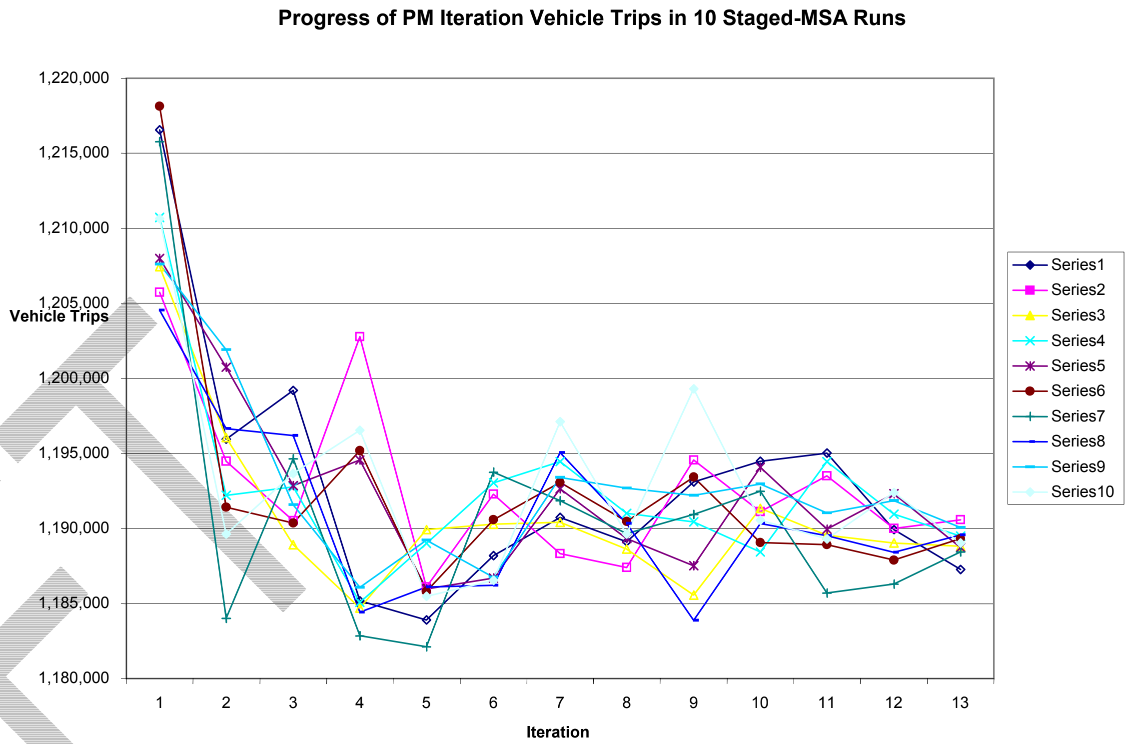
Figure B tracks the number of vehicle trips produced by the demand models during each iteration, in the same model run as above. Note these are not successively averaged. (The link volumes are.) It appears the first iterations show a shift from peak to off-peak time-of-day choice, more than a reduction in total vehicle trips, due to congestion. Random fluctuation is evident, but an amount is expected due to the Monte Carlo process.

Figure B



Specifically, the standard deviation of an amount of iteration trips from DaySim (in whole or a defined category) is approximately $\sqrt{s_i t_i}$, where t_i is the number of trips, and s_i is the sampling rate, which is also the scale used to expand the individual simulations up to the scale of the population. So, for example, the number of PM trips during any iteration in the 8-iteration stage has a standard deviation of approximately $\sqrt{8(1{,}190{,}000)} \approx 3100$, so the range of fluctuation should mostly be within ±2σ, or ±6200, which is 0.5%. To further examine random fluctuations, Figure C shows the PM iteration vehicle trips for ten runs of this model, each identical in inputs except for the random number seed for DaySim. The widest random fluctuation is seen in the first four iterations, as would be expected; in the fourth to the twelfth iteration, almost all are within the theoretically predicted spread of ±6200, while the final values from a full-population simulation have a much smaller spread (predicted near ±2200).

Figure C



Some measures of convergence were examined that summarize changes in zone-to-zone travel time during each iteration, from the skimming before the demand models, to the skimming after assignment. The first measure is the largest absolute change in skimmed travel time for O-D pairs having at least one trip; the second is the root-mean-square (RMS) average travel time change across all O-D pairs, weighted by the number of trips. Figure D summarizes the absolute change statistics for one of these staged-MSA runs. The most varying period, the PM peak, fluctuates within around ±2 minutes in its extreme O-D change; that is, between the next to last and last iteration, the O-D pair with the biggest change in auto travel time saw a change of about 2 minutes. Figure E shows the RMS average travel time change for that run. In the late iterations, the RMS average travel time change for the PM period is below 0.2 minutes, and is less for the other periods.

Figure D

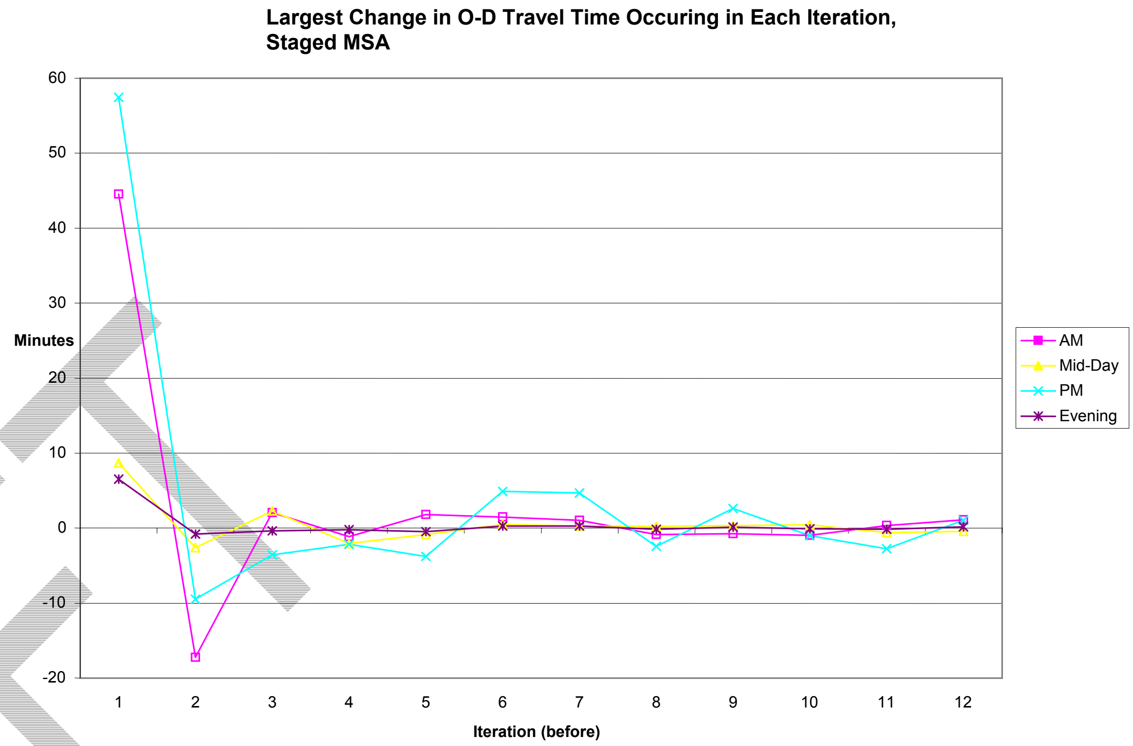

Largest Change in O-D Travel Time Occuring in Each Iteration,
Staged MSA
60
50
40
30
20
10
0
-10
-20
Minutes
1
2
3
4
5
6
7
8
9
10
11
12
Iteration (before)
AM
Mid-Day
PM
Evening

Figure E

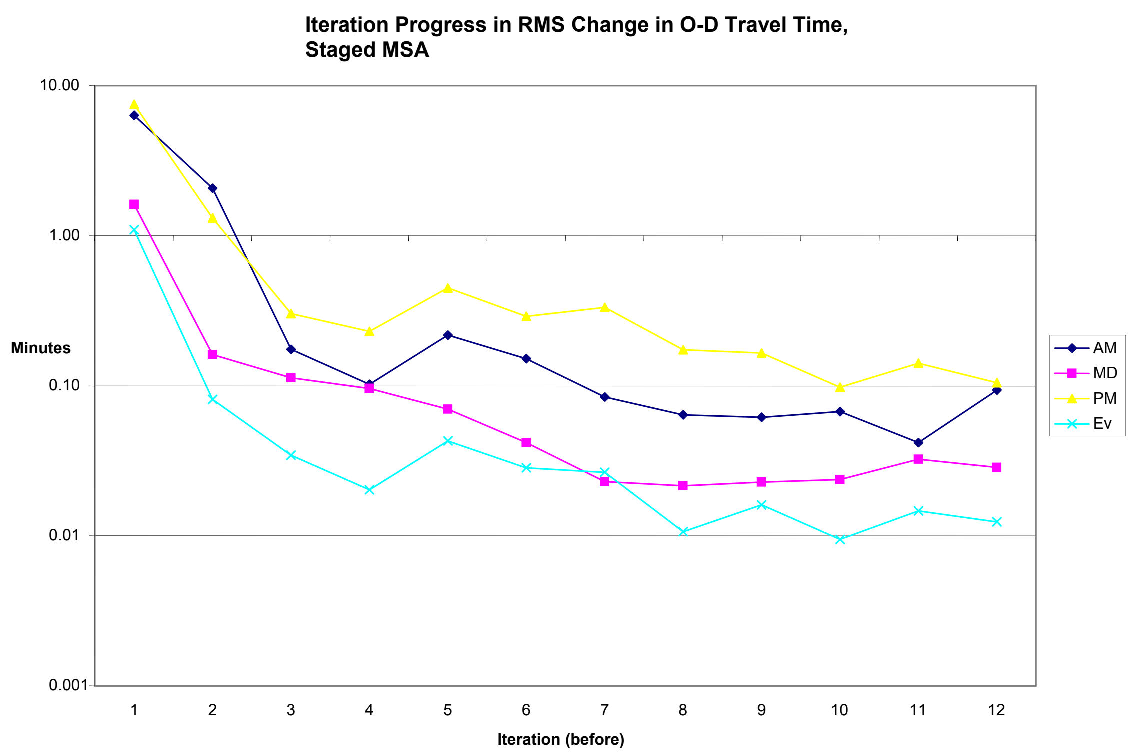

Iteration Progress in RMS Change in O-D Travel Time,
Staged MSA
10.00
1.00
0.10
0.01
0.001
Minutes
1
2
3
4
5
6
7
8
9
10
11
12
Iteration (before)
AM
MD
PM
Ev

Table Y shows an iteration schedule used in a series of experimental constant step-size runs. This particular sampling scheme can be easily adapted to different numbers of iterations, but not to a different constant step size.

Table Y
Experimental Constant Step Size Iteration Schedule

i	s_i	m_i	λ_i	Series of households sampled
1	128	128	1	128, 256, 384, 512...
2	128	64	0.5	64, 192, 320, 448...
3	64	32	0.5	32, 96, 160, 224...
4	32	16	0.5	16, 48, 80, 112...
5	16	8	0.5	8, 24, 40, 56...
6	8	4	0.5	4, 12, 20, 28...
7	4	2	0.5	2, 6, 10, 14...
8	2	1	0.5	1, 3, 5, 7... (completes all HH)
9	1	1	0.5	1, 2, 3, 4... (final full pass)

Figures G, H,… show comparable iteration convergence statistics for these runs. When comparing them to those from the staged MSA models, recall that (1) small step sizes dampen changes in some statistics, and (2) this model makes 2 total passes through the population, and the staged MSA model uses just slightly more, 2.13 passes.

Figure G

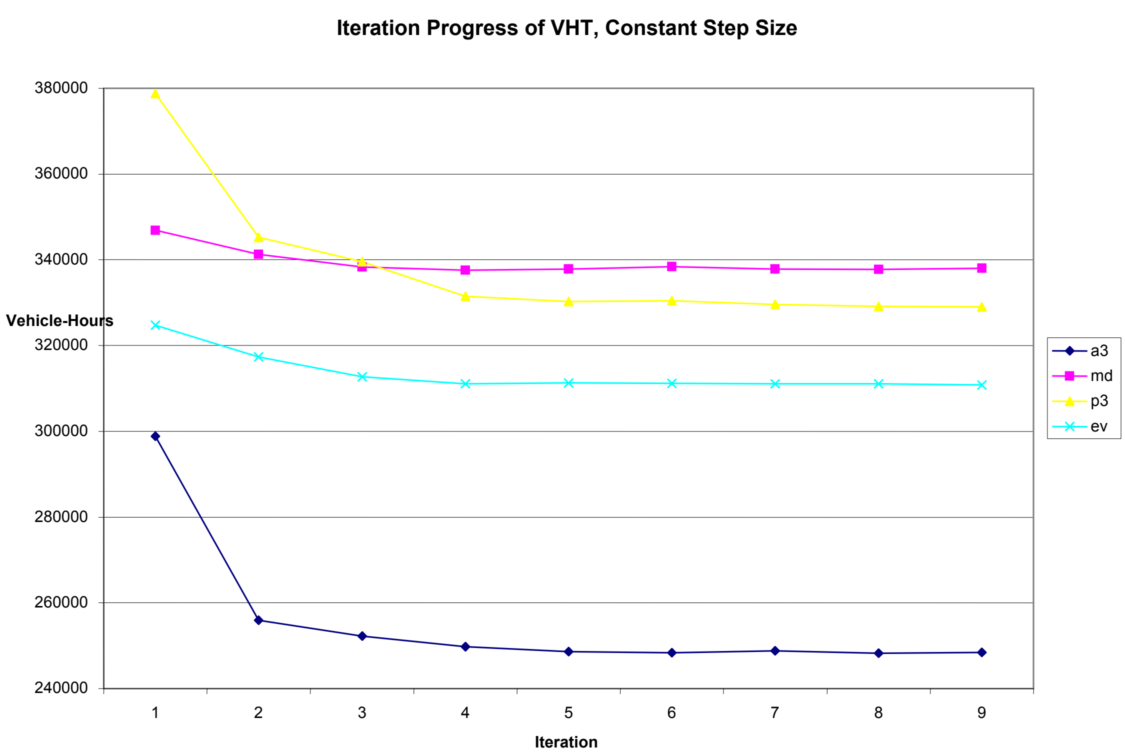


Figure H

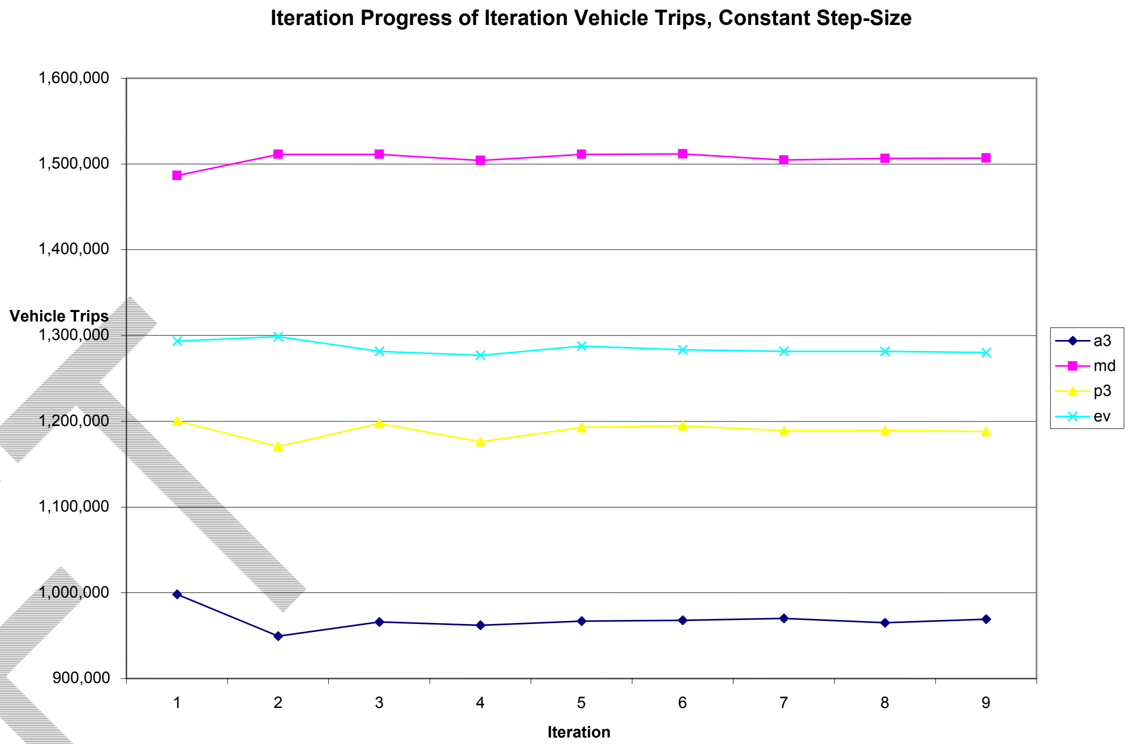


Figure I

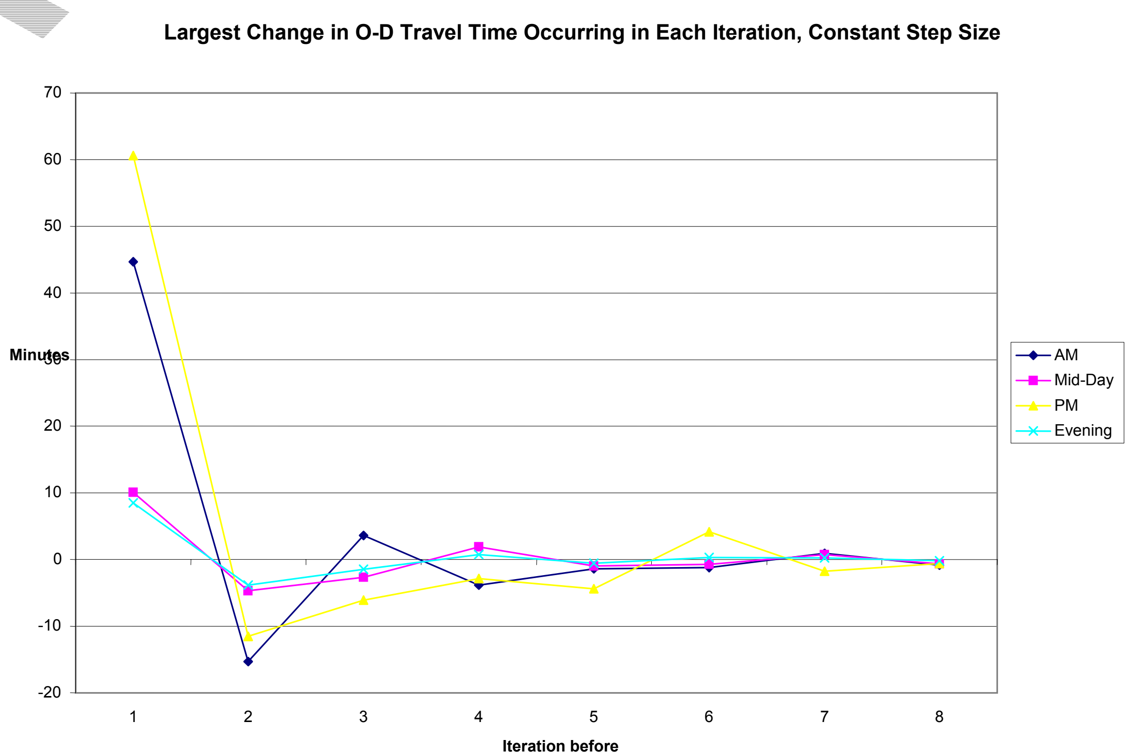
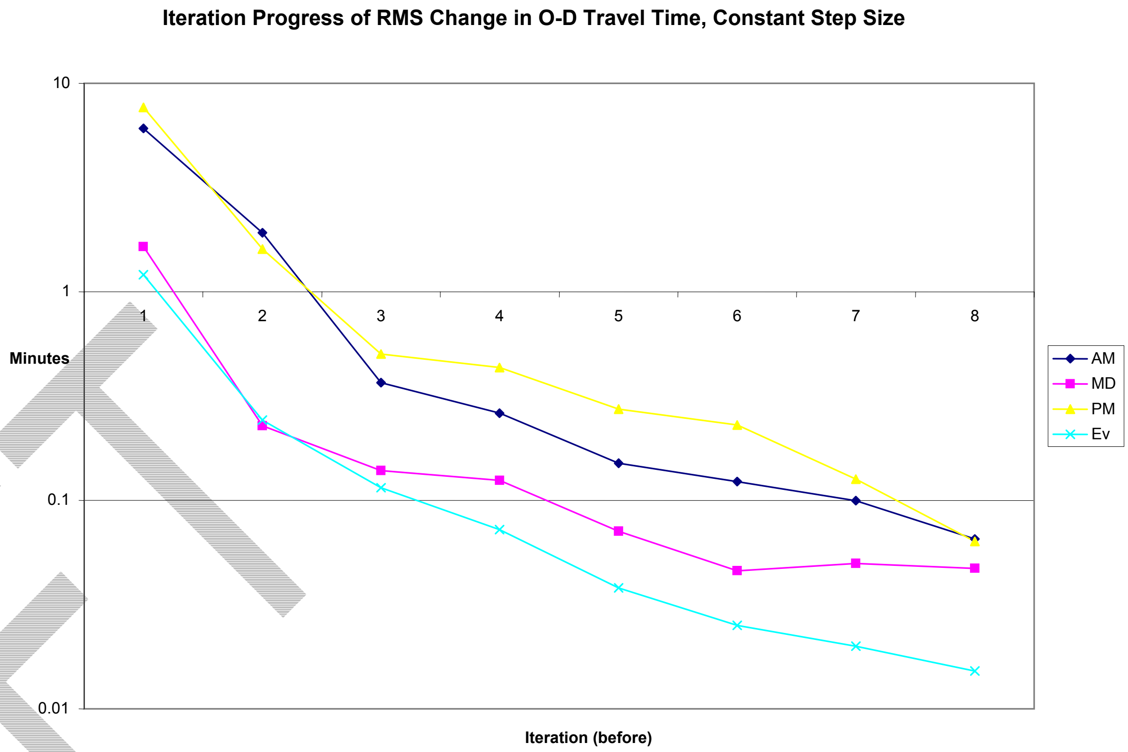


Figure J



Some General Remarks

Both of the example procedures steadily progress toward equilibrium, reaching a fair approximation in equilibrium travel times with a fraction of the population actually simulated, and zone-to-zone travel demand dominated by “noise” from the Monte Carlo simulation process. One pass through the population (across 8 to 12 iterations) achieves a precision of around 0.15 minutes in PM zone-to-zone travel time, and better for other time periods. This demonstrates the compensatory nature of equilibrium trip assignment upon volumes and zone-to-zone travel times: random perturbations in trip demand are smoothed out in assignments into comparatively small perturbations in the resulting travel times. Individual travel demand matrix elements can have standard deviations comparable to their own values, yet after assigning those trips, the corresponding elements in travel time matrices can be precise to the minute.

The constant step size example achieved comparable levels of equilibrium precision to the staged MSA example, with fewer iterations (9 vs. 13), slightly less simulation (2 passes through the population instead of 2.13) and approximately two thirds the total run time (about 21 hours vs. 31 hours). (Test runs were under Windows XP on a PC with 2 GB RAM and dual 3GHz Pentium D processors. The entire SacSim run is singlethreaded; while SacSim ran, the machine was used for relatively low intensity office applications.) While DaySim’s computation time is dominated by the number of household simulations, other aspects of simulation are not, so reducing the number of DaySim simulations and the number of da-iterations both reduce total run time. This is consistent with experience on various trip-based models, in which constant step sizes usually converge in fewer iterations than MSA. It is recommended that further application and development of SacSim focus on the constant step size method, the MSA method should be retained as a "fall-back" for applications with convergence difficulty.

An efficient approach for some difficult cases might be to switch from constant-step to MSA in the middle of the run. The basic idea is that after i iterations of constant step size, keep the sampling rate the same as s_i (at its last value in the constant step series), and select offset m values that cycle through the not-yet-simulated households. The first such iteration would have a step size of 1/3, the next 1/4, etc. The switch can be made at any iteration. Bar Gera and Boyce (2006) suggest the constant step-size models may need the step size reduced when excessive oscillation is detected.

References

Bowman, J. L., Bradley, M. A. (2006) Activity-Based Travel Forecasting Model for SACOG: Technical Memos

Number 1 - Model System Design
Number 2 - Population Synthesis
Number 3 - Design of Model System Application Software
Number 4 - Mode Choice Models
Number 5 - Intermediate Stop Location Models
Number 6 - Day Pattern Activity Generation Models
Number 7 - Time of Day / Activity Scheduling Models
Number 8 - Usual Location and Tour Destination Models
Number 9 - Household Auto Availability Model
Number 10 - DaySim05 Documentation
Number 11 - Impedance and Accessibility Effects

DKS Associates (2002), *Model Update Report, Sacramento Regional Travel Demand Model Version 2001 (SACMET 01)*, Sacramento Area Council of Governments 02-003.

DKS Associates (1994) *SACMET Regional Travel Demand Model Version 94.0 Model Development and User Reference Report*, for Sacramento Area Council of Governments.

Long, J., Gibb, J., Garry, G. (1994) *Improving the Estimation Process for HOV Lane Demand in a Multi-Modal Corridor,* presented at TRB 7th National Conference On High-Occupancy Vehicle Systems.

NuStats Research and Consulting (2000) *2000 Sacramento Area Household Travel Survey Final Report*, for Sacramento Regional Council of Governments

Bowman, Bradley, and Griesenbeck (July 3, 2002) *Sacramento RT DNA Rail Access Mode Choice Model*, memorandum, with airport access mode choice model spreadsheet application.

Cube, Voyager, and *TP+,* Version 4.0 (2006), Citilabs, Oakland.

Blain L. (1994). *Park-and-Ride Choice using Matrix Convolutions.* Presented at the 9th Annual International EMME/2 Users Group Conference, Montréal, Québec.

Spiess, H. (1996), *A Logit Parking Choice Model with Explicit Capacities*, EMME/2 Support Center, Aegerten, Switzerland.

Spiess, H. (1990) Conical Volume-Delay Functions, *Transportation Science*, Volume 24, Number 2, pp. 153-158.

Boyce, D., Ralevic-Dekic, B., and Bar-Gera, H. (2004), Convergence of Traffic Assignments: How Much is Enough? In *Journal of Transportation Engineering,* 130:1(49), American Society of Civil Engineers.

Boyce, D., Zhang, Y-F, and Lupa, M (1994) Introducing "Feedback" into Four-Step Travel Forecasting Procedure Versus Equilibrium Solution of Combined Model, in *Transportation Research Record 1443.*

EMME/2 Release 9 (1998), INRO Consultants, Inc., Montréal.

Bar Gera, H. and D. Boyce, (2006), Solving a non-convex combined travel forecasting model by the method of successive averages with constant step sizes. In *Transportation Research Part B,* 40 (2006) 351–367.

Evans, S. (1976) Derivation and Analysis of Some Models Combining Trip Distribution and Assignment, *Transportation Research Part B* 10, 37-57.

Miller, H. (1997) *Towards Consistent Travel Demand Estimation in Transportation Planning: A Guide to the Theory and Practice of Equilibrium Travel Demand Modeling*, U.S. FHWA Travel Model Improvement Program (TMIP) Clearinghouse.

Nagurney, A., Dong, J. (2002) A Multiclass, Multicriteria Traffic Network Equilibrium Model with Elastic Demand, *Transportation Research Part B* 36, 445-469.

SacSim Reference

This section describes the command script files, data files, and data flow in SacSim.

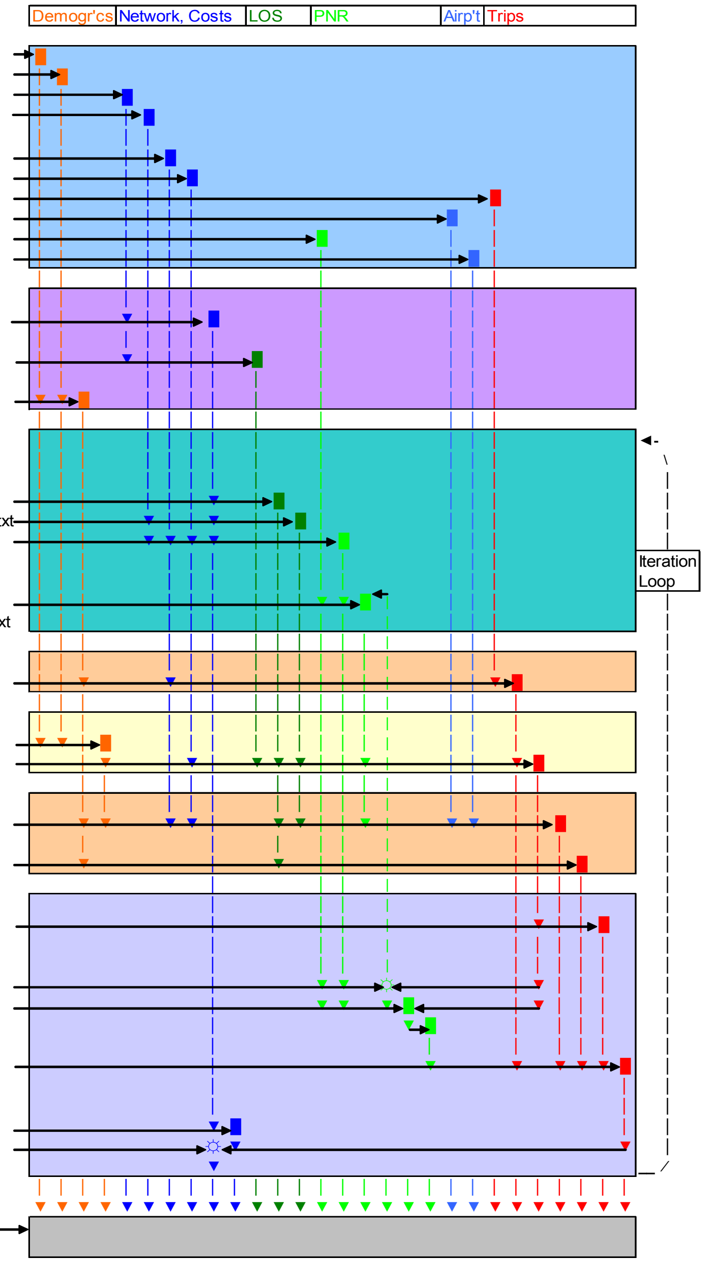
The SacSim scripts require TP+ or Voyager version 4.0 or higher. Particular features needed include the ability to sort data records, and the relative gap assignment stopping criterion.

The present implementation is in a series of script files, and a batch file to assemble a complete run script. This approach of modularity was more versatile for development and experimentation than Cube. The script files may be viewed and/or edited in ordinary text editors, as well as Cube's editor. (Do not use word processors to edit them.) The script files reference no folders; all referenced files are in the "work" folder. Consequently, the scripts can be copied to any folder on any computer and run without modifications. (The interested user can still "Cube-ize" the script modules, but will then have to use Cube's methods to manage references to specific data files and folders.)

Figure 1 (in the beginning of this document) is a general flow chart of SacSim. Figure #R1# shows the system flow in more detail.

Figure #R1#
SacSim Process and Flow Chart

Legend: █ = given or output, ▼ = input, ☼ = update for use in next loop
Data files internal to a module are not shown



Given	
households cross-classed	mt00_marg.dbf
parcel employment	parcel.dat
highway network	mt00base.net
transit network	mt00base.lin, .sup
zonal data	
terminal times	tazdat.dbf
parking costs	tazdat.dbf
external generators	mt00tgsp.dbf
airport districts	airportdistrict.txt, tazdat.dbf
PNR capacities	mt00pnrcap.dbf
airport survey	airportsurvey.dbf
initialize.s	
mimic network w/zero vols	??????vo.net
walkskim.s	
walk skim matrix	skim.walk.mat, skwalk.txt
tazsumdata.s	
zonal h'holds, emp'd res, empl't	tazsumdata.txt
Begin Loop	
skims.s	
auto LOS matrices	skim.auto.??.mat, skau??.txt
transit walk LOS matrices	skim.tranwalk.??.mat, sktw??.txt
PNR special skims and G.C.	skim.pnrgc.??.mat
pnrchoicefree.s, first pass in run only,	
pnrchoiceskim.s, all other passes (uses pnrfillseq.txt)	
PNR skims	skim.tranpark.??.mat, skim.trandrop.??.mat, sktd??.txt
externals.s	
external trip distribution	ixximat.txt
DaySim	
h'holds x-classed with autos	pout.dbf
person trip list	sout.dbf
airport.s	
Airport trips by mode	trips.airport.mat
cvtgtd.s: commercial vehicles	trips.cv.mat
gettrips.s	trips.??.mat
pnrloaddisagg.s	
Simulation of PNR lot filling	pnrfillseq.txt
PNR lot choices for trips	dtwwtd.pairs.chron.dbf,
Auto I-K trips	trips.dtwwtd.auto.mat
vehtrips.s	veh.??.mat
asnveh.s: Auto Assignment with MSA	
Prepare input network	??????vi.net
Loaded network volumes, times	??????vo.net
Final Trip Tables, Assignments	
Transit assignment	
Peak-hour assignment	
Attach skims to simulated trips	
Other post-hoc analysis	

Process Sections

- Fixed inputs (GIS attributes, TP+ networks, other external files)
- Cold-start LOS skims, compile inputs (TP+/Voyager)
- Iteration LOS skims (TP+/Voyager)
- Activity-based models (DaySim)
- Trip-based models (TP+/Voyager)
- Trip processing and assignment (TP+/Voyager)
- Final assignments, analysis (TP+/Voyager)

Script Files

The TP+/Voyager script files of SacSim are as follows:

Initialize.s sets up "loaded" networks expected by other processes, with zero volumes and free-flow times. Establishes other miscellaneous data files to appropriate start-up values. Used only in the beginning.
Walkskim.s skims the zone-to-zone walk distance matrix. Run only in the beginning, since these do not change with congestion.
Tazsumdata.s reduces household and employment data for use in other SacSim modules. Run only in the beginning.
Skims.s calculates zone-to-zone auto and transit travel times, distances, and costs, accounting for traffic congestion. Begins each system iteration loop.
Pnrchoicefree.s derives park-and-ride transit skims from the auto and transit skims. This version does not have parking capacity restraint, and is used only in the first iteration.
Pnrchoiceskim.s derives park-and-ride transit skims from the auto and transit skims, accounting for the parking constraint schedule most recently estimated by pnrloaddisagg.s. This can only be run in the second and subsequent system iterations.
External.s applies the external trip models. This must be run before DaySim, which uses its output.
Airport.s applies the airport ground-access trip-making and mode choice models. It uses cross-classified household information generated by DaySim.
Cvtgtd.s applies the commercial vehicle generation and distribution models.
Gettrips.s aggregates trips from DaySim into person-trip matrices.
Pnrloaddisagg.s applies the park-and-ride lot choice model to transit drive-access trips from DaySim and from the airport model, so the corresponding auto and transit trips may be included in their respective assignments. This accounts for parking capacity restraint, and records a "schedule" of when lots fill up.
Vehtrips.s compiles the auto trips from the various models, and splits and/or stratifies by occupancy and time of day where necessary, producing assignable vehicle trips.
Asnveh.s assigns vehicle trips to the network. Uses run-time variable `ssi`, the inverse of the step size, for convex combinations calculation.
Convergence_skims.s tracks changes in zone-to-zone auto skim times from one iteration to another, as part of convergence monitoring.
Trip_displacement.s tracks changes in trip demands from DaySim and their interaction with travel times, as part of convergence monitoring.
Transitassign.s compiles and assigns transit person-trips. It is an end-of-run option, not a required part of a SacSim run.

Makemodl.bat is an MS-DOS batch file that, when run, compiles all required TP+/Voyager scripts (except end-of-run options), DaySim invocations, and iteration parameters, into a combined script named **runmodel.s**. Certain file commands are inserted to save selected intermediate files for later examination. The iterations are specified sequentially, each with its own parameters specified as runtime or batch variables. In the resulting compiled script, the iterations are repeated sequentially, so the system runs from the beginning to the end. Specified iteration parameters are:

`I` = iteration number. Used only for labeling iteration-specific data and files.
`S` = household sampling rate for DaySim.
`M` = starting household index for DaySim.
`ssi` = step-size inverse, i.e. 1/(step size), for convergence process.

Data File Types

Data format types used in SacSim are:
`.dbf` = dBase database files
`.net` = TP+/Voyager highway network (Citilabs proprietary binary format)
`.lin` = text file with TP+/Voyager transit network coding
`.sup` = text file with TP+/Voyager transit network coding
`.mat` = TP+/Voyager matrix (Citilabs proprietary binary format)
`.txt` = text file with fixed-width or delimited fields

Input Files

All input files for SacSim must be located in the "work" folder where the model run-created files are to be made. See separate documentation for the files and formats required by DaySim.

"????" stands for the four-character data file prefix entered in the TP+/Voyager startup screen. In script code, this is represented with a single question mark. This prefix feature permits information identifying a model run scenario to be embedded in the file names; it is most useful when files for different scenarios must be prepared or compared. (It is still recommended that different model scenarios be run in different folders.)

Several matrices are conveyed to DaySim in text files. These are written in fixed-width format, but read as delimited. No particular field widths are required, only enough to contain the data with space between values. Unless otherwise specified, the first field is the "*I*" zone (origin or production), the second is the "*J*" zone (destination or attraction), and the indicated matrices follow in successive fields. Zeros must be written for zero values, except that if all fields after a field are zero, they may be omitted. (SacSim normally writes all the zero values, unless *all* values in an *i-j* cell for a file are zero.)

????_marg.dbf - cross-classified households
Also used by DaySim, with additional fields required.

Required fields for TP+/Voyager applications:

```
Zone,
hh101,hh102,hh103,hh104,hh105,
hh201,hh202,hh203,hh204,hh205,
hh301,hh302,hh303,hh304,hh305,
hh401,hh402,hh403,hh404,hh405,
hh111,hh112,hh113,hh114,hh115,
hh211,hh212,hh213,hh214,hh215,
hh311,hh312,hh313,hh314,hh315,
hh411,hh412,hh413,hh414,hh415,
hh221,hh222,hh223,hh224,hh225,
hh321,hh322,hh323,hh324,hh325,
hh421,hh422,hh423,hh424,hh425,
hh331,hh332,hh333,hh334,hh335,
hh431,hh432,hh433,hh434,hh435
```

The "hh" fields contain numbers of households of particular classifications living in the zone. The first numeric digit in the field name is the number of persons in the classification; the second digit is number of employed persons, and the third is the household income classification. The income categories are the same as in the SACMET model system; in year 2000 dollars, the ranges are approximately:

1 = $0 to $14,999
2 = $15,000 to $24,999
3 = $25,000 to $44,999
4 = $45,000 to $74,999
5 = $75,000 or more.

Parcel##.dbf - parcel data ("##" stands for a year, such as "00")
Also used by DaySim, with additional fields required.
Required fields for TP+/Voyager applications:

`TAZ,` zone number
`STUDK12P,` K-12 students
`STUDUNIP,` college and university students
`EMPEDU_P,` educational employment
`EMPFOODP,` food-service employment
`EMPGOV_P,` government employment
`EMPOFC_P,` office employment
`EMPOTH_P,` other employment
`EMPRET_P,` retail employment
`EMPSVC_P,` service employment
`EMPMED_P,` medical employment
`EMPIND_P,` industrial employment
`EMPTOT_P,` total employment

SacSim uses the totals of each field in each TAZ.

Tazdat.dbf - zonal data
Also used by DaySim, with additional fields required.

Required fields for TP+/Voyager applications:

- `TAZ,` zone number
- `autacc,` auto access time, i.e. origin terminal time, in hundredth-minutes
- `autegr,` auto egress time, i.e. destination terminal time, in hundredth-minutes
- `RAD,` Regional analysis district

????tgsp.dbf - External trip generation
Required fields:

- `Z`, gateway zone number (1-30)
- `hbwxi`, home-based work productions (X-I person trips)
- `hbwix`, home-based work attractions (I-X person trips)
- `pbprod`, personal business productions (X-I person trips)
- `pbattr`, personal business attractions (I-X person trips)
- `shprod`, shopping productions (X-I person trips)
- `shattr`, shopping attractions (I-X person trips)
- `srprod`, social-recreational productions (X-I person trips)
- `srattr`, social-recreational attractions (I-X person trips)
- `c2xi`, 2-axle commercial vehicle productions (X-I vehicle trips)
- `c2ix`, 2-axle commercial vehicle attractions (I-X vehicle trips)
- `c3xi`, 3+ axle commercial vehicle productions (X-I vehicle trips)
- `c3ix`, 3+ axle commercial vehicle attractions (I-X vehicle trips)

????thru.dbf – Through trips
Required fields:

- `I`, origin gateway
- `J`, destination gateway
- `AUXX`, vehicle trips by automobiles
- `C3XX`, vehicle trips by trucks

Airportdistrict.txt - correspondence between RAD and airport allocation district
Used to select which airport survey records represent an area.
Delimited text
Field 1: RAD (regional analysis district)
Field 2: airport allocation district

Airportsurvey.dbf - Airport passenger survey
Converted with practically no modification from airport access sample-enumeration model spreadsheets.
Required fields:

- `hbnhb`, 1 if home-based, 2 if non home-based
- `exfac`, expansion factor from the survey to the scale of the population
- `tazds`, zone number of the trip non-airport end, in the original application. (Only used for validation of records; does not need to be updated to newer zone system.)
- `RAD`, regional analysis district

`hhinc`, household income category
`hvehs`, number of vehicles in household
`hsize`, number of persons in household
`stay`, number of days of trip
`acmp4`,
`seg`, modeling segment (1 to 4)
`party`, number of persons in traveling party

????base.net - Highway network
TP+/Voyager binary network containing node coordinates and link data
Required link fields:

`A, B,` from- and to-nodes of the link. Links are directional.
`TSVA`, free-flow speed in tenths of miles per hour
`DISTANCE`, link distance in miles
`SPDCURV`, congestion curve parameter selection

0 = zone connector
1 = freeway
2 = rural highways
3 = urban arterials

`CAPCLASS`, capacity class (1 to 63)

1 = Freeway
2 = Expressway
3 = Major Arterial
4 = Minor Arterial
5 = Collector
6 = Ramps
7 = Walk-Only Link
8 = HOV lanes
9 = HOV connector dummy links
16 = Freeway-to-Freeway Ramps
24 = Rural Highways
62 = Park-and-ride access dummy links
63 = Zone connector

`LANES`, number of lanes in the link's direction of travel
`DELCURV`, indicates metered ramp links

????base.lin - transit lines, and
????base.sup – transit supply data – special access and transit links
Text files in TP+/Voyager transit network specification language for the Trnbuild or Public Transport program.
Conventions:

- Two time periods are represented:

  Period 1 = Peak periods. Directional services are entered in the AM direction; PM peak services are implicitly the same as AM but in the reverse direction.

Period 2 = Off-peak (mid-day and evening service)

- Drive access is only done from the zone containing or representing each park-and-ride lot (PNR entry). The park-and-ride lot choice model obtains the auto drive access attributes from all other origin zones to the parking zones. Each PNR…ZONE coding must include the zone containing or representing the park-and-ride lot.
- Additional conventions of modes, line names, etc. apply from SACMET models.

Files created by SacSim

The files described below are those that pass information among script modules and to or from DaySim, or are relevant output for post-hoc analysis. Additional files are created by some modules mainly for use within those modules, or for debugging or monitoring.

Skim.walk.mat (binary matrix format), and
Skwalk.txt (text) - zone-to-zone walk distance matrix
One matrix: walk distance. Binary is in miles, text is in hundredth miles.
Text fields are origin zone, destination zone, distance.
Tazsumdata.txt – compilation of household and employment data
Fixed-width text
Fields:
1, zone
2, households
3, employed residents living in zone
4, K-12 students
5, college-university students
6, educational employees
7, food-service employment
8, government employment
9, office employment
10, other employment
11, retail employment
12, service employment
13, medical employment
14, industrial employment
15, total employment

Skim.auto.am.mat, skauam.txt,
Skim.auto.md.mat, skaumd.txt,
Skim.auto.pm.mat, skaupm.txt,
Skim.auto.ev.mat, skauev.txt
Auto level-of-service skim matrices
Matrices:
Time
Distance

Excess time due to links at over 1.2 times free-flow time
Excess time due to links at over 1.5 times free-flow time
Tolls (presently an inactive placeholder)

Binary matrices: units are minutes, miles, cents.
Text matrices: units are hundredth-minutes, hundredth-miles, cents.

Skim.tranwalk.am.mat, sktwam.txt,
Skim.tranwalk.md.mat, sktwmd.txt

Transit walk-access level-of-service skim matrices
Matrices:

- Number of transfers
- Transfer time
- First-wait time
- Fare
- In-vehicle distance
- Walk time
- In-vehicle time

Binary matrices: units are minutes, miles, cents.
Text matrices: units are hundredth-minutes, hundredth-miles, cents.

skim.tranpark.am.mat,
skim.trandrop.md.mat,
skim.tranpark.md.mat

Transit auto-access level-of-service skim matrices.
Matrices:

- Parking lot zone (not used, only the final reported for AM)
- Transfer time
- First-wait time
- Drive time
- Fare
- Drive distance
- In-vehicle distance
- Walk time
- Number of transfers
- In-vehicle time

Binary matrices: units are minutes, miles, cents.
Text matrices: units are hundredth-minutes, hundredth-miles, cents.

Trips.external.mat – External trip distribution matrices. The trips are categorized by the activity at the internal zone. The *I*-zone is the production zone, the *J*-zone is the attraction zone. (External commercial vehicle trips are in trips.cv.mat.)
Matrices:

- Work person-trips
- Personal-business person-trips
- Shop person-trips

Social-recreational person-trips

Ixximat.txt - External trip distribution, text form for input to DaySim. The trips are categorized by the activity at the internal zone. In this file, the *I*-zone is the external zone, and the *J*-zone is the internal zone.
Matrices:

I-X Workers
X-I Workers
I-X Personal-business person-trips
X-I Personal-business person-trips
I-X Shop person-trips
X-I Shop person-trips
I-X Social-recreational person-trips
X-I Social-recreational person-trips

Pout.dbf – Person records output from DaySim
Fields required by SacSim:

`persn`, person index within household, each household's beginning with 1.
`expfac`, expansion factor (to the scale of the whole population)
`hhincome`, household income (c. 2000 dollars per year)
`hhsize`, number of persons in household
`hhcars`, number of cars available to the household

Sout.dbf – Trip (tour-segment) records output from DaySim
Fields required by SacSim:

`sampn`, household index within population
`persn`, person index within household
`otaz`, origin zone
`dtaz`, destination zone
`deptime`, departure time from origin
`arrtime`, arrival time to destination
`mode`, mode of travel (Table 1)
`expfact`, expansion factor (to the scale of the whole population)

Trips.airport.mat – Airport passenger ground-access person-trips by mode (not counting chauffeurs), and vehicle trips by occupancy (including chauffeurs and return trips). P-A orientation; all are in column 285, attracted to the airport.
Matrices:

`AuDrop`, auto dropped-off and picked-up person trips
`AuPark`, auto-park person trips
`Taxi`, taxi person trips
`Van`, shuttle van person trips
`TrWalk`, transit walk-access person trips
`TrDriv`, transit parked auto access person trips
`TrDrop`, transit dropped-off/picked-up auto access person trips

APVTDA, single-occupant vehicle trips
APVTS2, two-occupant vehicle trips
APVTS3, three or more occupant vehicle trips
DTVTDA, transit drive access single-occupant vehicle trips*
DTVTS2, transit drive access two-occupant vehicle trips*
DTVTS3, transit drive access three or more occupant vehicle trips*

*Transit drive-access vehicle trips in this file are still in the airport attraction column; application of the park-and-ride lot choice model determines the actual park-and-ride lot.

Trips.cv.mat – Commercial vehicle trips, I-I, I-X and X-I.
Matrices:

CV2X, 2-axle vehicle trips
CV3X, 3 or more axle vehicle trips

Trips.a3.mat, Trips.md.mat, Trips.p3.mat, Trips.ev.mat, Trips.a1.mat, Trips.p1.mat
Person-trips from DaySim aggregated into zonal matrices, grouped by mode and time of day. Travel direction is from *I* to *J*.
Matrices:

dtw, drive-transit-walk
wtd, walk-transit-drive
wtw, walk-transit-walk
sb, school bus
s3, auto shared-ride, 3 or more persons
s2, auto shared-ride, 2 persons
da, auto drive-alone
bk, bicycle
wk, walk

Pnrfillseq.txt – Park-and-ride lot filling sequence (during AM peak period)
Written in fixed-width fields, read as delimited.
Fields:

Sequence index (1, 2, 3,…)
Normalized time in which parking at zone fills up (between 0 and 1)
Zone number

Dtwwtd.pairs.chron.dbf – Park-and-ride lot choices for trip pairs, sorted in chronological order of DTW trip, and a random number to break ties. Data are from joined pairs of DTW and WTD trips, each by the same person in chronological order.
Fields:

OZONE1, origin zone of DTW trip
DZONE1, destination zone of DTW trip
PERIOD1, time period of DTW trip
DEPTIME1, departure time of DTW trip
RANDOM, a random number
OZONE2, origin zone of WTD trip

DZONE2, destination zone of WTD trip
PERIOD2, time period of WTD trip
PARKZONE, parking zone chosen by PNR lot choice model
TRIPS, weight to scale record to trips

Trips.dtwwtd.auto.mat – Auto trips to and from park-and-ride lots
Trips are vehicle trips in direction of travel, from origin to park-and-ride lot, or from park-and-ride lot to destination, for inclusion in the vehicle trip assignments.
Matrices:
a3, trips in AM peak 3-hour period
md, trips in mid-day period
p3, trips in PM peak 3-hour period
ev, trips in evening period

Veh.a3.mat, Veh.md.mat, Veh.p3.mat, Veh.ev.mat
Vehicle trips for assignment in each period of the day, compiled from all models
Matrices within each file:
DA, drive-alone vehicle trips
S2, two-occupant vehicle trips
S3, three or more occupant vehicle trips
C2, commercial vehicles, 2 axles
C3, commercial vehicles, 3+ axles

????a3vo.net, ????mdvo.net, ????p3vo.net, ????evvo.net
Loaded highway networks
Required fields for input to skims and assignment:
A, B, from- and to-nodes of the link. Links are directional.
V_1, Volume in vehicle trips
TIME_1, Time in minutes
TSVA, free-flow speed in tenths of miles per hour
DISTANCE, link distance in miles
SPDCURV, congestion curve parameter selection
0 = zone connector
1 = freeway
2 = rural highways
3 = urban arterials
CAPCLASS, capacity class (1 to 63)
1 = Freeway
2 = Expressway
3 = Major Arterial
4 = Minor Arterial
5 = Collector
6 = Ramps
7 = Walk-Only Link
8 = HOV lanes

9 = HOV connector dummy links
16 = Freeway-to-Freeway Ramps
24 = Rural Highways
62 = Park-and-ride access dummy links
63 = Zone connector

`LANES`, number of lanes in the link's direction of travel
`DELCURV`, indicates metered ramp links

Fields added or updated by assignment:

`V_1`, new total directional volume, a weighted average of preloading and new assignment according to the current step size.
`TIME_1`, new congested time in minutes
`PRELOAD`, the former value of `V_1`
`OLDTIME`, the former value of `TIME_1`
`VC_1`, new demand-volume to capacity ratio
`CSPD_1`, new congested speed (whole miles per hour)
`V1_1`, single-occupant newly assigned volume (including trucks), new assignment only, not blended with preloading
`V2_1`, HOVs not using median HOV lanes, new assignment only, not blended with preloading
`V3_1`, HOVs eligible to use all HOV lanes, new assignment only, not blended with preloading
Other volume-derived fields may be present.