TRANSIMS DEPLOYMENT CASE STUDY:

SACOG DaySim-TRANSIMS Integrated Model Development

Final Report

March 2010

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DATA ■ ANALYSIS ■ SOLUTIONS

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1.0 PROJECT APPROACH

1.1 Project Objectives

This project has two primary goals. The first goal is to advance the current state of TRANSIMS implementation by integrating the existing DaySim activity-based model with the TRANSIMS Router. The second goal is to demonstrate the advanced capabilities and policy sensitivities of the new integrated DaySim-TRANSIMS model system by using this tool to test the alternative Watt Avenue bridge configurations. The ultimate product of this study will be a fully disaggregate and spatially and temporally detailed model system, where individual travel behavior is simulated from long-term travel choices such as usual work location through the selection of specific paths through the regional network for each individual trip segment. Benefits of this disaggregation include the ability to use individuals' characteristics to explain travel behavior, more accurate measures of level-of-service especially for short trips of all modes, and the ability to reflect time-sensitive travel conditions and pricing policies.

The development of activity-based demand models and TRANSIMS have largely followed separate paths. Activity-based models have been unable to achieve their full potential because they have been integrated with traditional equilibrium assignment models, which discard the behavioral, spatial and temporal detail provided by activity-based models such as DaySim. TRANSIMS has been unable to achieve its full potential because implementation efforts have encountered difficulties developing and integrating a behaviorally based activity and travel demand component. This model integration effort sought to overcome both weaknesses by integrating the existing Sacramento Area Council of Governments (SACOG) DaySim activity-based model with TRANSIMS.

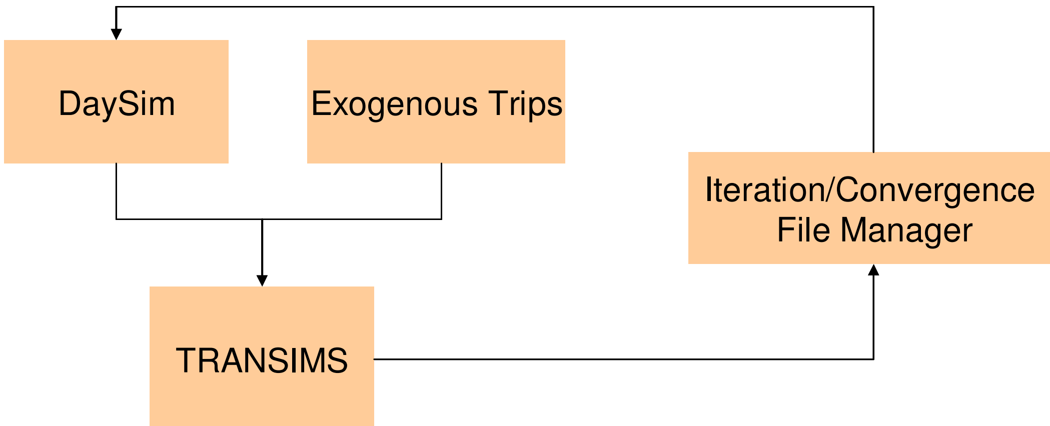
DaySim synthesizes a population for the entire Sacramento region and simulates a detailed itinerary for each person in that population, with parcel-level locations for each stop, plus departure time and travel mode for each trip. The current implementation of the DaySim aggregates these activities both spatially and temporally and assigns the resulting trip tables by mode, using a trip-based equilibrium approach for roadway assignments. The resulting travel times from the assignment are then post processed with parcel-level access times and fed back to subsequent DaySim iterations.

TRANSIMS provides sophisticated router and traffic microsimulator tools, which are sensitive to timing and modal constraints for determining which paths will be chosen by travelers. These tools can be used to estimate roadway performance measures at finer spatial and temporal resolution than possible with the traditional equilibrium assignment. By using TRANSIMS to assign the spatially and temporally disaggregate travel demand produced by DaySim to transportation networks, it is possible to estimate roadway performance measures at finer spatial and temporal resolutions than possible with the traditional equilibrium assignment. These more detailed network performance measures can then be used to provide more precise inputs to DaySim.

For this project, DaySim and the TRANSIMS Router have been integrated via a model structure in which DaySim feeds travel itineraries such as activity files and trip files to the TRANSIMS Router. In turn, the Router feeds network performance information back to DaySim, as shown in Figure 1. This data exchange occurs iteratively so as to achieve consistency of inputs and outputs between DaySim and the Router. The geographic scope of the integrated DaySim-

TRANSIMS model is regional, so that the travel of most residents is contained within the modeled area. This regional travel demand supplied by DaySim is augmented by trips to and from special generators within the region, trips to and from external stations, and commercial traffic, as occurs currently in the SACOG model system. Note that in the current version of the integrated model, the TRANSIMS Router is used to route only auto and commercial traffic on roadways. Transit trips are not assigned to the transportation networks.

Figure 1. Integrated Model System



1.2 SACOG Region

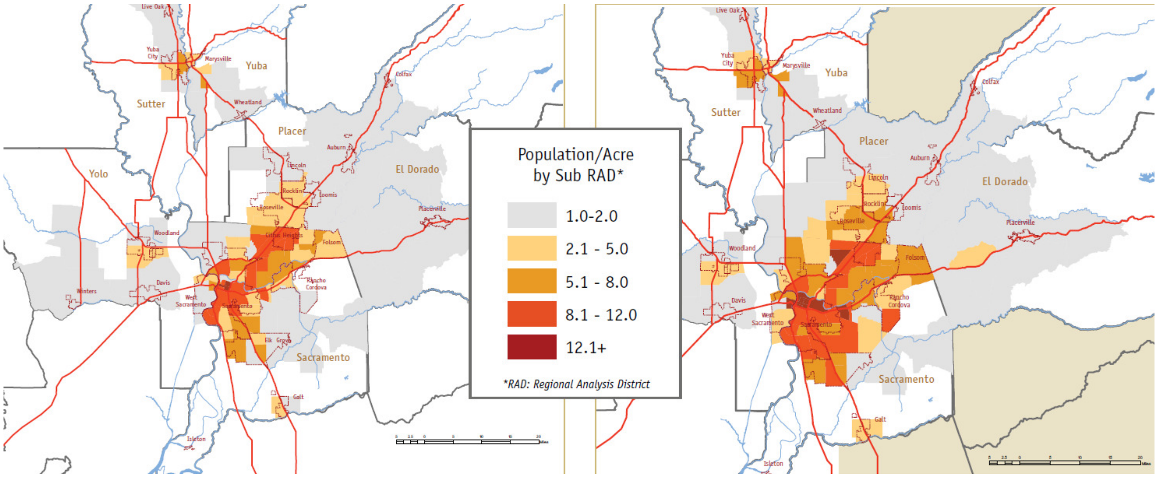
The Sacramento Area Council of Governments (SACOG) is an association of governments in the six-county Sacramento region. Its members include the counties of El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba as well as 22 mid and large-sized cities and towns. SACOG as the metropolitan planning organization (MPO) provides transportation planning and funding for the region and serves as a forum for the study and resolution of regional issues. SACOG also serves as the Regional Transportation Planning Agency (RTPA) under California state law resulting in considerable overlap between the agency's federal and state responsibilities. In addition to preparing the region's long range transportation plan, SACOG approves the distribution of affordable housing in the region and assists in planning for transit, bicycle networks, clean air and airport land uses.

Figure 2. Six-county SACOG Region

Source: SACOG Metropolitan Transportation Plan

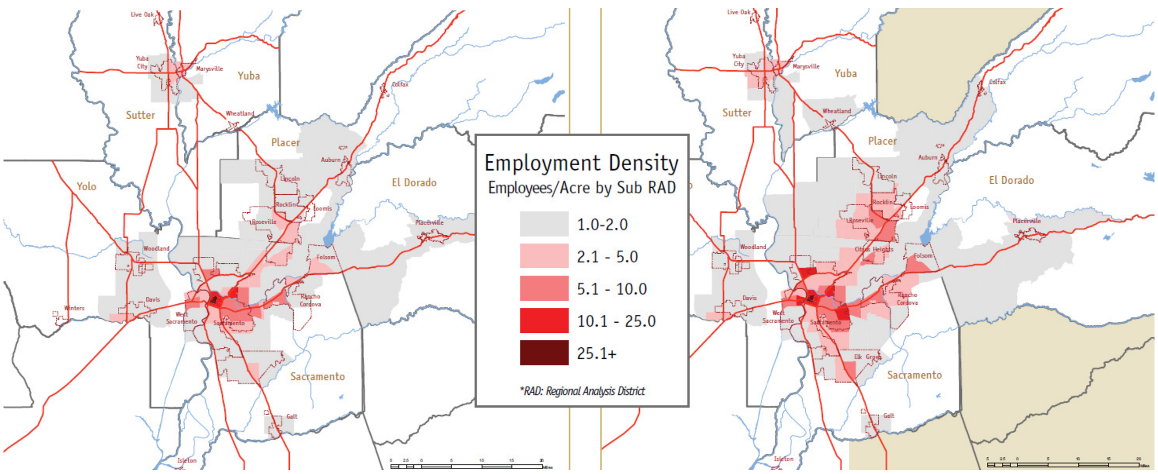
By 2035 the region is expected to grow from approximately 800,000 households and 2 million residents to more than 1.3 million households and 3.4 million residents. In addition, the number of jobs is expected to increase from 1 million to more than 1.5 million jobs in 2035. SACOG is keenly aware of the challenges associated with this level of expected growth and is also facing new budgetary challenges given the shortfalls faced by the State of California. Planners increasingly need tools that are capable of answering a broad range of policy questions related to infrastructure expenditures and the kinds of questions that might potentially be better addressed by fully disaggregate travel models. As such, SACOG has embraced and incorporated a disaggregated travel demand model known as DaySim into their travel modeling framework known as SACSIM. As part of this research project, as well as the upcoming SHRP2-C10 project, SACOG is participating in the development of disaggregate supply side models that can be linked and integrated with DaySim. SACOG is uniquely positioned to be one of the first large MPOs in the country with a fully integrated disaggregate model that will represent the next generation of regional travel models.

Figure 3. SACOG Population Density: 2005 and 2035



Source: SACOG Metropolitan Transportation Plan

Figure 4. SACOG Employment Density: 2005 and 2035



Source: SACOG Metropolitan Transportation Plan

1.3 SACSIM AND DaySim

SACOG, as the designated Metropolitan Planning Organization (MPO) for the Sacramento region, has the primary responsibility for the development and maintenance of travel demand forecasting methods and models for the region. These models are used for analyzing transportation and land use policies, as well as for assessing the effects of changes to key model inputs, such as fuel prices. The Sacramento Activity-Based Travel Simulation Model (or SACSIM) is the most recent and advanced model system developed for SACOG. The model system was developed in order to provide decision-makers with a tool that is sensitive to more policy options and is capable of producing a broader set of measures and indicators.

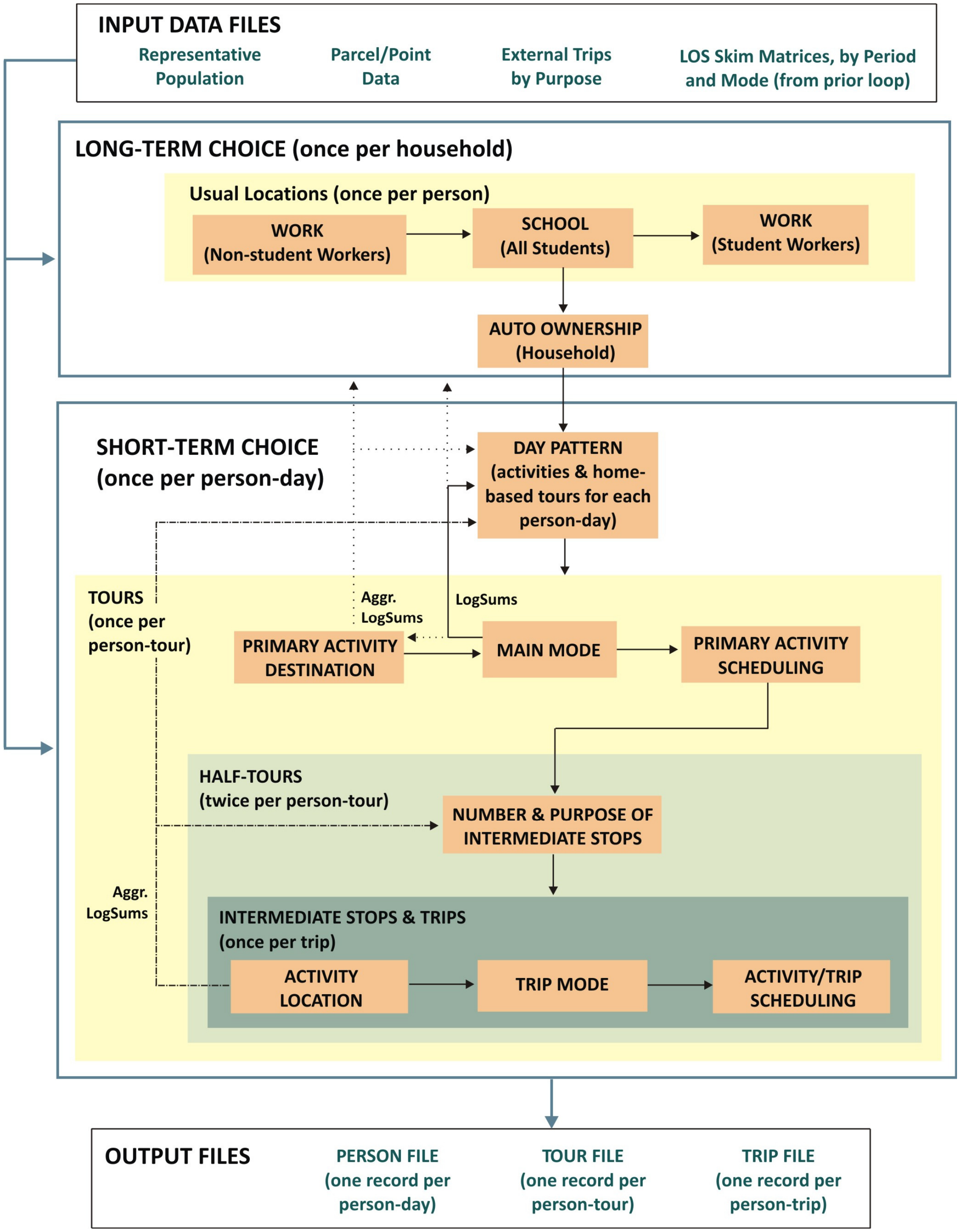
SACSIM is comprised of a set of component models that represent both travel demand and supply. Travel demand of regional residents and visitors is predicted, as is commercial vehicle demand. This demand is then “assigned” to detailed transportation networks in order to develop estimates of network volumes, speeds, and delay. In turn, this critical information on network speeds and delay is then iteratively fed back to the demand model in order to ensure that model inputs and outputs are consistent and that any analyses based on the model are reasonable.

The distinguishing feature of the SACSIM model system is DaySim. DaySim is a "typical weekday" model that simulates 24-hour itineraries for individuals with spatial resolution as fine as individual parcels and temporal resolution as fine as single minutes, so it can generate outputs at the level of resolution required for input to dynamic traffic simulation. DaySim also explicitly treats time. Durations of activities and travel times are constrained by the length of a day, and travel choices as modeled account for time explicitly in 30 minute blocks. DaySim's predictions in all long-term and short-term dimensions (usual workplace location, activity and travel generation, tours and trip-chaining, destinations, modes, and timing) are sensitive to travel times and costs that vary by mode, origin–destination (OD) path, and time of day, so it can, in turn, effectively use as inputs the improved network travel costs and times output from a dynamic traffic simulator. DaySim captures the effects of travel time and cost upon activity and travel choices in a way that is balanced across modes and times of day and consistent with the econometric theory of nested choice models. Originally written in Delphi, DaySim is being translated to C++, and will be able to be compiled to run in both 32- and 64-bit environments. In addition, DaySim can be used in a distributed manner by running separate instances on different processors on different partitions of the region's population, and then merging the results.

DaySim is structured as a series of hierarchical or nested choice models. The general hierarchy places the long term models at the top of the choice hierarchy, and the short term models at successively lower levels in the hierarchy. The detailed hierarchy and flow through the DaySim model components is illustrated in Figure 5. Models lower in the hierarchy are conditioned by the outcomes of models higher in the hierarchy. Most of the models simulate multiple outcomes for a given household, and the simulation sequence proceeds as follows:

- All person-level outcomes are modeled one person at a time, in a fixed priority sequence
- Household-day outcomes are modeled one household at a time
- Person-day outcomes are modeled one person at a time, in a fixed priority sequence within household
- All model outcomes above the tour level are simulated before any tour-level models are run.
- All tour-level and trip level outcomes are modeled one tour at a time, in a fixed priority sequence.
- Time window availability is restricted as tours and trips are simulated.

Figure 5. DaySim Flow Chart



Note that the general flow is down from the long term models to the short term models. Moving down from top to bottom, the choices from the long term models influence or constrain choices in lower level models. For example, household auto ownership affects both day pattern and tour (and trip) mode choice, by influencing auto ownership variables used in those component models. In addition to these direct influences, utilities from lower level models flow upward to higher level models, too. "Logsums" (expected utilities) from tour destination and tour mode choice models affect other short term models, as well as the upper level, longer term models. Some of the logsums from lower level models are aggregated for use in the long term models, in order to reduce the computational load of using fully detailed disaggregate logsums in such a complex nesting structure.

In order to simulate the behavior of the regions residents, DaySim uses a "synthetic population." This synthetic population is a list of household and person records that represent regional travelers. Starting with demographic forecasts of households by TAZ and income category, households by TAZ and household size, and households by TAZ and number of workers, DaySim uses iterative proportional fitting to estimate a three-dimensional distribution of households within each zone by income, household size and number of workers. DaySim then draws households from the 2000 census Public Use Microdata Sample (PUMS) to match the distribution, keeping several of the PUMS attributes, including household income, gender, age, student status & grade level, and worker status & hours. After sampling, these PUMS households and persons are then distributed the housing units at the parcel level.

For this project, the core DaySim model was fully integrated with TRANSIMS. However, not all regional travel is captured in DaySim. Consequently, SACSIM contains a number of additional components that reflect other segments of the regional travel market, including:

- Air passenger ground access, which reflects travel to and from the Sacramento International Airport made by both regional residents and visitors to the region;
- Commercial vehicle travel, which includes all trips made for the transportation of goods and services; and
- External trips including both internal-external (trips made by region residents to points outside the region), external-internal (trips made by residents from outside the region to points within the region), as well as through trips.

In this integrated model development effort, demand derived from these models components was assigned using the TRANSIMS tools, but the demand remains "fixed". Specifically, the network performance measures produced by TRANSIMS are not fed back into these components. However, significant effort was made to add as much temporal and spatial detail as possible to this demand prior to assignment in TRANSIMS. This effort is described in a subsequent section on auxiliary demand.

1.4 TRANSIMS

TRANSIMS is a series of integrated transportation analysis and forecasting models that was originally developed at the Los Alamos National Laboratory. Subsequently, TRANSIMS has been moved into the realm of open-source software. Although TRANSIMS is primarily maintained and enhanced by FHWA contractors, a burgeoning and engaged user community is emerging around the software. The three principal components of TRANSIMS are an activity generator, an intermodal route planner, and a traffic microsimulator. TRANSIMS is not so much a transportation planning software package such as TransCAD and CUBE, but rather a toolbox of more than 50 utilities, functions, and executables that can be configured and specified in any number of ways by the user to address questions germane to a specific project. The following paragraphs briefly describe all three principal components, but only a single component, the route planner or Router, was used for this project.

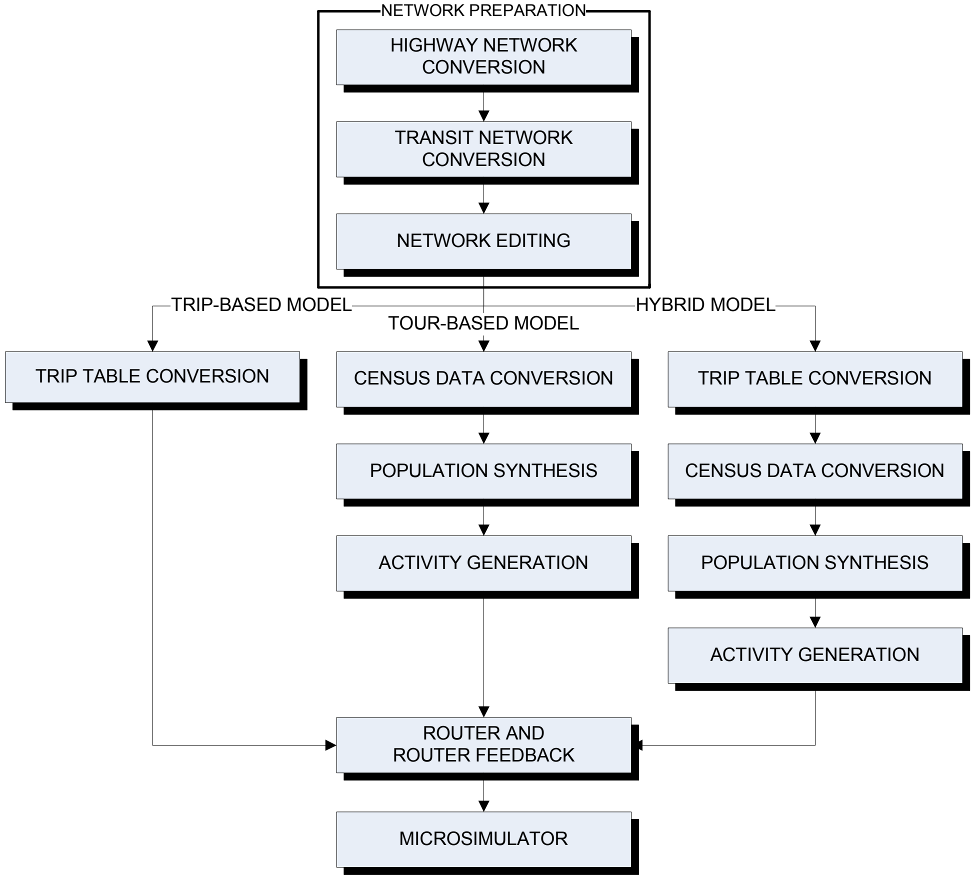
The TRANSIMS activity-based travel demand module know as the "Activity Generator" estimates the number, characteristics and locations of activities in which individuals will participate during the simulation period, typically an average week day. Activities include work, shopping and recreation. These activity estimates are based on the characteristics of individuals, their households and available vehicles. A population synthesizer is a sub-module that develops a synthesized population based on observed data such as Public Use Microdata Sample (PUMS). The TRANSIMS Activity Generator was not used for this project.

The intermodal trip planning module known as the "Router" computes combined mode trip path-plans to accomplish the desired activities. The Router attempts to accommodate all the desired activities in a way that maintains the interconnectedness of a traveler's daily itinerary. The Router also maintains the identities and characteristics of individual travelers and of the personal and/or transit vehicles used throughout their daily trips. So-called activity locations are identified by specific geographic point locations that become origins and destinations of travel. The Router, like all TRANSIMS components can be configured by users in many different ways. The implementation details for this project effort are described in a subsequent section. Extensive documentation of the Router, and all TRANSIMS components, can be found at the TRANSIMS website (http://www.transims-opensource.net/).

Finally, the traffic microsimulator module uses the intermodal paths developed by the Router to perform a regional or subarea microsimulation of the vehicle interactions on the roadway network. The microsimulator computes the second-by-second operating status, location, speed, acceleration and deceleration of all vehicles throughout the simulation period as they encounter other vehicles on the roadway and stop at signalized intersections, etc. As a result, the microsimulator produces detailed link volumes, speeds and delays by time of day for every vehicle on every link in the simulation network. The Microsimulator was not used for this project.

TRANSIMS is a complex system of travel demand models and traffic assignment models. Each implementation can be customized to the user's particular needs and available data, as shown in Figure 6. The primary difference among the three approaches listed below concerns how the trip matrices are estimated. The "Trip Table Conversion" method relies on fixed trip tables estimated outside of TRANSIMS and converted into TRANSIMS format. This approach is often referred to as a "Track 1" implementation. The "Tour-Based Model" is an implementation of a tour-based model inside the TRANSIMS framework. The "Hybrid Model", is a combination of the two previous approaches (e.g. fixed external and commercial vehicle trip matrices can be read into TRANSIMS along with activities from a tour-based model). Models that rely on the demand models within TRANSIMS are often called "Track 2" implementations.

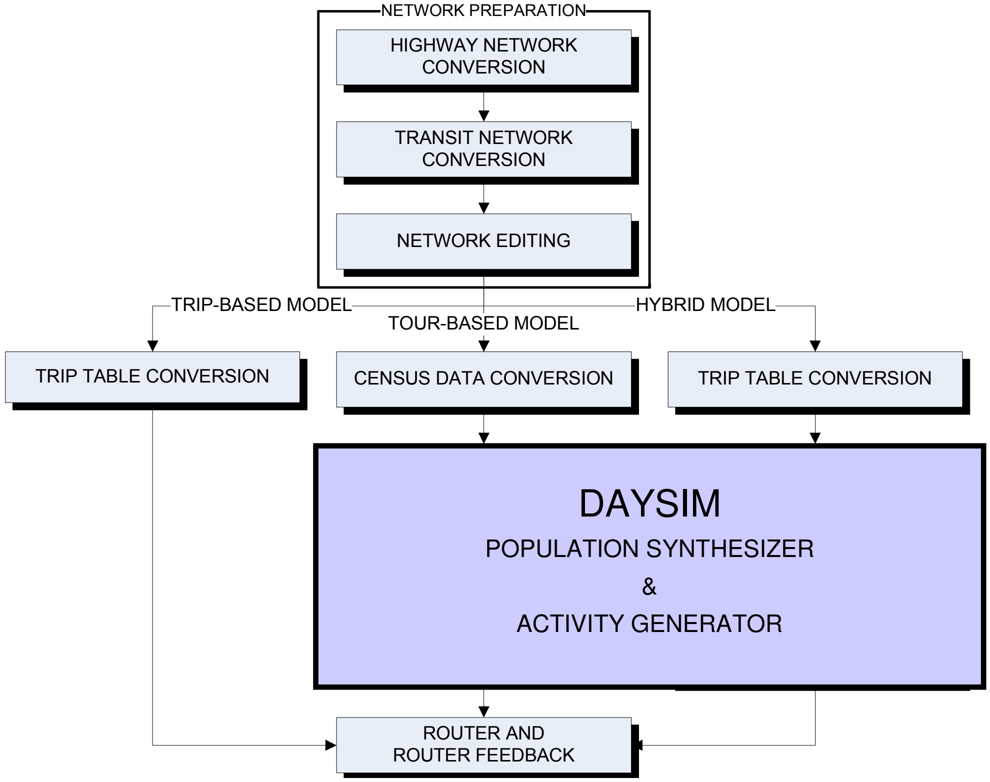
Figure 6. Three Ways to Implement TRANSIMS



For practitioners familiar with the traditional 4-step aggregate travel modeling framework, trip generation, mode choice, and distribution are replaced by the Activity Generator. Vehicle assignment is replaced by the Router and the Microsimulator provides functionality not typically associated with 4-step models.

For this research project the goal is to build a variant of the "Hybrid Model" that replaces the TRANSIMS population synthesizer and activity generator with an existing activity-based demand model known as DaySim. The project will integrate DaySim with the TRANSIMS Router and provide feedback between the demand-side and supply-side models. The Microsimulator has not been included as part of this work, but future work could seek to add this and perhaps other modules to the Integrated Model stream developed for this project. Although excluding the Microsimulator reduces the sensitivity of the integrated model system to some smaller scale operation controls and effects, it makes the integrated model runtimes tractable. Figure 7 is a reproduction of the preceding illustration that shows DaySim now replacing the TRANSIMS population synthesizer and activity generator.

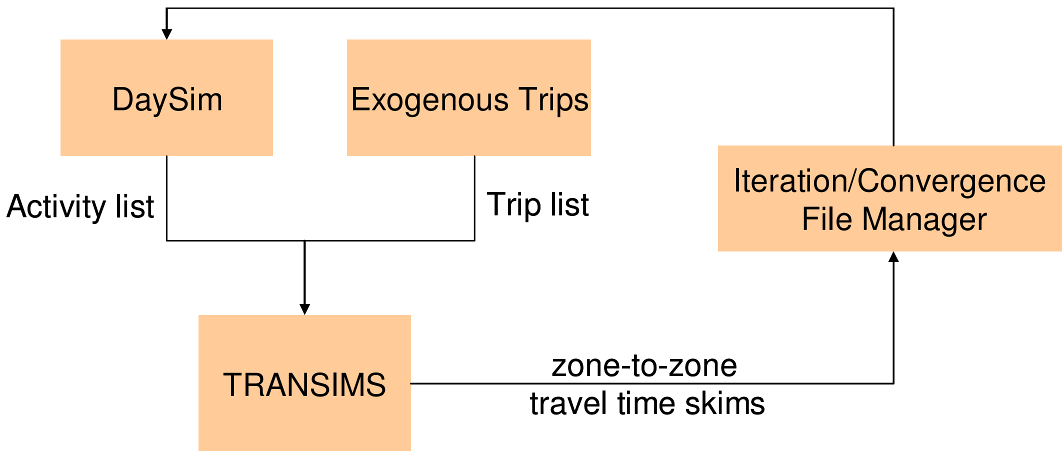
Figure 7. Three Ways to Implement TRANSIMS with DaySim



2.0 Model Design

Two key linkages between DaySim and TRANSIMS were established as part of this model integration exercise. First, a linkage between DaySim and TRANSIMS was created by modifying DaySim to produce TRANSIMS-required activity and vehicle files, in addition to standard trip lists and other outputs. It was also necessary to enhance DaySim to distinguish shared-ride mode drivers from shared-ride mode passengers. A set of rules and observed distributions were used to assign an auto driver or auto passenger designation to each shared-ride auto tour and auto trips, so that only driver trips were assigned using the Router. Finally, it was necessary to convert parcel-level destinations to activity-locations using a correspondence file, and to convert DaySim clock times to TRANSIMS clock times. These modifications are described in greater detail in the DaySim-TRANSIMS section that follows.

Figure 8. Integrated Model System



The second linkage between TRANSIMS and DaySim was established by configuring TRANSIMS to produce network level of service skims based on TRANSIMS network assignment, and by modifying DaySim to read these new TRANSIMS-based skims. Establishing this second linkage was significantly more involved. The TRANSIMS Router assigns the activities output by DaySim to produce a set of plans which contain detailed path information for each assigned trip, though when assigning the Router maintains the linked nature of trips in each tour. The Router also produces a set of link volume and delay files, which are currently configured to use a 15-minute time resolution. These link delay files were used with TRANSIMS's Router and PlanSum tools to create a set of skims containing information on congested travel times, distances and costs. For Stage 1 model development, skims were created for each of the four broad time periods used by DaySim. The spatial resolution of these skims was at the TAZ-level rather than the more detailed activity location-level used in the TRANSIMS assignment. For Stage 2 of integrated model development, DaySim is being modified to use more spatial and temporally disaggregate level of service information derived from the detailed TRANSIMS link delay files. These approaches are discussed in greater detail in the TRANSIMS-DaySim section that follows.

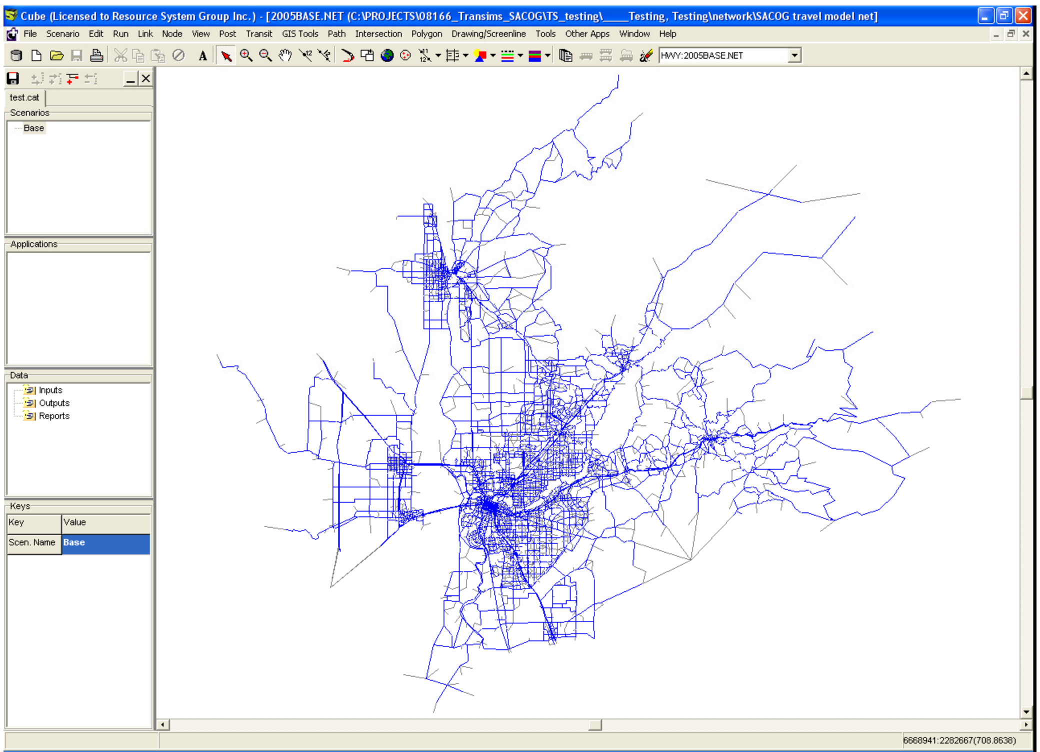
3.0 Model Implementation

3.1 TRANSIMS Network Preparation

The general process for converting traditional 4-step regional model networks, both highway and transit networks, is now fairly well-documented given the number of TRANSIMS implementations that have been conducted in recent years. The process begins with specific functions in the TRANSIMS toolbox that utilize input link and node information in a variety of software formats and converts the data for processing by the principal network build utility called TRANSIMSNet. This utility uses the input link and input node data that define the geographical representation of the network and synthetically generates the physical characteristics of the roadway network that are represented in a TRANSIMS microsimulation network. These characteristics include lane connectivity, pocket lanes, activity locations, parking lots, signalized and unsignalized intersection locations, and finally process links which connect activity locations to parking lots.

The TP+ network maintained by SACOG for use in their SACSIM regional travel demand model was used as the starting point for developing a detailed microsimulation TRANSIMS network for the region. The 2005 base year model highway network has approximately 27,000 links and 11,500 nodes that represent the major roadway facilities in the 6-county region. The CUBE/TP+ base year highway network is a typical “stick-network” where the links do not reflect true shapes and zonal access to the street grid is modeled with centroid connectors.

Figure 9. SACSIM TP+ Network



The first step of the network build process was to utilize the CUBE network editor to export a shapefile representation of the highway network. The TRANSIMS utility GISNet is then used to convert this shapefile to the Input Link, Input Node, and Input Shape text files required to run the network build procedure. The GISNet utility also accommodates a conversion scripting that allows the user to define the equivalencies between link and node attributes in the original CUBE network and the new attributes generic to the TRANSIMS input link and node text files. This is a convenient way of passing certain attributes such as capacity and the number of lanes while also converting other attributes such as distance and time to the metric units required by TRANSIMS.

TRANSIMSNet reads the Input Link, Node, and Shape files and generates the files that define the detailed microsimulation network including links, nodes, activity locations, and lane connectivity. For this demonstration project the microsimulator was not used to perform a dynamic traffic assignment. Therefore, no effort to develop signal phasing and timing plans for the signalized intersections was conducted and the tool IntControl was therefore not utilized. Because this research focused on integrating an existing activity-based demand model with the TRANSIMS Router, we limited our network debugging efforts and made network corrections only when validation/calibration findings indicated obvious errors. Furthermore, transit assignment was not explicitly addressed in this effort so conversion of the transit network was likewise not performed. The ArcNet utility was frequently used to visualize all the TRANSIMS network files by generating ArcView shapefiles for each unique file that is synthesized by TRANSIMSNet.

Figure 10 illustrates the network preparation build process that was applied to synthesize a TRANSIMS network for the SACOG region

Figure 10. TRANSIMS Network Build Process

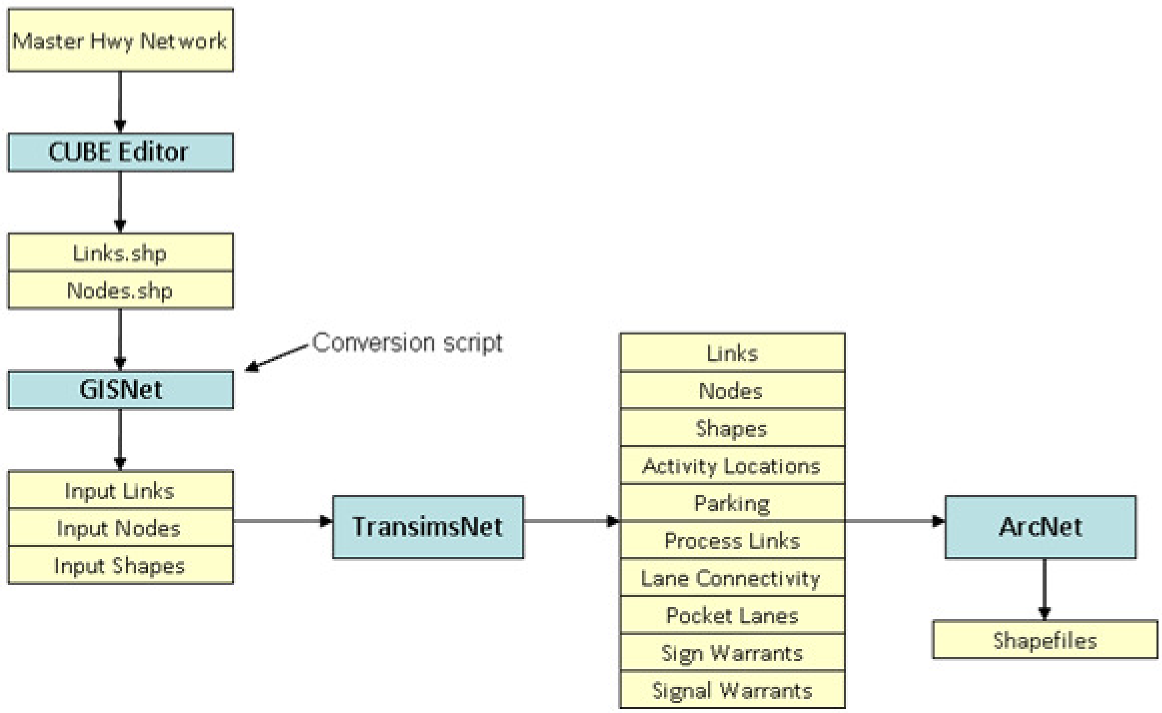


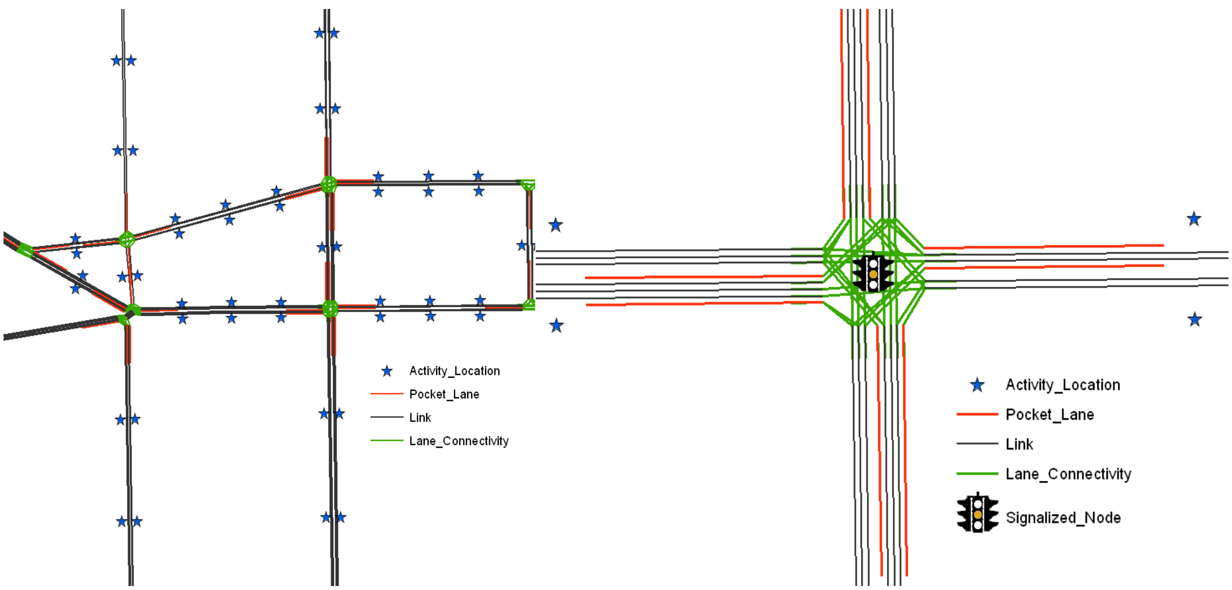
Table 1 below provides the number of records in each of the TRANSIMS network files generated by the network preparation described above. The SACOG TRANSIMS for the 2005 analysis year has 4,500 nodes, 6,800 links and 22,000 activity locations. To synthesize TRANSIMS simulation network data, the number of links into and out of a given node is used along with intersection logic to construct turn pockets, lane connectivity and traffic controls, both signs and signals. Unique logic is applied depending on the facility type of the link. For instance, arterial intersections examine the relative orientation or each movement and the functional class of each link to determine when and where to include turn pockets and signals or signs. In general, if an approach has opposing traffic, a turn pocket is added to accommodate the movement. The signal warrants are determined based on the number of legs and the user-specified functional class by area type signal warrant parameters.

Table 1. TRANSIMS Network Size

Network File	Records
Nodes	4,479
Links	6,803
Activity Locations	22,050
Parking Lots	22,050
Process Links	44,100
Pocket Lanes	8,707
Lane Connectivity	34,471
Unsignalized Nodes	905
Signalized Nodes	2,624

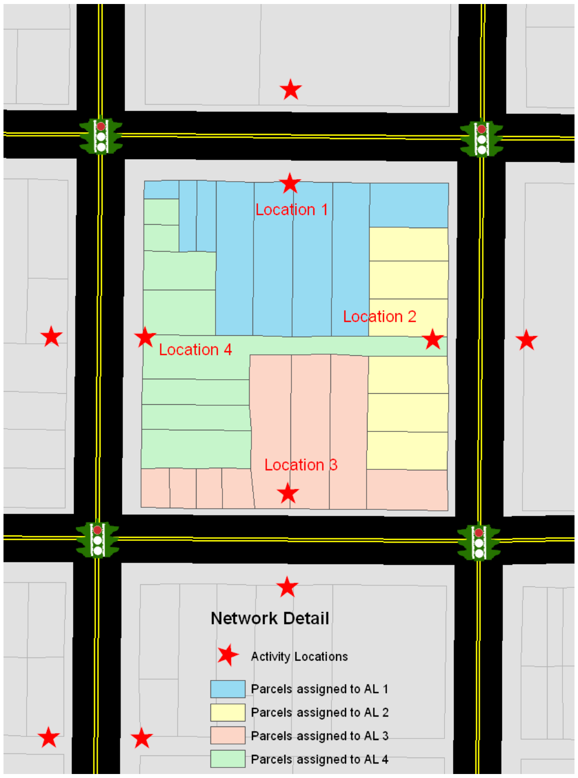
Figure 11 shows the TRANSIMS network detail including the links, pocket lanes, lane connectivity and the signalized node locations. The graphic on the right is a zoomed-in view of an intersection that depicts the detailed lane connectivity that is automatically synthesized by the TRANSIMSNet utility.

Figure 11. TRANSIMS Network Detail



Because DaySim operates at a parcel level and TRANSIMS operates at an activity location level, it is necessary to establish a correspondence between parcels and TRANSIMS activity locations. An automated GIS process was implemented to create this correspondence. Figure 12 shows the relationship between parcels, activity locations and TRANSIMS network elements such as links and signals.

Figure 12. Parcel-Activity Location Correspondence



3.2 DaySim-TRANSIMS INTEGRATION

3.2.1 Activity File

The primary modification of DaySim required to integrate DaySim and TRANSIMS was the adding to DaySim the capability to create TRANSIMS input activity and vehicle files. These modifications were relatively straightforward given the comparability and the list-based nature of both DaySim's trip output and TRANSIMS activity file input.

3.2.1.1 Activity Files vs. Trip Files

TRANSIMS can accept two types of list-based inputs: activity files and trip files. A trip file is straightforward: it is a list of trips to be assigned to the network and includes information on the origin activity location, the destination activity location, and departure time of the trip and the mode of travel used. All of the auxiliary demand used in the integrated model, such as airport ground access trips and commercial vehicle trips are converted from SACSIM trip matrices into TRANSIMS trip files. When the TRANSIMS Router assigns a trip file to the network, each trip is considered a discrete movement, independent from any other trips in the file.

Activity files are more complex. An activity file is a list of activities undertaken by regional residents, and does not explicitly include trips. For each household, person and activity, the activity file includes a purpose, start time, end time, duration, mode, and location. Using this information, the TRANSIMS Router creates a plan for each movement required for an individual to reach their desired activity locations. These plans are essentially equivalent to trips. The critical distinction between using an activity file and a trip file is that when routing activities TRANSIMS treats each all the movements as interconnected – the "tour" structure is preserved within each person. As currently configured, the activity durations are fixed, so if it takes longer for a traveler to reach their activity location, the remainder of their trips and activities will be pushed back in time as well. This has distinct implications for the integration of the activity model with the TRANSIMS Router, and for the overall model system calibration and validation, an issue discussed in a subsequent section of this report. This approach was necessary in the initial model development in order to ensure that all trips were assigned and conserved. Future integrated model development efforts will consider how re-scheduling and time-pressures can be flexible accommodated in DaySim, TRANSIMS, or both.

Using a simple tour comprised of two trips, with a single trip on each tour leg, Table 2 and Table 3 illustrate the differences between the original DaySim trip output file and the TRANSIMS activity input file. Both files indicate the household and person travelling. For each of the two given trips in Table 2, the DaySim trip output file contains information on the person tour number on which the trip occurs, the tour half (outbound or return) on which the trip occurs, and the trip number within the tour. Critical trip details are also included, such as the origin and destination parcel and TAZ numbers, the travel mode used to make the trip, the origin and destination purposes, the trip departure time and the trip arrival time.

Table 2. DaySim Trip List Output Example

SAMPN	PERSN	TOURNO	TOURHALF	TRIPNO	OTAZ	OCEL	DTAZ	DCEL	MODE
1	1	1	1	1	445	429711	1088	133524	7
1	1	1	2	1	1088	133524	445	429711	7

(continued)

OPURP	DPURP	DEPTIME	ARRTIME	EACTTIME	TRAVTIME	TRAVDIST	EXPFACT
8	4	1222	1238	1556	16.09	8.56	1.00
4	8	1556	1615	2659	18.65	8.56	1.00

Table 3. TRANSIMS Activity File Example

HHOLD	PERSON	ACTIVITY	PURPOSE	PRIOTITY	START	END	DURATION	MODE	VEHICLE	LOCATION	PASSENGER
1	1	111110	0	9	1	44520	44519	1	0	5937	0
1	1	11111	4	9	45480	57360	11880	2	1	13688	0
1	1	11121	0	9	58500	97140	38640	2	1	5937	0

Whereas the DaySim trip output contains two records representing two trips, the TRANSIMS activity file record contains three records representing three activities. The first activity represents the person's "at home" activity, where they start their day. TRANSIMS derives one trip to take the person from their home to their first activity location (shown in the second activity file record), and then derives a second trip to take the person to their next activity location, which is back home, as indicated by the common location id in the first and third activity records. Adding this initial "at home" activity was one of the key changes made to the DaySim output. Tours can also be work-based. For each home-based work tour, DaySim predicts the exact number and primary work-based subtours associated with that work tour.

3.2.1.2 Temporal Units

Table 3 also shows that this first "at home" activity ends at time 44520. Another key change made to the DaySim output involved the conversion of the time units from hours and minutes (for example, 1222 represents 12:22 in the original DaySim trip list output), to seconds. The first activity is shown to end at 44520, and when translated from seconds to hours and minutes, this time is also 12:22. So the end time for each activity in the activity file is the same as the start time for the trip that takes the traveler to their next activity, consistent with the DaySim trip file. Note that the start time for the second activity, which is "out of home" as indicated by the new location identifier, is 45480. Subtracting 44520 from 45480 results in 960 seconds, which is consistent with the 16 minutes shown as the travel time for the first trip in the DaySim trip list output.

3.2.1.3 Spatial Resolution

Table 2 and Table 3 also illustrate the differences in the geographic resolution between the DaySim trip list output and the TRANSIMS. As previously described, DaySim uses detailed parcels as the fundamental spatial unit, but in the SACSIM implementation this parcel-level detail is aggregated to a TAZ-level (of which there are approximately 1500 in the SACSIM model) prior to network assignment using traditional static equilibrium assignment methods. The DaySim trip list output contains both the origin and destination parcel and TAZ information. When integrated with TRANSIMS for network assignment, DaySim uses "activity locations." Activity locations are more fine-grained spatially than TAZs (there are approximately 22,000 activity locations in the Sacramento region), but not as detailed as individual parcels (there are approximately 650,000 parcels in the Sacramento region). A correspondence file between parcels and activity locations was developed in order to translate parcel information to activity locations prior to assignment in TRANSIMS. This spatial disaggregation in assignment, from 1500 TAZs to 22,000 activity locations, is one of the distinguishing aspects of the integrated model.

3.2.1.4 Mode

Two changes in the configuration of DaySim to produce a TRANSIMS activity file involved the treatment of mode. The simpler of the two changes involved recoding of the travel modes used in DaySim into the pre-established mode codes used in TRANSIMS. For example, Table 2 showing the original DaySim trip list output shows the first trip using mode 7, which is "drive alone" in DaySim. Table 3 showing the new activity file shows that the second record contains mode 2, which is the TRANSIMS "drive alone" mode used to make the travelers first trip to their first out of home activity location.

This mode logic is significantly more involved for shared ride trips. In existing activity-based model implementations that have used static network assignment procedures, shared ride trips are simply aggregated to the zonal level, and divided by an assumed occupancy rate in order to calculate vehicle trips. This approach does not work in a disaggregate assignment simulation such as TRANSIMS because the goal is to preserve the details about each individual trip. It is not appropriate or logical to divide discrete shared rides trip by an occupancy rate in order to estimate vehicle trips. Instead, it is necessary to assign driver and passenger status to travelers whose mode is identified as shared ride.

Using TRANSIMS, we only want to assign auto driver tours. DaySim predicts the occupancy for auto trips – Drive Alone (DA), Shared Ride 2 (SR2) or Shared Ride 3+ (SR3), but it does not predict whether the person is the auto driver or the passenger, and it does not coordinate the driver and passengers within a household. In addition, there may be different trip modes (vehicle occupancies) for different trips within an auto tour. A detailed analysis was used to derive the most realistic and unbiased method for assigning an auto driver or passenger designation to each auto tour and trip, so that we can select which tours to send to the Router.

In order to determine which car trips are part of car driver tours, a set of rules was established to deal with mixed tours that include some car trips and some non-car trips. Car trips that are part of school bus or transit tours are typically car passenger trips where the person gets a ride in one tour direction and takes a bus in the other direction. For simplicity, it was assumed that these trips are all passenger trips and do not need to be routed in TRANSIMS. In addition, there are mixed mode auto tours that include one or more walk or bike trips. Because these are difficult to handle in TRANSIMS, and the number of them is quite small, it was assumed that those the auto trips in those tours are passenger trips. Using assumed occupancy values of 1.0, 2.0, and 3.63 for the three auto modes and the total number of trips in each tour mode, the expected number of car driver trips was calculated. A method was established for determining which tours of each occupancy level to assign as driver tours based on other trip modes used on the tour. For example, if a tour includes one or more walk or bike trips as well as shared rider trips, it is designated as a car passenger tour. In contrast, if a tour includes no walk or bike trips, but does include one or more drive alone trips, it is designated as a car driver tour. Finally, if a tour includes only shared ride tips, a certain proportion of these tours are randomly designated as car driver tours and the rest are designated as car passenger tours based on proportions derived from survey and modeled data.

Table 4. DaySim Driver/Passenger Mode Recoding

DaySim Code	Mode	Trips	Percent	Tours	Percent
1	Drive-Transit-Walk	6,360	0.1	6,110	0.2
2	Walk-Transit-Drive	6,430	0.1		
3	Walk-Transit-Walk	104,930	1.3	57,120	1.6
4	School Bus	131,880	1.6	73,560	2.1
5	Shared Ride 3+ - Driver	344,340	4.2	196,280	5.6
6	Shared Ride 2- Driver	644,990	7.9	322,500	9.3
7	Drive Alone	3,512,870	43.1	1,390,650	39.9
8	Bike	129,960	1.6	56,590	1.6
9	Walk	500,070	6.1	204,240	5.9
10	Shared Ride 3+ - Passenger	1,221,700	15.0	610,920	17.5
11	Shared Ride 2- Passenger	1,549,650	19.0	465,930	16.2
	Total	8,153,180	100.0	3,383,900	100.0
	Total Car Trips	7,273,550	89.2	3,086,280	88.6
	Total Car Driver Trips	4,502,200	55.2	1,909,430	54.8

One final note on mode coding is that in the TRANSIMS activity file, all of the activities that are accessed using the drive alone and shared ride-driver modes are identified as MODE=2. TRANSIMS then uses information in the PASSENGER field to determine if the trip is truly drive alone or shared ride. If PASSENGER=0, the trip is treated as a drive alone trip and assigned to the network. However, if PASSENGER>0, the trip is treated as a shared ride driver trip, and is assigned to the HOV network.

3.2.2 Vehicle File

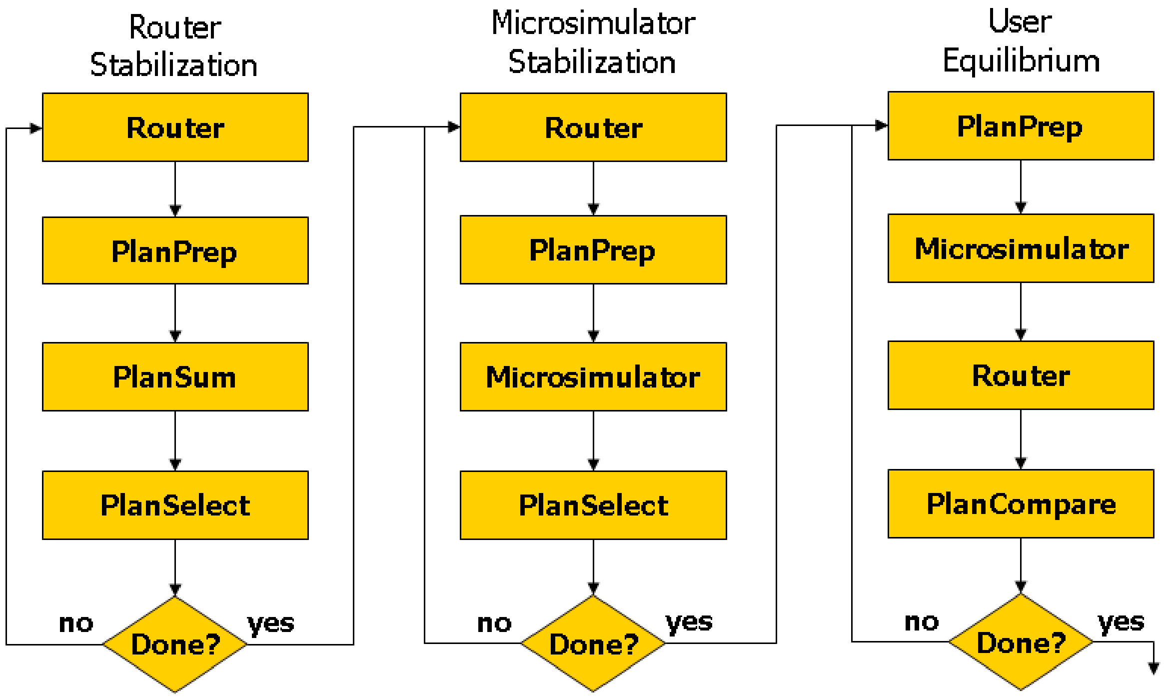
TRANSIMS has the ability to allocate or assign vehicles to individual travelers, and track these vehicles throughout the day. However, DaySim does not allocate vehicles to individual travelers. Thus, when creating the activity file, a separate vehicle is created for each auto driver tour, unconstrained by the number of vehicles each household is predicted to own or by competition amongst household members for the household vehicles. The project team anticipates enhancing DaySim so that is will assign household vehicles to each auto driver tour as part of other research efforts. This would enhance the value of the integrated model by enabling it to more realistically model vehicle usage and resulting air quality impacts in the region.

3.3 TRANSIMS-DaySim INTEGRATION

3.3.1 RouterStabilizer

Once the network preparation has been completed and the demand has been established either by using an activity generator or converting traditional 4-step travel demand matrices or both, a model design and structure must be defined. In most of the TRANSIMS implementations conducted thus far, a similar TRANSIMS model design and approach has been pursued. In the first process, the Router creates plan-paths for each traveler and vehicle being loaded on the network. In the second process, the Microsimulator loads the vehicles and simulates their movement on the network. Because microsimulating the whole network for an entire day is very time consuming, it is common to start by iterating the Router and recalculating the travel times using conventional Bureau of Public Roads (BPR) volume-delay equations. Once a certain level of network assignment convergence has been achieved in the Router (the paths generally reflect congested travel times), the Microsimulator is then introduced. In the Microsimulator vehicles are moved through the network on a second-by-second basis. Once the Microsimulator has reached an accepted level of convergence (the paths now reflect a more refined set of travel times generated by the microsimulation), a final User Equilibrium process is introduced. The typical process described here is illustrated in Figure 13.

Figure 13. Typical TRANSIMS Network Simulation Process



As described above, the so-called "Router Stabilization" process is iterated because microsimulating the entire network can take a very long time. The Router Stabilization essentially provides a warm-start for the "Microsimulator Stabilization" process that will follow. During the Router Stabilization iterative process, convergence involves selecting a portion of the assigned trips to be re-assigned in the subsequent iteration. Typically, users have employed any different rules and criteria to perform this selection process, for example, selecting travelers whose travel times change substantially from one iteration to the next or who encounter significant delays in the form of links with high volume-to-capacity ratios. However, only a subsample of all regional travelers are re-routed since the only aim here is to use the Router Stabilizer to provide a warm-start for the microsimulation phase. An iterative scheme that approaches a User Equilibrium condition is applied later in the final stage where all travelers are re-routed each time the Router is executed.

The SACOG integrated model links DaySim with just the TRANSIMS Router. The Microsimulator was not included in the model stream as part of this work. Therefore enhancements to the typical Router Stabilization were required so that network assignment convergence was achieved while also approximating a user equilibrium condition. In the initial model system implementation, shown in Figure 14, the substantive difference in the Router Stabilization process was that all travelers are re-routed during each iteration and a successive averaging of link delays is applied. A revised approach to Router Stabilization, shown in Figure 15, was implemented and tested after receiving feedback from this project's peer review panel. In this revised approach, no heuristics are used when subselecting travelers, rather a purely random process is employed. A method of successive averages is used to determine the share of regional travelers for whom to use updated paths. This approach is more consistent with current dynamic traffic assignment practice. A fixed number of 25 to 50 router assignment iterations are currently being performed by the integrated model. However, a quit criteria could be developed since gap measures are being utilized to calculate and identify when network convergence has been achieved. SOV and HOV specific paths are developed that reflect link-level vehicle occupancy restrictions. The Router is currently configured to use either the default BPR volume delay function and parameters or a conical volume delay function. A conical function is used in the SACSIM model, and an adapted version of this conical function was tested as part of this project. Use of the conical function slightly improved the network assignment validation, and provided different model sensitivities, particularly with respect to congested speeds. Comparisons of BPR-based assignments to conical-based assignments are presented in the subsequent model validation section.

Figure 14 depicts the initial Router Stabilization process that was applied in the integrated model to achieve network assignment convergence and a user equilibrium condition. Figure 15 depicts the revised RouterStabilizer process that was subsequently implemented based on feedback from the Peer Review panel, and which is described in Section 4.1.5.

Figure 14. Initial Integrated Model RouterStabilizer Process

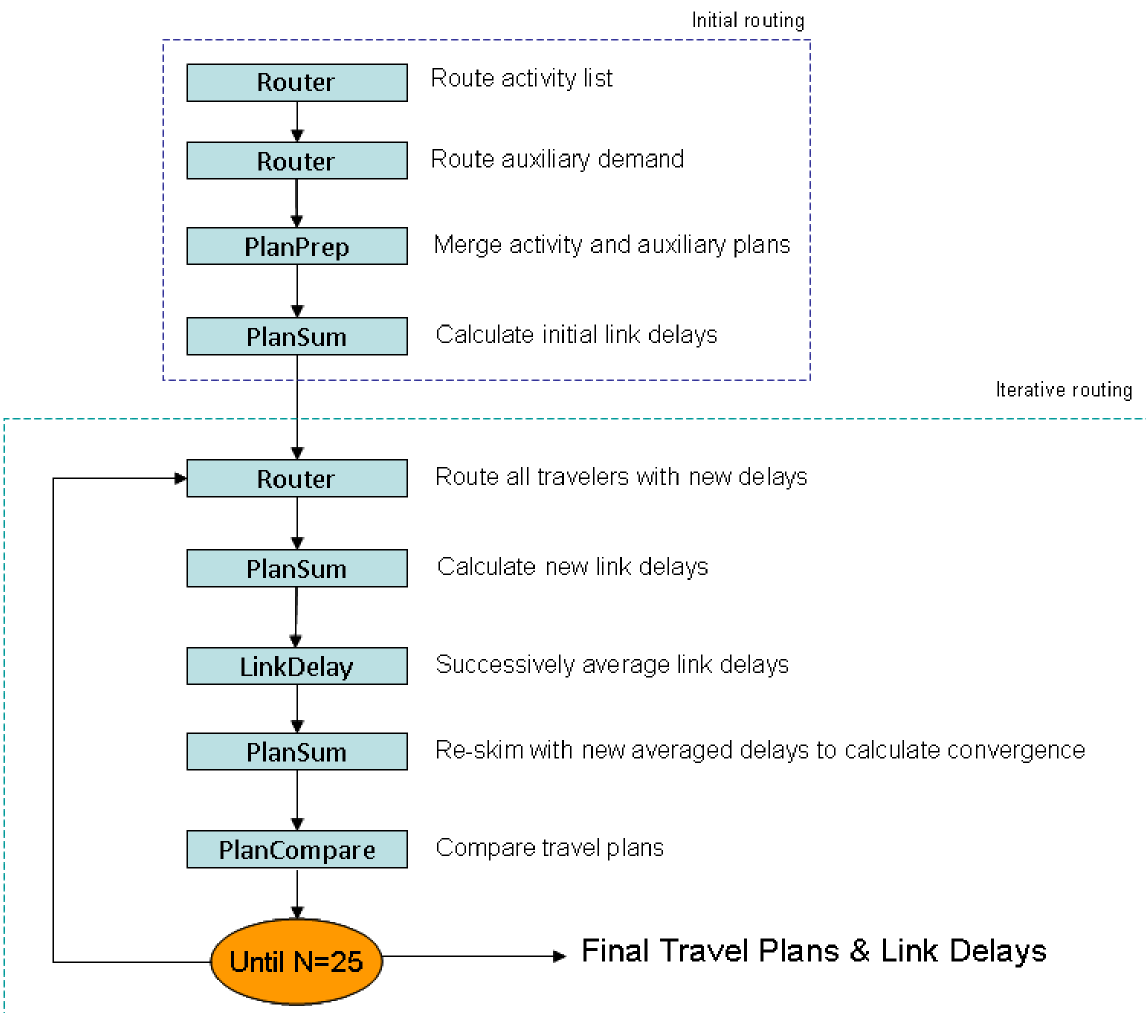
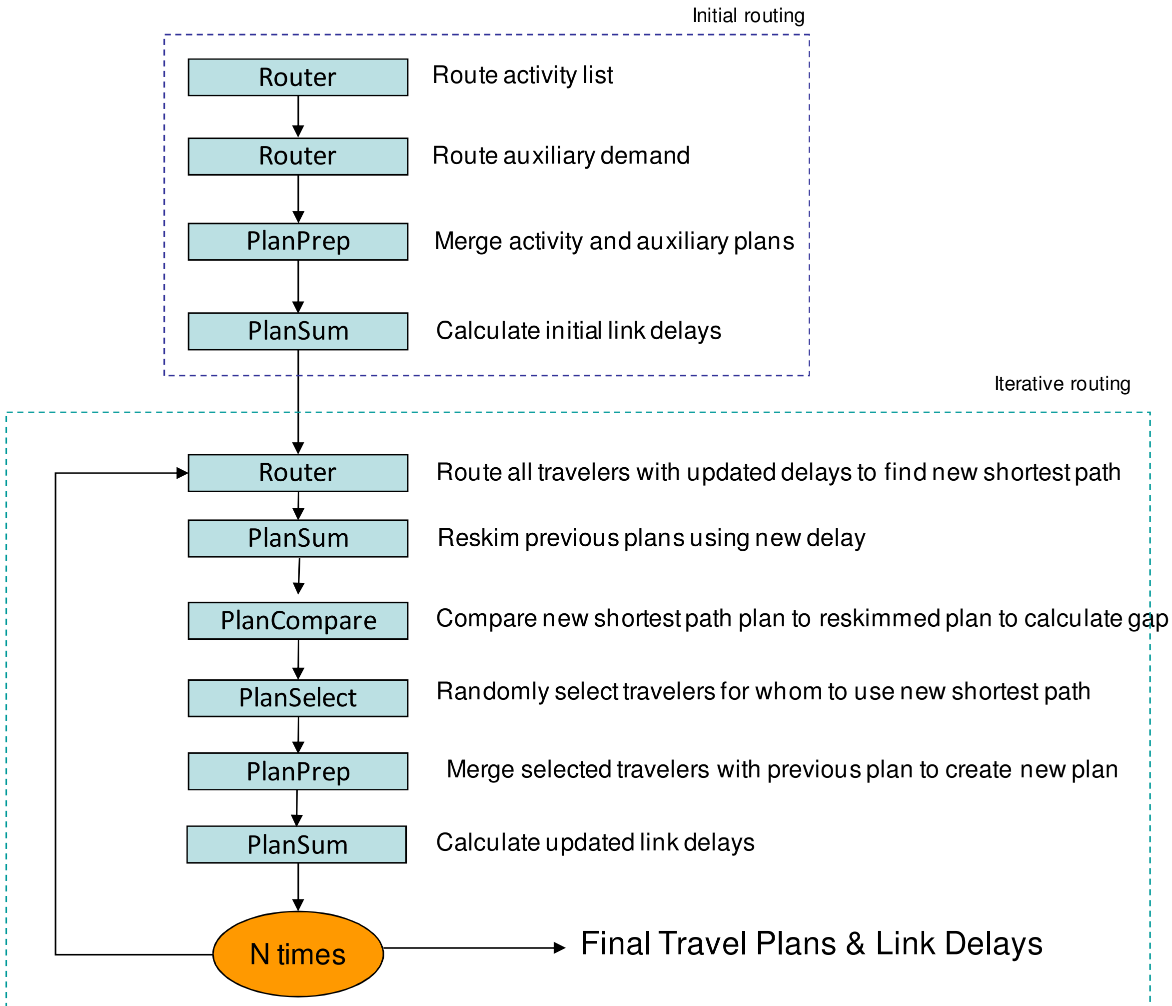


Figure 15. Revised Integrated Model RouterStabilizer Process



3.3.2 Network Skims

The primary modification required to integrate TRANSIMS with DaySim involved the creation of processes for skimming TRANSIMS network-based level of service measures that can be used by DaySim to predict travel choices. This effort involves a three-stage approach. In the first stage, which has been successfully implemented, the TRANSIMS Router and other tools were configured to produce zone-to-zone travel times for the four broad time periods used in DaySim. These travel time and costs skims are based on the detailed TRANIMS network link delay files, but are analogous to those produced by an aggregate static assignment procedure. In the second stage, which has also been successfully implemented, the TRANSIMS Router and other tools were reconfigured to produce zone-to-zone travel times for a total of twenty-two time periods, and DaySim was revised to accommodate this increased temporal detail. In the third and final stage, which has been designed but not implemented, network level of service will exploit activity location-to-activity location spatial resolution and use link delays at a 15-minute temporal resolution. However, transitioning to the third stage involves significant technical and computational challenges because it is infeasible to develop full matrices of activity location-level skims at 15 minute increments and store this information in a manner that facilitates reasonable model runtimes.

3.3.2.1 Stage 1 Skims Process

System feedback is achieved by iterating the integrated DaySim-TRANSIMS model system. After each system iteration, router derived congested travel times are fed back as input to DaySim in the form of shortest path travel time skim lists. In the initial Phase 1 integration, TRANSIMS tools were configured to create network level-of-service skims for the four broad time periods used by DaySim:

- AM peak (7:00am to 10:00am)
- Midday period (10:00am to 3:00pm)
- PM peak (3:00pm to 6:00pm)
- Evening (6:00pm to 7:00am)

For each origin-destination TAZ pair the following attributes are produced:

- Congested travel time
- Congested travel distance
- Excess1 time (the amount of time spent on links in the path that have a congested to freeflow time ratio greater than 1.2)
- Excess2 time (the amount of time spent on links in the path that have a congested to freeflow time ratio greater than 1.5)

In addition, AM and PM period skims are provided for two separate vehicle classes, single-occupant vehicles (SOV) and high-occupant vehicles (HOV). Given the distinct time periods, vehicles classes, and excess time criteria, 18 unique skim lists are generated.

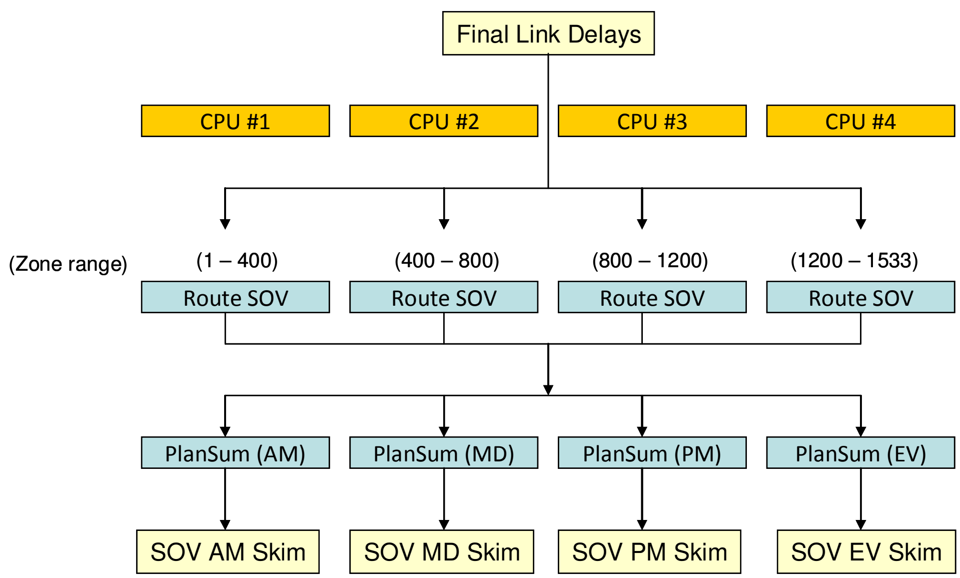
The first step in the skim development process is to produce plan-paths with the TRANSIMS Router that reflect the link delays from final iteration of the Router stabilization process described earlier. The Router can be configured to save paths to and from every activity location. However, given that the SACOG TRANSIMS network has roughly 22,000 activity locations and there are 96 15-minute time periods in a day, the computational and technical challenges quickly multiply. Strategies for fully addressing the spatial and temporal detail are discussed in the following Stage 3 Skim Process section.

For the Stage 1 model development, TRANSIMS was configured to produce skims analogous to those produced using the current TP+-based assignment and skim methodology. Because TRANSIMS is designed to use detailed activity locations as the fundamental spatial unit, it was necessary to develop a set of "dummy" activity locations that represent TAZs. TRANSIMS tools can then be applied to develop a complete matrix of all times and costs to and from these TAZ/activity locations that can be used in DaySim. By setting the range of ROUTE_FROM and ROUTE_TO to specify only the range of "dummy" TAZ locations, it is possible to generate a plan set to/from these locations based on congested link times that emulates a tradition zone-to-zone impedance matrix.

In order to develop unique SOV and HOV skims for the AM and PM periods vehicle class restrictions on links in the TRANSIMS network were required. Using the lane use restrictions table we identified the link IDs of the HOV links in the system and prohibited SOV vehicles from using these links during the 7am-10am and 3pm-6pm periods. Setting the ROUTE_WITH_SPECIFIED_MODE in the Router control as well as the skim mode selection in the PlanSum control allows the user to control when certain link paths are available to certain TRANSIMS modes. Mode 2 is for drive-alone (SOV) plan-paths while TRANSIMS modes 10, 11, and 12 are for carpool (HOV2, HOV3, HOV3+) plan-paths. The excess time skims were developed by calculating excess time at the link level using congested time and “congested time to freeflow time ratio” fields in the link delay file, and using this to create a “capped” link delay file. A skim that only contains the Excess1 time for links that have a congested time to freeflow time ratio exceeding the 1.2 or 1.5 threshold described above can be created by running PlanSum on this capped link delay file.

Initially, in order to develop time period specific skims, the first step involves configuring the Router to use the ROUTE_AT_SPECIFIED_TIMES key. For example, specifying this as “12:00..13:00” (noon-1pm) and then further specifying the ROUTE_BY_TIME_INCREMENT key to 60 minutes results in a set plans that represents average travel times from noon to 1:00pm. The second step of the process requires running PLANSUM on the congested plan set from to save and write out the TAZ-to-TAZ skim list. This is accomplished by setting SUMMARY_TIME_PEIOD to 12:00..13:00 (noon-1pm) and the SUMMARY_TIME_INCREMENT again to 60 minutes. Prior to using these spatially and temporally aggregate skims, the skims travel times, distances and paths are evaluated for reasonableness. The graphic below illustrates how single occupant vehicle skims are generated for the AM, MD, PM, and EV time periods. Parallelization in the routing is accomplished by specifying unique zone ranges for each processor.

Figure 16. SOV Skim parallelization process



A significant drawback of this approach is that, in order to generate these broad time period skims, it is necessary to discard much of the detailed network level of service information produced in 15-minute increments by TRANSIMS. As described in a subsequent section on model system enhancements, this can have serious impacts on the model system’s sensitivity. As a result, the skim process was revised so that network level of service for each hour of the day is developed, and then averaged within each time period. This revised skim process continues to show some anomalous behavior in the PM peak, but the overall time of day profile seems more reasonable, and the network assignment validation results by time of day are significantly improved.

3.3.2.2 Skims and Time Constraints

In the process of validating the integrated model system, a critical issue was identified that influences aspects of the model structure, implementation, calibration and application. As mentioned earlier, in order to integrate DaySim with TRANIMS, it was necessary to translate DaySim output into a format that could be utilized by the Router. Given the choice of translating DaySim demand into either a trip format (which does not maintain the relationships between the trips on a given tour) and an activity format (which does maintain theses relationships), DaySim was modified to produce activity files in order to maintain the greatest amount of consistency between the demand and supply side simulations. The critical difference between an activity file and a trip file is that an activity file contains a travel itinerary for each traveler and all tours and trips made by the traveler are treated as connected by the TRANSIMS Router. For example, DaySim predicts when a given traveler wishes to arrive at each successive activity during their day, and the expected duration of this activity is derived from the difference between these arrival times and the expected amount of time required to travel from one activity to the next.

The TRANSIMS Router contains many parameters that allow users to control how travelers' paths are determined and assigned to the network. In the initial development and configuration of the integrated model, it was necessary to set one of these parameters, IGNORE_TIME_CONSTRAINTS, to TRUE. When time constraints were not ignored, hundreds of thousands of trips were being "lost" or not assigned to the networks, which was clearly unacceptable given the desire to maintain a fully disaggregate model structure in which all travel demand is conserved.

This issue arose due to the nature of the activity file, the DaySim structure, the skims used as input to DaySim, and the TRANSIMS Router design. On the outbound (or first) half of each tour, DaySim predicts the travelers desired arrival time. In the standard DaySim trip list output, the departure time for a given trip is calculated by subtracting the skim-based expected travel time from the predicted arrival time. However, in order to produce the TRANSIMS activity file, DaySim translates the expected trip departure time into the end time for the previous activity. The start time for a given activity is based on the previous activity departure time plus the expected skim-based travel time. Problems arise when there are inconsistencies between the expected skim-based travel time that DaySim uses and the actual network-based travel time as the Router builds paths. If the activity start time can't be met (within a parameterized threshold) given the scheduled previous activity end time plus the TRANSIMS network path time, the trip is not assigned.

When IGNORE_TIME_CONSTRAINTS is set to TRUE, the Router doesn't evaluate whether there is an inconsistency between the implied travel time and the actual network travel time. Instead, the Router routes a trip to get to each activity with one essential feature – it treats the activity duration as fixed. If it takes longer to reach a given activity location given network travel times, the start time and the end time for that activity is delayed, causing a cascade effect through the traveler's entire daily activity pattern, with trips being pushed later and later in the day. This issue became apparent in reviewing network assignment results, with the AM peak and midday time periods being under predicted in terms of total volumes, and the evening time period being radically over predicted, as shown in Table 5.

Table 5. Effect of Skim Method on Model Validation by Time Period

Time Period	Integrated Model Original Skim % Diff	Integrated Model Revised Skim % Diff
AM	-13.2	1.4
MD	-2.2	2.3
PM	-0.7	3.1
EV	37.5	15.0
DAILY	6.0	5.1

The problem was attenuated, but not resolved by making revisions to the skim process. As previously described, in the initial Phase 1 integration, TRANSIMS tools were configured to create network level-of-service skims for the four broad time periods used by DaySim. In order to generate these broad time period skims, it was necessary to discard much of the detailed network level of service information produced in 15-minute increments by TRANSIMS. In order to generate time-period-level skim, the level of service from a single representative hour was used, and therein lays the fundamental problem: the level of service skimmed for a given hour and subsequently fed back to DaySim is frequently inconsistent with the detailed TRANSIMS network-based level of service. For example, the evening time period skim was initially based on travel times between midnight and 1am, although most travel in this period probably occurs earlier, when there is more delay. With each successive global iteration, the trips by time of day become more unreasonable, as seen in Table 5.

In the course of the validation of the overall model system, an evaluation of the evolution of network level of service across system iterations was performed in order to understand the changes in trip-making predicted by DaySim. This investigation revealed significant changes in travel by time of day, and the aggregate network skim process was revised to address this model sensitivity. In the revised skim process, network level of service for each hour of the day is developed, and then averaged within each time period. Figure 17 and Figure 18 show the effect on tripmaking by time-of-day for two alternative network skimming procedures. The revised skim process continues to show some anomalous behavior in the PM peak, but the overall time of day profile seems more reasonable, and the network assignment validation results by time of day are significantly improved.

Figure 17. Trip Arrival Times by Hour of Day and System Iteration: Original Skim Method

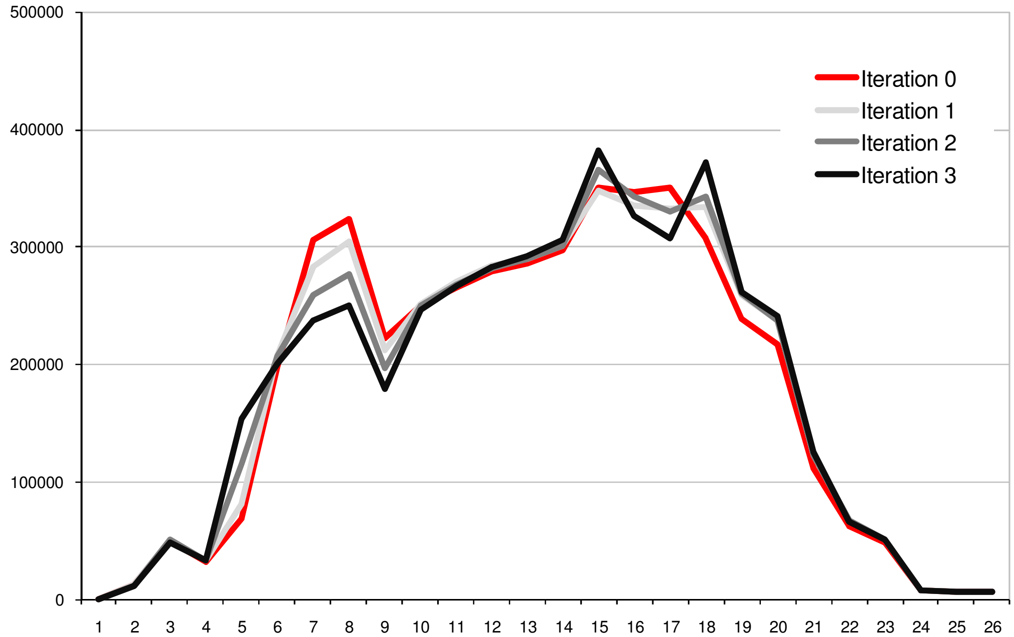
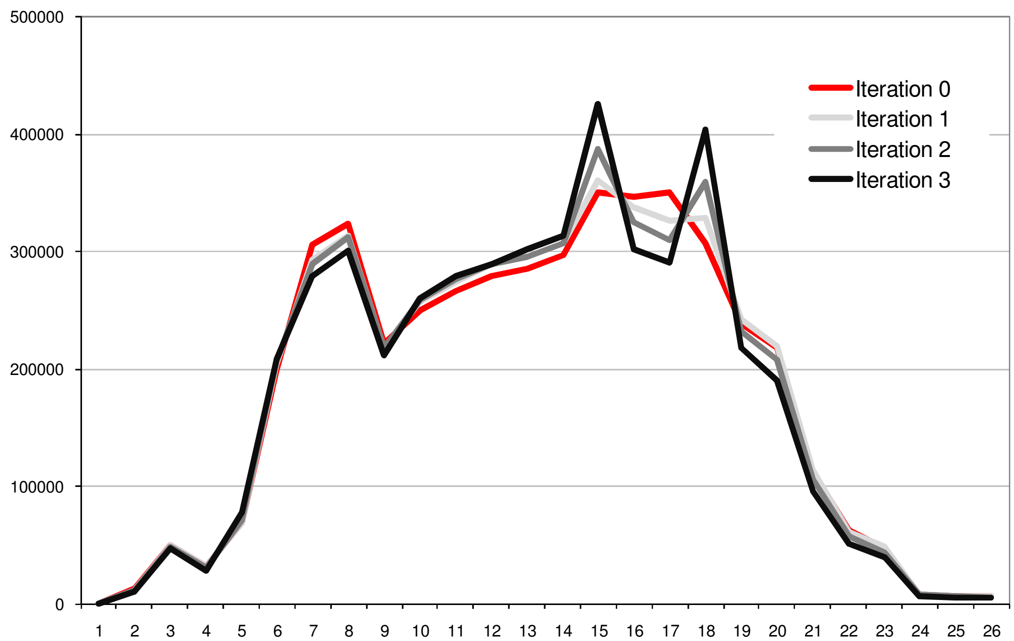


Figure 18. Trip Arrival Times by Hour of Day and System Iteration: Revised Skim Method



Although this figure suggests that the revised skimming procedure does a better job of emulating the time-of-day distribution that results from the use of TP+ skims, it also reveals a significant amount shifting around the PM peak period. This is likely a reflection of the fact that the DaySim time-of-day models have a number of constants that enforce the basic shape of the trip distribution by time of day. If the PM peak period is congested, trip arrivals/departures are shifted out of this period and into the mid-day and evening periods. The expected result is that overall demand in the PM peak period would decline, but that the period would retain its peaked shape, which seems evident in the time of day distribution. These results suggest that the TRANSIMS-based skims are more congested than original SACSIM TP+ based skims. In order to resolve, it is likely necessary to either run more system iterations, or may simply need to be recalibrated to reflect the use of new TRANSIMS-based skims.

Ensuring consistency between the input network level of service that the choice models are exposed to and the output level of service that is produced by the network assignment process is, of course, of great importance. Conserving all demand and not losing trips is also a critical integrated model goal. One would expect that as the Phase 3 "on the fly" skim methods are implemented that time constraint issues would diminish. Similarly, one would expect that as more global iterations of the model system are performed that time constraint issues would also diminish, though not disappear.

However, it may also be possible to reconfigure the interaction between DaySim and TRANSIMS such that there is more flexibility to accommodate those instances where the inconsistency between input and output level of service persist. For example, TRANSIMS could be revised to be consistent with DaySim in that activity duration is not explicitly predicted but is instead determined as the difference between two modeled departure (or arrival) times and the travel time between the two activities. In this scheme, if TRANSIMS routes a trip given the departure time but the resulting subsequent arrival time is later than the prescribed start time of the next activity (prescribed in the activity file), then TRANSIMS could allow that next activity's duration be reduced in order to adhere strictly to the departure time from the next activity that has been scheduled by DaySim. This method might also be refined to allow for different types of flexibility based on person or activity purpose. For example, travelers might have more discretion to shorten shop activities in order to maintain the predicted schedule, while work activity durations might be more rigid, and result in the rescheduling of travel.

3.3.2.3 Stage 2 Skim Process

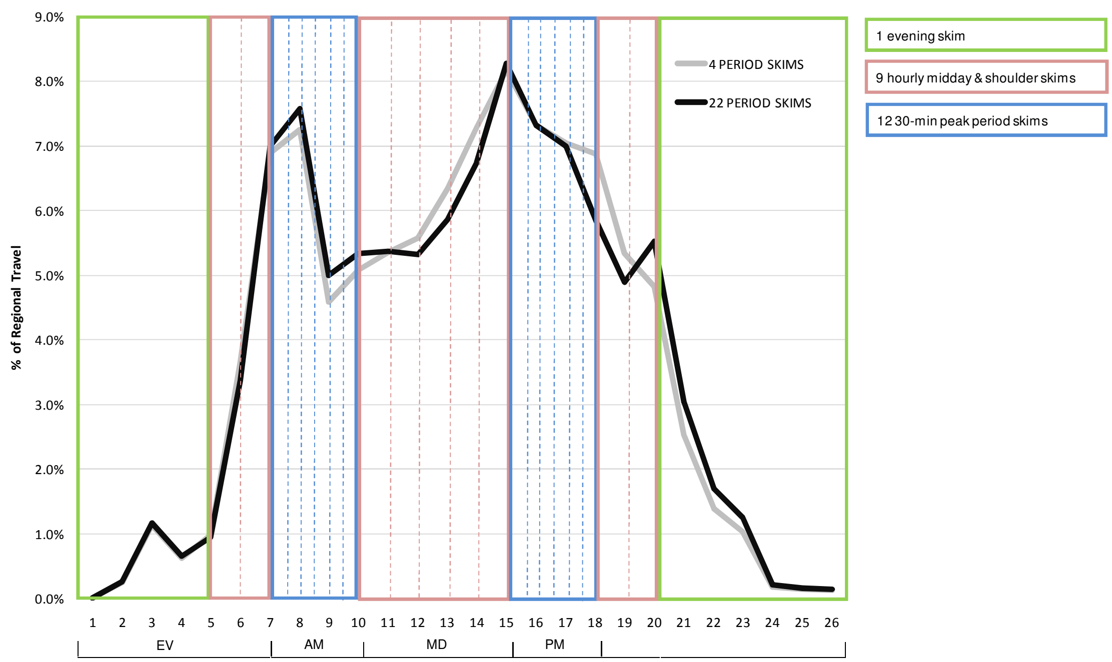
As a transitional stage between the spatially and temporally aggregate skims developed in Stage 1 and the fully disaggregate skims envisioned in Stage 3, the Stage 2 skim process provides increases temporal detail but continues to function at the level of travel analysis zones rather than the more detailed activity locations. Rather than four broad time periods, the Stage 2 skim process is characterized by the use of separate skims for 22 different time periods (12 half-hour periods during the AM and PM peaks, 9 1-hour periods during the midday, pre-AM peak and post-PM peak, and a single 9-hour period during the night and early morning.)

However, even implementing the interim temporal resolution of the Stage 2 approach presented significant technical challenges.   To accommodate 22 time periods in memory, with each time period having 12 matrices representing various time and cost variables by mode, DaySim would have to hold 12 x 22, or 264 matrices in memory, which is not possible within the current 32-bit memory limitations. To address this limitation in the short-term, two options were tested: modifying DaySim to use an efficient disk-based temporary storage structure and swapping LOS in and out of memory, or reducing DaySim's memory needs wherever possible in order to fit the 22 travel time matrices in memory without a major overhaul of the memory-handling methods and code. This second option was pursued in Stage 2, and the first option will be implemented in Stage 3. Reducing DaySim's memory needs for near-term testing purposes involved:

- using only the original four time periods for the toll variables: Currently there are no tolls in the Sacramento region, but the variable is included for policy testing.
- using only the original four time periods for the distance variables: Although paths can vary by time of day, the difference between path differences in minor, and only effects fuel cost in the models.
- using HOV2 times for the HOV3+ mode: There are currently no HOV3+ facilities in Sacramento.

Figure 19 illustrates the effect of using the revised 22 time-period skimming and DaySim procedures. However, these results only reflect the use of the skims in a single global iteration. Further investigation is necessary to determine the effect when the integrated model system is run with more global iterations.

Figure 19. Percent of Regional Travel by Hour and Skim Method



3.3.2.4 Stage 3 Skim Process

The use of TAZ-level skims at the resolution of broad time periods discards significant detailed information that could greatly enhance the sensitivity of the DaySim model. However, the use of activity location-level travel times and costs for detailed time periods presents significant technical challenges. There are several important objectives for the Stage 2 software implementation:

- For auto modes, to allow the origins and destinations for LOS data to be defined as activity locations (AL), where activity locations are aggregations of parcels and zones are aggregations of ALs
- To allow the LOS data to be supplied via zonal skim files for any mode, or via AL-to-AL LOS retrieval for auto modes. To eventually allow AL-to-AL LOS retrieval for all modes.

- To allow mode-specific time ranges (each with uniform attribute values) as small as the time-of-day models (currently 30 minutes) or as large as 24 hours (as in the current walk skims
- To implement AL-to-AL LOS retrieval procedures and data structures

The basic elements of the proposed approach are:

- Use a LOS Roster (and possibly also one or more control file parameters) to define the time periods for every mode, to determine whether the LOS data comes from AL-to-AL calculations or from zonal skims and, for zone-based skims, the skim file to be used. (This provides for flexibility in defining time periods and allows various combinations of zone-based and AL-based LOS).
- Calculate AL-to-AL LOS at strategic points in the DaySim looping process when destinations must be sampled. (This saves time compared to calculating LOS for all possible cases at the beginning of a DaySim run or within models every time they need it.)
- Sample ALs instead of TAZs in the first stage of the two-stage destination sampling procedure. Save the first stage sample and corresponding LOS in random access binary files and re-use them up to a user-specified number of times. (This saves time compared to sampling every time a sample is needed. It saves memory compared to keeping all LOS in memory.)
- Each time an AL sample is used, conduct the second stage of the two-stage destination sampling to sample a parcel within the sampled AL. (This reduces the lumpiness of the sampling, compared to re-using the second-stage sample.)
- For modes with TAZ-based LOS, support two methods of dealing with LOS. Both methods read all the LOS data from skim files as prescribed by a LOS Roster, at the beginning of a DaySim run. Method 2 stores the LOS data in a disk-based binary data structure similar to the structure used for AL-based LOS data, but for all destination zones instead of only a sample. Method 1 stores the LOS data in a memory-resident array similar to the disk-based structure, but spanning all origin zones. (Method 2 mimics the approach described for AL-to-AL LOS storage and retrieval. Method 1 saves computation time if enough memory is available.)
- When destination samples and LOS are retrieved and/or generated for use, store them in memory-resident arrays that the models access directly when they need LOS information. (This saves computation time compared to making function calls from within the models.)
- Contain the logic that triggers sampling and the calculation of LOS in two functions, getDestSample() and getIntStopSample(), which are able to determine and handle the type of LOS retrieval that needs to occur:
    - zones vs. ALs for first stage sample
    - zone-based vs. AL-based LOS
    - disk-based vs. memory-resident storage and retrieval method for zone-based LOS
    - retrieve and use a first stage sample vs. generate a new one.

- Enhance destination sampling to support the above approach. This includes (a) separating the destination sampling protocol into two stages that can be called separately; (b) changing the first stage to sample ALs instead of TAZ, (c) eliminating the unique sampling protocol for intermediate stops, instead using a variation of the destination sampling protocol that draws half the sample from around the tour origin and the other half from around the stop origin; and (d) enhancing the sampling pre-calculations (that run once at the beginning of a DaySim run) to support the enhanced sampling procedure.
- Implement a Router enhancement that generates and returns AL-to-AL LOS attributes for a set of ODs, given the following information:
    - a single AL for the start or end of the trip
    - a time-of-day associated with the trip start or end
    - whether the single end is the start or end of the trip
    - a set of ALs for the other end of the trip

The above approach would enable DaySim to support the Stage 2 DaySim-TRANSIMS implementation with a different spatial aggregation scheme (AL-to-AL LOS for auto modes, parcels as destinations, and two-stage sampling with AL then parcel.). However, it is important to continue supporting the current SACSIM implementation and the Stage 1 DaySim-TRANSIMS implementation with the existing SACSIM spatial aggregation scheme (zonal skims, parcels as destinations, two stage destination sampling with zone then parcel). Also, at least two and perhaps as many as five additional spatial aggregation schemes are likely to be needed within the next several years, as listed in Table 6. Scheme 3 would enhance the DaySim-TRANSIMS interface to use TRANSIMS for transit assignment, with DaySim using AL-based LOS for all modes. Scheme 4 would be used to support regions that lack parcel data. Scheme 5 would support regions that lack parcel data but are able to define virtual subzones with regard to basic size attributes and transit accessibility. Schemes 6 and 7 would support regions that can disaggregate their spatial data, but with geographic units larger than parcels that could be used directly as TRANSIMS ALs.

Table 6. Spatial Aggregation Schemes

	Scheme	OD LOS	Destination alternatives	Destination sampling
1	SACSIM original, and DaySim-TRANSIMS Stage 1	zonal skims	parcels	zone-->parcel
2	DaySim-TRANSIMS Stage 2	AL LOS (auto) zonal skims (other modes)	parcels	AL-->parcel
3	DaySim-TRANSIMS (all modes)	AL LOS (all modes)	parcels	AL-->parcel
4	Zonal destinations	zonal skims	zones	zone (single stage)
5	Virtual subzones	zonal skims	virtual subzones	zone-->subzone, or subzone (single stage)
6	AL-TRANSIMS	AL LOS (auto) zonal skims (other modes)	ALs	AL (single stage)
7	AL-TRANSIMS (all modes)	AL LOS (all modes)	ALs	AL (single stage)

Ideally, the proposed current approach could be implemented with an eye toward these potential additional schemes. The additional capabilities would need to include the following:

- To support scheme 1: Enable DaySim to use zones as the first sampling stage by defining ALs that correspond 1-to-1 with zones, so that the AL-based first sampling stage produces a sample of TAZ.
- To support schemes 3 and 7: Implement disk-based AL-to-AL structures for all non-auto modes and enable the functions that get LOS information to handle them like they handle auto LOS. Enhance the Router to supply AL-to-AL LOS for non-auto transit modes.
- To support scheme 4: Verify that scheme 1 DaySim would work effectively with one parcel defined per zone. Enable DaySim to work without second stage sampling, with only one AL defined per sampled per zone.
- To support scheme 5: Treat subzones as parcels with two stage sampling, or as ALs with one-stage sampling.
- To support scheme 6: Verify that scheme 2 DaySim would work effectively with one parcel defined per AL. Enable DaySim to work without second stage sampling.

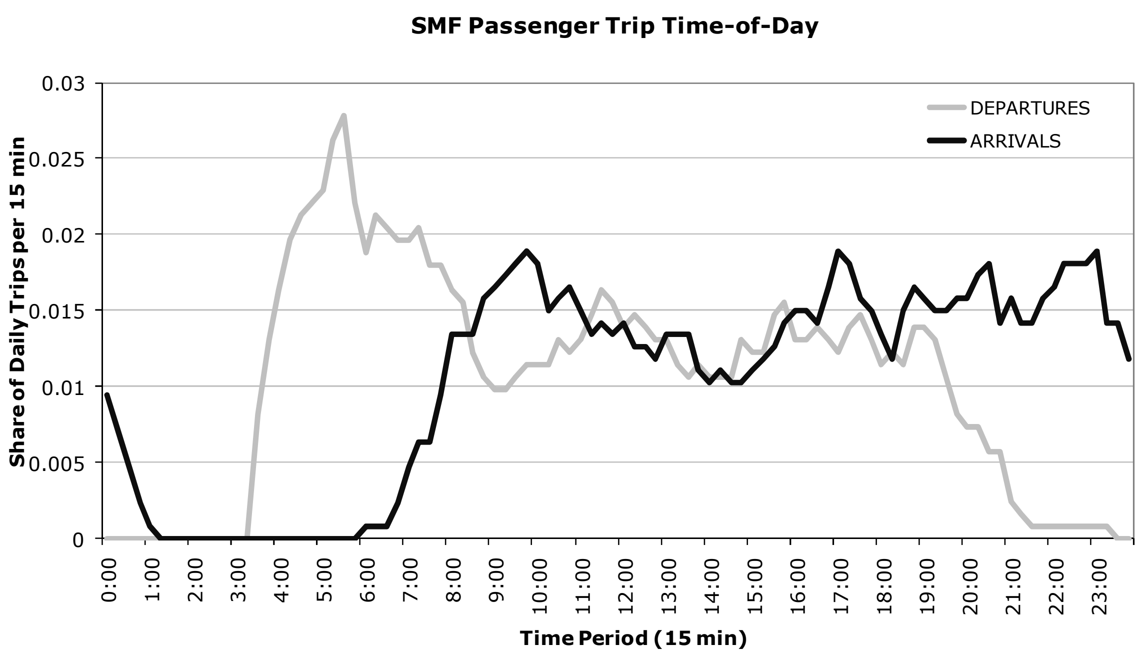
3.4 Auxiliary Demand

The SACOG travel model includes auxiliary travel demand that is not predicted by the core DaySim model, such as airport ground access trips, external trips, and commercial vehicle trips (2-axle and 3+-axle trucks). To incorporate these components of regional travel demand, a trip table conversion process was developed that disaggregated these fixed trip tables both spatially and temporally, using population- and employment-based weights and detailed purpose-specific diurnal distributions. The triptable conversion process uses the ConvertTrips utility that is included in the TRANSIMS distribution. The following sections each type of auxiliary demand and the process for disaggregating his demand spatially and temporally.

3.4.1 Airport Ground Access

Airport ground access trips are derived from trip matrices provided by SACOG. These matrices including information on vehicle trips by occupancy class, and are spatially disaggregated to activity locations using a size term based on housing units and non-retail employment. The airport diurnal distributions are based on the Sacramento International airport (SMF) flight arrival and departure schedule from 2008, and are applied by direction (to airport and from airport). Separate airport departure trip and airport arrival trip diurnal distributions (resolution=1 hour) were developed for a typical weekday. These arrival and departure airport vehicle-trip diurnal distributions were then further adjusted by shifting flight departure trips earlier by -90 minutes (to account for the fact that people have to arrive at the airport at least an hour early) and shifting flight arrival trips by +30 minutes to account for the fact that people have to disembark, get bags, and encounter other delays.

Figure 20. Sacramento International Airport Ground Access Arrival and Departure Diurnal Distribution



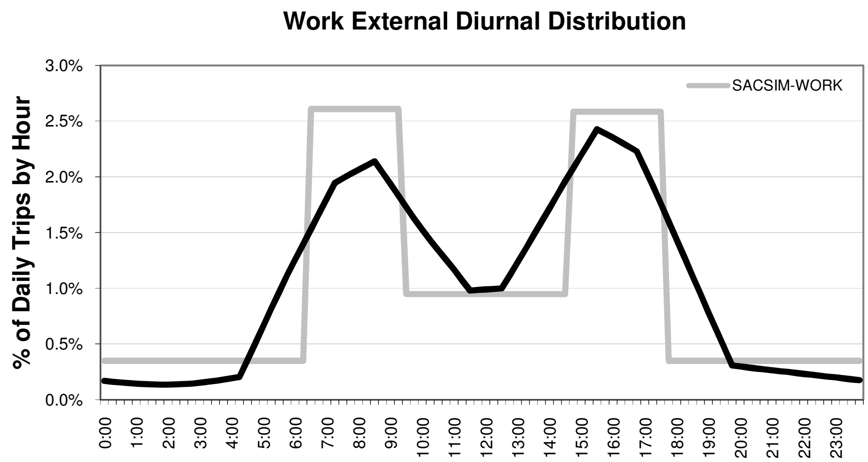
3.4.2 Externals

External trips are derived from trip matrices provided by SACOG. For external trips by purpose made by SACOG residents to external stations, the non-external station trip end (production end) is disaggregated using a size term based on housing units and total employment. For external trips by purpose made by non-SACOG residents to internal zones, the non-external station trip ends (attraction end) are disaggregated using a size term based on employment, housing units, and enrollment consistent with the purpose-specific composite size terms found in DaySim model scripts and documentation.

The external demand diurnal distributions are segmented by purpose, and are based on a combination of hourly Caltrans volumes at external stations (which don't include purpose-specific information) and the existing SACOG purpose/time-of-day factors, as shown in Figure

21. The thru trip diurnal distributions are based on Caltrans volumes at external stations (for person travel) and Caltrans truck counts (for commercial travel).

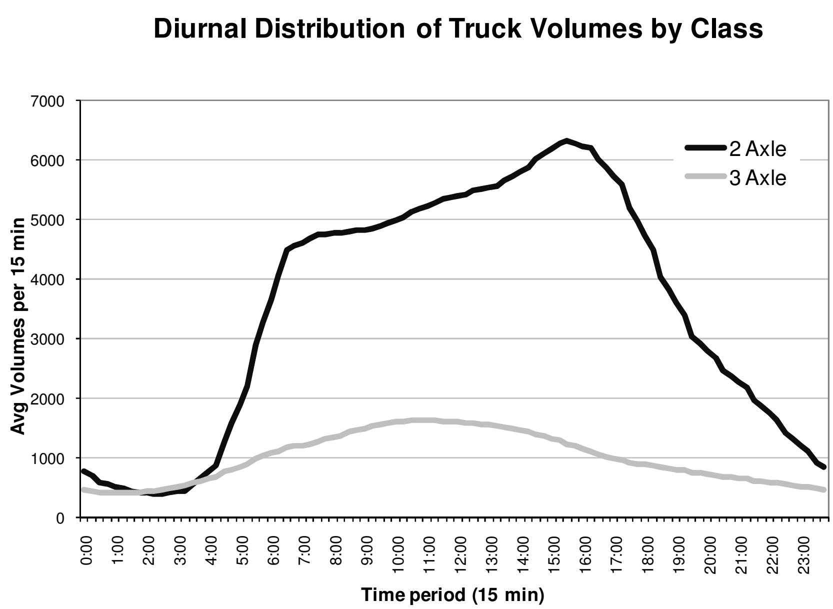
Figure 21. External Work Trip Diurnal Distribution



3.4.3 Commercial Vehicles

For commercial vehicles, tripends are disaggregated at both the origin and destination using 2-axle and 3-axle-specific size terms reflecting distributions of households and employment by sector. The same size term by class is used at the origin and destination end. The commercial vehicle demand diurnal distributions are also segmented by 2-axle and 3-axle vehicles, based on Caltrans hourly truck volumes by class.

Figure 22. Commercial Vehicle Diurnal Distribution



4.0 CONVERGENCE / EQUILIBRATION

Model system convergence is achieved when the inputs to the model system are consistent with the outputs from the model system and the model system has converged on a solution. Convergence is necessary in order to ensure the behavioral integrity of the model system. The impedances or level-of-service measurements used as the basis for accessibility measures and as key inputs to the destination and mode choice models must be approximately equal to the travel times and costs produced by the final network assignment process. Model system convergence is also necessary to ensure that the model system will be useful as an analysis tool. The stability of model outputs, especially measures such as link flows, is essential to support planning and engineering analyses, and changes to demand or supply should lead to reasonable changes in model outputs.

Model system convergence is typically achieved through iterative feedback. This feedback occurs both within the network assignment phase, most frequently by using an aggregate deterministic user equilibrium traffic assignment process, and within the overall model system by feeding the impedances output by the network assignment process back to the beginning of the model run stream. The fully disaggregate integrated DaySim-TRANSIMS model provides a unique platform for pursuing network assignment and model system convergence. Although there is not consensus that fully dynamic mesoscopic traffic assignments can approach a true user equilibrium solution, the Router's sensitivities, which exclude phenomena such as queuing, do not preclude the pursuit of user equilibrium. The disaggregate nature of both the demand and supply side simulations also provide unique capabilities and opportunities, such as the ability to reroute portions of households, persons or trips during network assignment rather than averaging assignment iterations, and the ability to resimulate subsets of households at both the demand and supply stages.

4.1 Network Convergence Strategies

It is not possible to achieve model system convergence without first having a method for approaching network assignment convergence. Network convergence assumes travel demand by origin, destination, mode and time of day as fixed. In seeking network assignment convergence it is typical to also seek a user equilibrium condition, convergence to a solution where no single trip can be improved by rerouting it alone. Network performance for this purpose is times, distances, and costs measured at an activity location-to-activity location resolution.

4.1.1 Dynamic User Equilibrium

In the context of dynamic traffic assignment, the notion of user equilibrium has been extended and is referred to as "dynamic user equilibrium." Dynamic user equilibrium (DUE) acknowledges that travelers sharing common origins and destinations will experience different travel times based on departure time. Dynamic network equilibrium requires that the equilibrium condition be established for each departure time rather than over a broad time period. The integrated Daysim-TRANSIMS model assigns a list of trips using extremely detailed spatial information (there are over 22,000 activity locations in the Sacramento region) and temporal information (at the resolution of minutes). Most significantly, the assignment of trips to the network is performed at a fully disaggregate person and vehicle-level, where a single path is determined for each movement. This disaggregate approach has implications for the convergence measures as well as the strategies for achieving an acceptable convergence.

4.1.2 Trip Gap Measure

The most common and standard measure of convergence in traditional user equilibrium traffic assignment is "relative gap." In traditional assignment, relative gap is a link-based measure of the percentage difference between the current value of the user equilibrium objective function and the best lower bound on the optimal value of that objective function. The best lower bound is obtained by linear approximation via shortest path assignment of all flows using the latest link travel times. For this effort, we propose to use a new gap measure of user equilibrium that exploits the disaggregate nature of the TRANSIMS Router, shown in Figure 23. This disaggregate measure is calculated at the trip level, and it captures the difference between the trip cost using the most recent equilibrium-weighted path and link costs and the trip cost using the shortest path and equilibrium-weighted link costs. This difference is summed across all trips and normalized. This measure is similar in conception to the link-based relative gap measure used in traditional assignment, but uses the disaggregate information provided by the TRANSIMS Router. Note that for each trip, the trip costs depends on the trip departure time, because trip cost is derived from time-dependent link costs.

Figure 23. Trip Gap Measure

$$\frac{\sum_s \left(c_{xs}(\{c_{at}\}) - c_{ys}(\{c_{at}\})\right)}{\sum_s c_{ys}(\{c_{at}\})}$$

where:

- s indexes trips
- $\{c_{at}\}$ is an updated set of time-dependent link costs after combining new trip routes for a subset of household with pervious iterations' routes for the other households
- c_{xs} is the cost of the trip s along the path that was used for the calculation of $\{c_{at}\}$
- c_{ys} is the cost of the trip s along its shortest path, assuming $\{c_{at}\}$

Use of this gap measure implies a distance from an optimum solution, and a search procedure for moving to that optimum. In the traditional link-based gap context, convergence is sought through iteratively assigning demand, averaging link volumes, recalculating link delays, and reassigning demand. In this disaggregate context where we are evaluating individual trip costs, our initial efforts sought convergence by averaging link volumes and recalculating delays. Multiple strategies were employed, including routing all travelers at every iteration, similar to a traditional assignment, as well as rerouting only the most problematic trips.

Figure 24. Disaggregate Trip Gap and Network Relative Gap Convergence

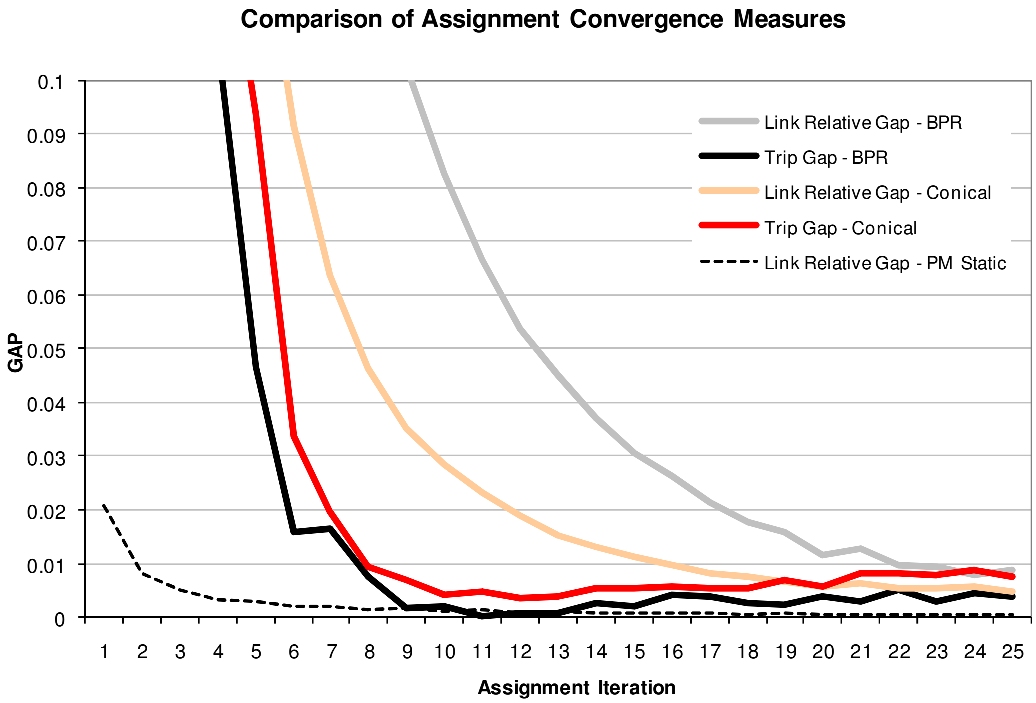
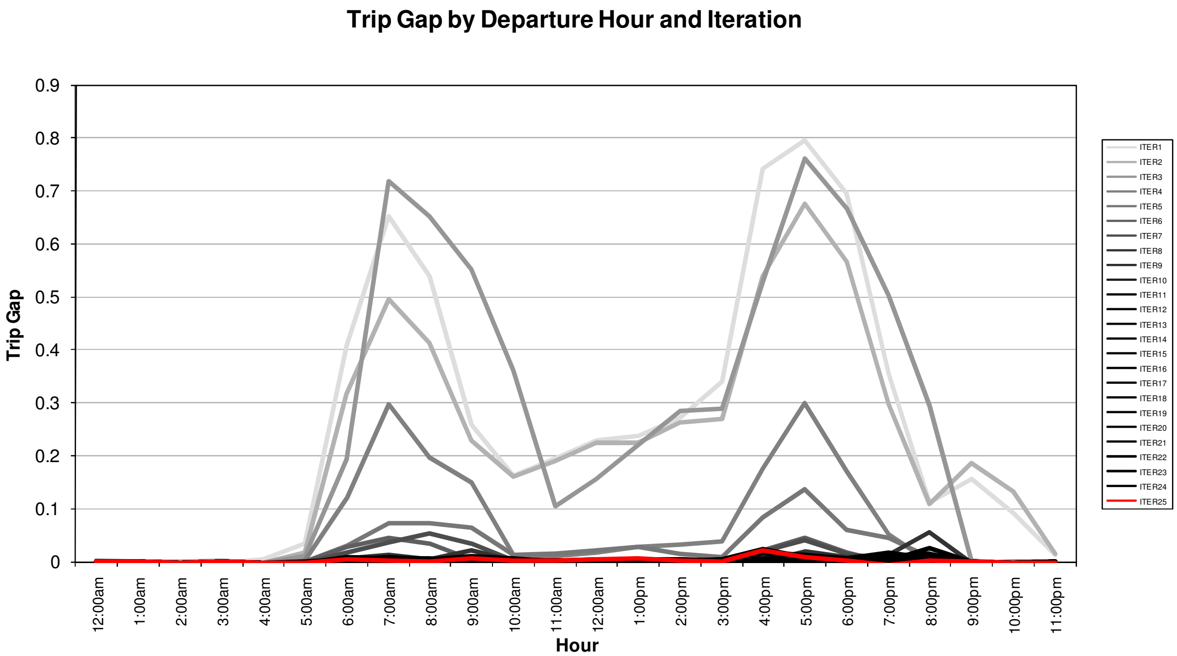


Figure 24 compares the convergence results of the conical and BPR assignment processes, using the trip gap measure presented above, as well as a traditional link-based relative gap measure. These results are from the final (4th) system iteration, and are the result of re-routing all trips at every assignment iteration. For comparison, a link-based relative gap measure from a SACSIM PM peak period assignment is included for comparison. The trip gap measures, whether based on conical or BPR functions, appears to converge more quickly than the traditional link-based relative gap measures. However, all of the TRANSIMS-based convergence measures are noticeably higher than the static assignment convergence measure.

Because it is based on a fully disaggregate network assignment process in which the details of every assigned trip are maintained, the trip gap measure can be presented at any level of temporal or spatial disaggregregation. Figure 24 illustrates the trip gap measure across all assigned trips and all times of day. However, this gap measure could be calculated for all trips departing or arriving at specified times of day or to or from specified locations. Figure 25 illustrates the calculation of the trip gap measure at an hourly temporal resolution (based on departure hour), and across every assignment iteration. This figure clearly shows that the trip gap measure varies significantly by hour of day, and also changes with each successive assignment iteration.

Figure 25. Trip Gap by Departure Hour and Iteration



4.1.3 Averaging Link Delays

Prior TRANSIMS development and application efforts have sought to identify means of combining travel paths and link travel times so that the times used to route trips are consistent with the estimated delays resulting from this routing. Successive averaging of link delays has been found to be an effective way of reaching this convergence. The TRANSIMS White House Study used a weighting factor of three to combine the previous average delays with the latest link delays. Effectively, 75 percent of the previous average delay is combined with 25 percent of the most recent Router-based delay in order to produce an average delay used in the next iteration. In the initial RouterStabilizer process, weighting factors of three and nine were tested. In the revised RouterStabilizer process, in response to concerns expressed by peer review panel members, the link averaging process was eliminated, as described in Section 4.1.5.

4.1.4 Routing Subsamples

One of the key capabilities of the TRANSIMS Router is that routing is performed at the disaggregate trip level, providing the ability to reroute subsamples of households, persons or trips (at present TRANSIMS does not have the ability to reroute tours). In prior TRANSIMS implementations, rerouting subsamples was used to achieve convergence more quickly by focusing efforts on those trips, persons, or households that are impeding convergence. The subsamples to be rerouted have typically been defined using critical V/C ratio measures, where trips, persons, or households traversing links that exceed a V/C threshold are identified, or by travel cost differences between the current and prior iteration. For this effort, initial tests involved identifying subsamples of trips that traverse links with V/C ratios > 1.5 in the most recent routing, which has proven useful as a means of addressing bottlenecks. Subsequently, subsamples of trips were identified by relative and absolute travel time discrepancies between the most recent routing and the prior routing. However, peer review panel members expressed concerns about the use of heuristics to select households. Rather, it was felt that, from a mathematical optimization perspective, each household should have an equal probability of switching to a new shortest path. The revised RouterStabilizer process, described in the next section, excludes the use of heuristics.

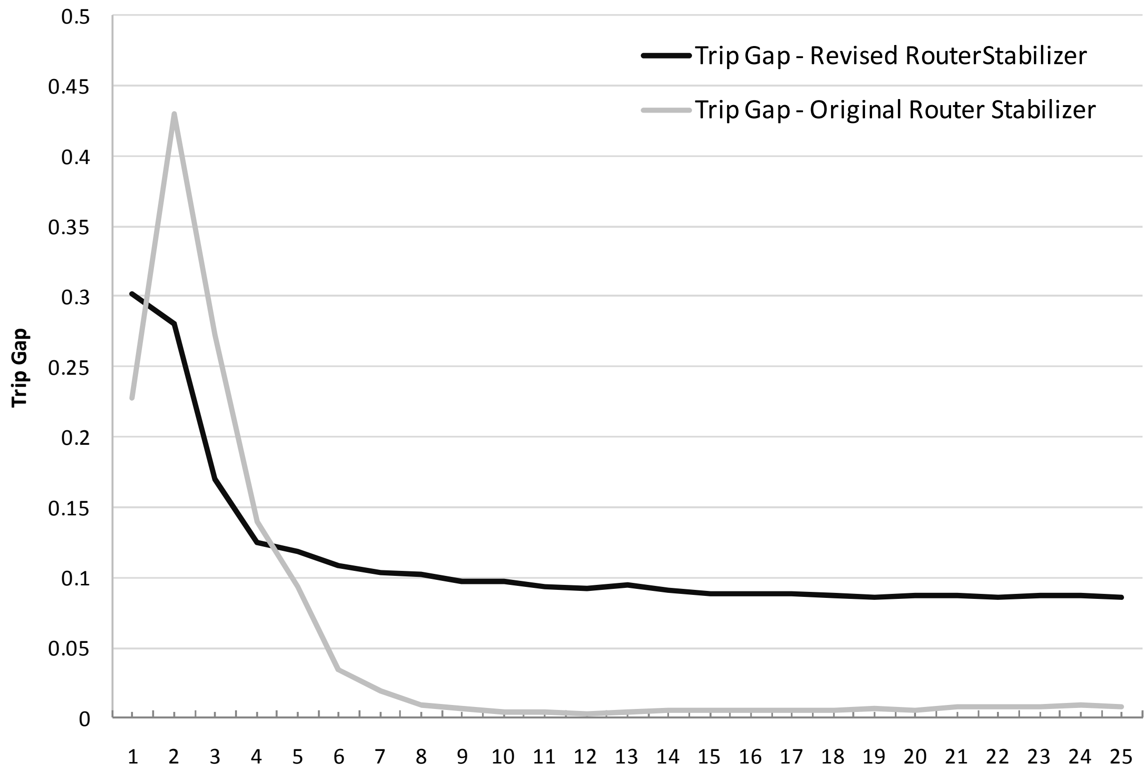
A very significant aspect of subsample rerouting is that the only a portion of the subsample is rerouted and that the share of the total trips, persons or households that can be rerouted is capped. Past TRANSIMS efforts have constrained the share of the subsample to be rerouted at 50%, and the share of the total trips, persons, or households to be rerouted at 10%. In the initial RouterStabilizer process, these guidelines were used when routing subsample.

4.1.5 Revised RouterStabilizer Process

In response to the concerns expressed by the peer review panel, a revised approach to Router Stabilization, shown in Figure 15, was implemented. In this approach, new shortest paths are determined for all travelers. A portion of these new shortest paths are used to update the full path set that includes all travelers. In this revised approach, no heuristics are used when subselecting travelers, rather a purely random process is employed. A method of successive averages is used to determine the share of regional travelers for whom to use updated paths. This approach is more consistent with current dynamic traffic assignment practice. In addition, as mentioned previously, no link averaging is performed. New link delays are calculated at each iteration, based on the updated set of traveler plans.

Figure 26illustrates the convergence, as measured using the previously described "trip gap" metric, of the revised RouterStabilizer process. These results suggest that the network assignment process does not converge as quickly using the revised router stabilizer method. Consideration of alternative RouterStabilizer configurations, including hybrid schemes that may employ different subselection probabilities, or that use heuristics during the initial iterations only, warrant further investigation.

Figure 26. Revised RouterStabilizer Trip Gap Measure



4.2 System Convergence Strategies

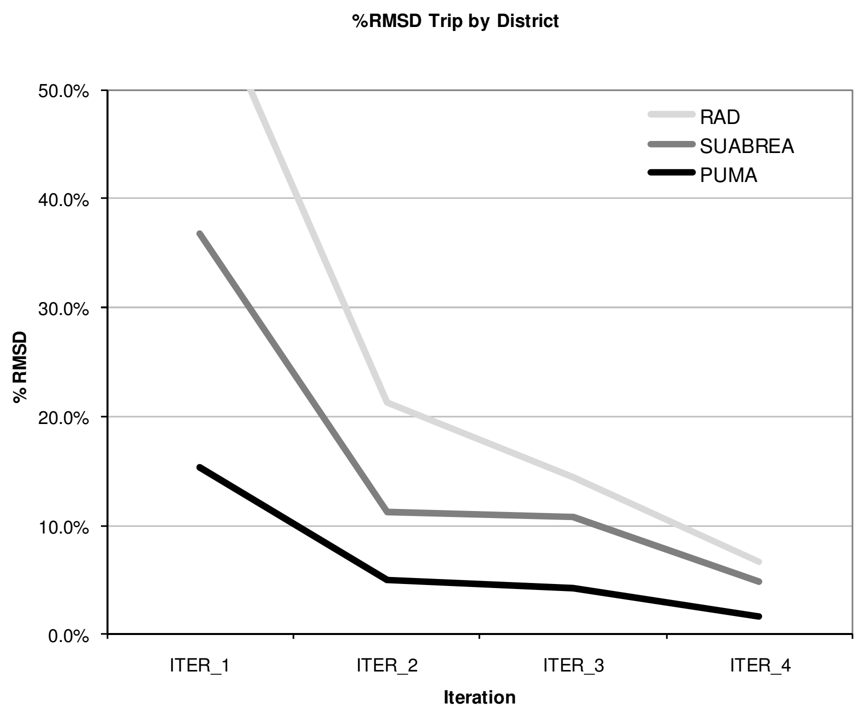
In order to ensure the behavioral integrity of the model system, the impedances or level-of-service measurements used as the basis for accessibility measures and as key inputs to the demand models must be approximately equal to the travel times produced by the final network assignment process. The link times and flows (from converged network assignment) used to generate the impedances used in the demand model should also match those from the subsequent traffic assignment. In principle, this model system convergence in the context of the Daysim-TRANSIMS integrated model can be achieved using established feedback methods employed in many traditional aggregate as well as some disaggregate models.

4.2.1 Feedback of Average Link Volumes

Commonly used and effective methods for achieving model system convergence in aggregate models is the use of successive averaging of travel demand, skims, link flows, link delays or combinations of these inputs/outputs. In the context of the integrated Daysim-TRANSIMS model system, it does not make sense to average travel demand, given that this can only be performed at an aggregate matrix level. It also does not make sense to average skims, as the second phase of the Daysim-TRANSIMS integration effort involves eliminating skim matrices and instead generating impedances from activity location-to-activity location "on the fly". Instead, we propose evaluate the method of averaging link volumes and recalculating delays, consistent with the network assignment convergence process.

For this initial Daysim-TRANSIMS integration, the primary criteria for assessing whether system convergence has been established was the root mean square difference for O/D flows at the district level. Figure 27 shows the percent root mean square difference using three different district systems. Regional Analysis Districts (RADs) are the smallest spatially, with about 70 in the region, meaning that a total of almost 5,000 RAD pairs were compared. Districts are larger, with about 40 in the region, resulting in approximately 1500 RAD pairs. PUMAs are largest, with about 15 in the region, resulting in approximately 200 PUMA pairs.

Figure 27. System Convergence: Percent Root Mean Square Difference by District



4.3 Coordinated Network and System Convergence Strategies

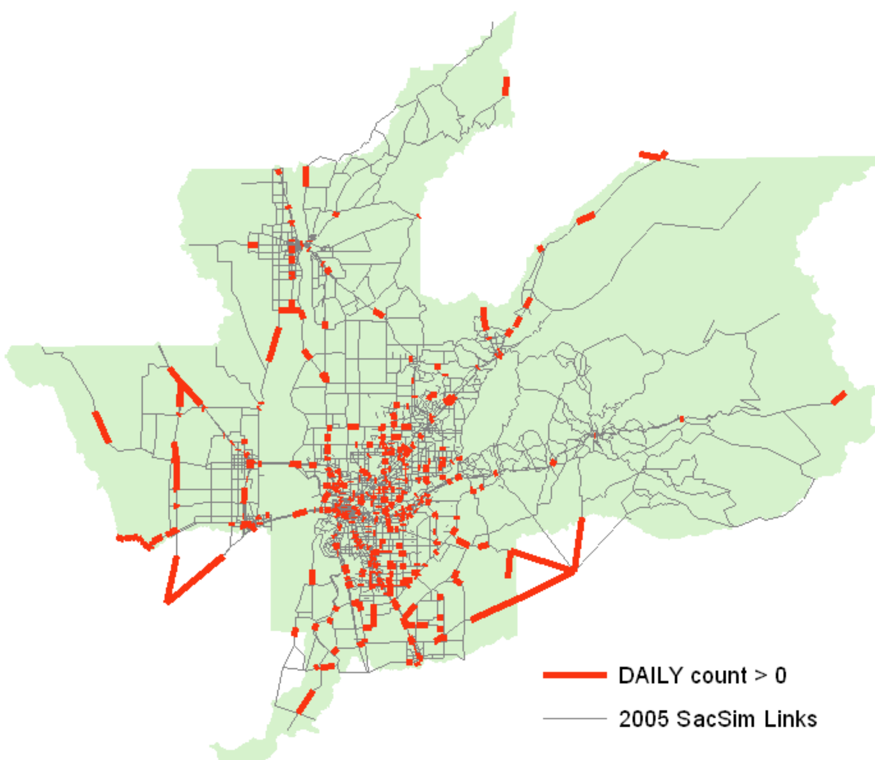
As alluded to earlier, the disaggregate natures of both Daysim and TRANSIMS provide a unique opportunity to integrate the network assignment and global model system convergence. Specific sub-samples of households can be rerouted using the Router either randomly or based on pre-determined selection criteria. Similarly, choices for subsamples of households can be re-simulated using Daysim. In other Daysim model implementations, a number of alternative strategies have been tested and employed to attain system convergence in reasonable runtimes by using smaller subsamples of households in earlier iterations and a full sample only in the final iteration, or by successively simulating portions of the regional households so that by the completion of the final iteration all households have been simulated. It is unlikely that either of these approaches can be directly applied in the context of the Daysim-TRANSIMS integrated model system, which requires a full household activity list for the first iteration (though as described above, allows for subsequent iterations to use smaller sub-samples).

The integrated Daysim-TRANSIMS model system provides the possibility of coordinating the simulation of household subsamples in order to identify, re-simulate, and re-assign those travelers whose patterns are contributing most significantly to system disequilibrium. Due to time constraints, no coordinated network and system convergence strategies have yet been tested.

5.0 MODEL VALIDATION

The Integrated Model is calibrated to a weekday for the year 2005, the same period and year as the SACOG SACSIM regional travel demand model. SACOG supplied the Daily, AM, MD, PM, and EV count sets that were used to calibrate the 2005 SACSIM model. These counts were used to calibrate the assignment results produced by the Integrated Model as well. Again the AM period is defined as 7-10am. The MD period is defined as 10am-3pm. The PM period is defined as 3-6pm with the EV overnight period defined as 6pm-7am. As you can see in Figure 28, the daily ground counts cover an extensive portion of the model area with the majority of the counts collected in the dense urbanized areas of Sacramento County. The primary calibration was performed against the Daily count set, but the time period calibration was also evaluated.

Figure 28. Traffic Count Locations



The validation exercise focused on the following items:

- The system-wide network validation comparisons to daily and period specific ground counts
- Use of a SACOG screenline representing the Sacramento River and American River crossings
- Comparisons of Integrated Model results against those produced by SACSIM

- Review of the operations within TRANSIMS, specifically the convergence of the Router Stabilizer process, as described in a previous section

The calibration steps largely included a continued refinement of the network including a better representation of the external station activity locations, detailed analysis of the skim development process used to derive congested times for input to DaySim, and investigation of Router controls that govern the time constraints applied to the activity list generated by DaySim.

5.1 Regional Validation

5.1.1 Daily

Table 7 shows the system-wide statistics comparing the daily model estimated link volumes to the observed count volumes. It is clearly shown that the simulated traffic volumes are close to the field traffic count by volume level. The total relative error over the network is 5.1 percent. It should be expected that the assigned volumes would be slightly higher than observed volumes. The DaySim model was calibrated in an aggregate zonal context, where 5%-6% of vehicle trips are identified as intra-zonal and are never assigned to the networks. The finer spatial resolution of activity locations necessarily reduces the number of trips that are not exposed to the network, thus increasing overall volumes on the network. In the integrated model, only 1.7% of trips are intra-activity location and thus not exposed to the network.

Table 7. Regional Daily Validation by Volume Class

Volume Level	# of counts	Estimated	Observed	Difference	% Difference	Avg Error	% Avg Error	% RMSE	R-Squared
0 - 1000	114	154,921	57,936	96,985	167.4	1,014	199.5	346.1	0.014
1000 - 2500	97	256,143	166,465	89,678	53.9	1,610	93.8	134.3	0.183
2500 - 5000	161	695,822	581,506	114,316	19.7	2,014	55.8	78	0.043
5000 - 7500	113	861,823	697,660	164,163	23.5	3,021	48.9	67.5	0.041
7500 - 10000	120	1,110,193	1,049,079	61,114	5.8	3,020	34.5	52.5	0.039
10000 - 25000	357	5,744,301	5,491,521	252,780	4.6	4,302	28	37.1	0.298
25000 - 50000	97	3,646,279	3,218,860	427,419	13.3	7,512	22.6	29.9	0.324
50000 - 75000	31	1,841,737	1,994,520	-152,783	-7.7	9,401	14.6	23.2	0.378
75000 - 100000	32	2,702,849	2,740,350	-37,501	-1.4	10,781	12.6	17.1	0.518
100000 - 500000	13	1,346,618	1,475,773	-129,155	-8.8	13,025	11.5	15.1	0.081
TOTAL	1135	18,360,686	17,473,670	887,016	5.1	3,850	25	41.1	0.91

5.1.2 Time Period

Table 8 through Table 11 show the system-wide statistics comparing the AM, MD, PM, and EV time period model estimated link volumes to the observed time period specific count volumes.

The total relative error over the network in the AM 3-hour period is 1.4 percent. The total relative error over the network in the MD 5-hour period is 2.3 percent. The total relative error over the network in the PM 3-hour period is 3.1 percent. The total relative error over the network in the EV 13-hour period is 15.0 percent. The tables also include the percent average error and the % RMSE, which provide additional information on the performance of the network assignment process.

Table 8. Regional AM Validation by Volume Class

Volume Level	# of counts	Estimated	Observed	Difference	% Difference	Avg Error	% Avg Error	% RMSE	R-Squared
0 - 100	9	1,401	407	994	244.2	110	244.2	329	0.245
100 - 250	20	7,944	3,450	4,494	130.3	293	170	250.1	0.082
250 - 500	41	30,678	15,840	14,838	93.7	464	120	164.8	0.138
500 - 750	41	38,286	26,162	12,124	46.3	452	70.8	109	0.053
750 - 1000	36	35,477	31,481	3,996	12.7	372	42.5	53.5	0.001
1000 - 2500	273	544,084	477,734	66,350	13.9	736	42	58.1	0.156
2500 - 5000	174	636,613	620,618	15,995	2.6	1,078	30.2	39.9	0.278
5000 - 7500	46	289,472	274,738	14,734	5.4	1,300	21.8	29.7	0.086
7500 - 10000	23	172,757	199,224	-26,467	-13.3	2,298	26.5	29.8	0.181
10000 - 50000	63	907,528	976,952	-69,424	-7.1	2,579	16.6	22.2	0.519
TOTAL	726	2,664,240	2,626,606	37,634	1.4	994	27.5	42.7	0.871

Table 9. Regional Midday Validation by Volume Class

Volume Level	# of counts	Estimated	Observed	Difference	% Difference	Avg Error	% Avg Error	% RMSE	R-Squared
0 - 500	35	18,775	9,326	9,449	101.3	384	144	222.1	0.115
500 - 1250	66	78,721	61,460	17,261	28.1	535	57.5	78.2	0.053
1250 - 2500	122	247,174	231,581	15,593	6.7	786	41.4	64.7	0.112
2500 - 3750	123	400,171	382,244	17,927	4.7	1,024	32.9	44.4	0.079
3750 - 5000	119	519,729	523,786	-4,057	-0.8	1,260	28.6	35.4	0.026
5000 - 12500	190	1,433,057	1,398,437	34,620	2.5	2,004	27.2	36	0.428
12500 - 25000	60	1,128,773	1,110,624	18,149	1.6	2,920	15.8	21.9	0.479
25000 - 37500	12	330,760	346,430	-15,670	-4.5	3,626	12.6	15.4	0.154
TOTAL	727	4,157,160	4,063,888	93,272	2.3	1,403	25.1	38.2	0.877

Table 10. Regional PM Validation by Volume Class

Volume Level	# of counts	Estimated	Observed	Difference	% Difference	Avg Error	% Avg Error	% RMSE	R-Squared
0 - 100	7	1,857	418	1,439	344.3	213	357.2	516.1	0.343
100 - 250	20	8,273	3,705	4,568	123.3	304	164.1	309.3	0
250 - 500	23	18,007	8,624	9,383	108.8	503	134.1	161.5	0.126
500 - 750	28	20,906	17,199	3,707	21.6	327	53.2	73.3	0.003
750 - 1000	28	28,925	24,317	4,608	18.9	455	52.3	78.8	0.031
1000 - 2500	206	386,870	360,865	26,005	7.2	625	35.7	55.1	0.176
2500 - 5000	242	848,449	857,909	-9,460	-1.1	1,096	30.9	40.9	0.192
5000 - 7500	78	482,646	469,522	13,124	2.8	1,474	24.5	34.6	0.194
7500 - 10000	25	215,808	212,112	3,696	1.7	1,701	20	27.9	0.219
10000 - 50000	70	1,120,764	1,083,475	37,289	3.4	2,610	16.9	22.2	0.631
TOTAL	727	3,132,505	3,038,146	94,359	3.1	1,066	25.5	40.1	0.879

The TRANSIMS Validate utility does not properly generate reports for the overnight period (6pm to 7am) since the time range and observed count data spans the end of the TRANSIMS day and constitutes a full 13-hour period as opposed to 6 hours until midnight and then an additional 7 hours after midnight. Therefore, r-squared, RMSE, and percent average error for the evening time period are not shown in the tables below.

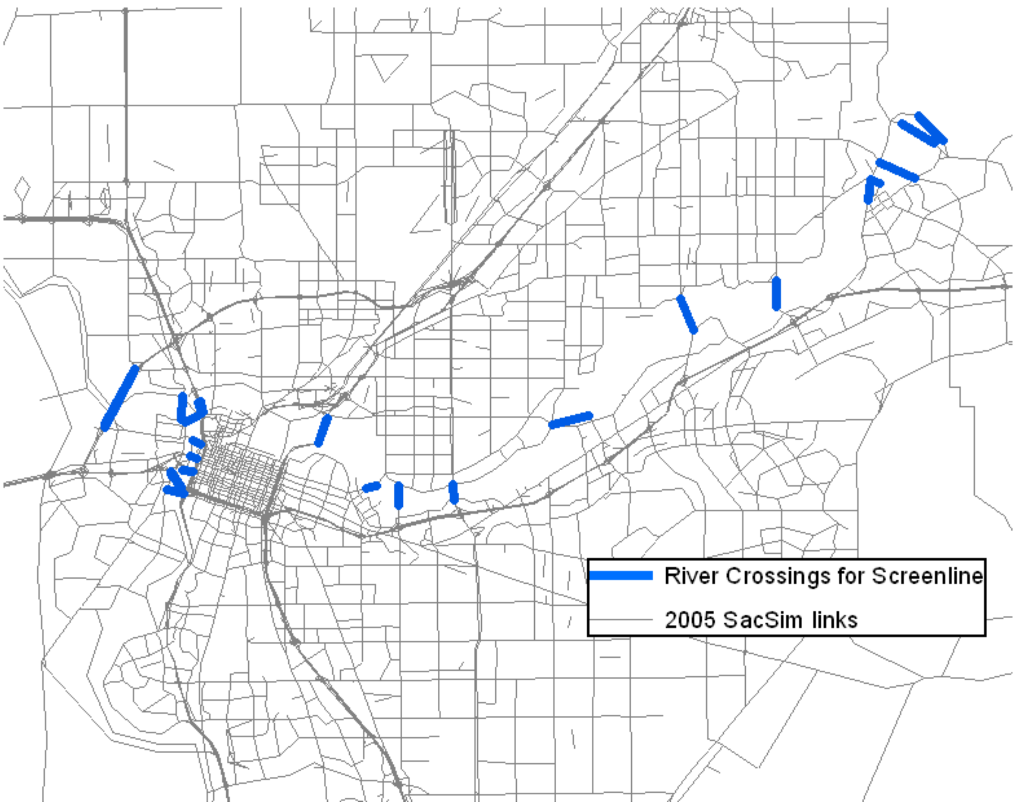
Table 11. Regional Evening Validation by Volume Class

Volume Level	# of counts	Estimated	Observed	Difference	% Difference
0 - 1000	108	118,998	56,930	62,068	109.0
1000 - 2500	158	427,864	269,265	158,599	58.9
2500 - 5000	197	908,736	704,708	204,028	29.0
5000 - 7500	92	672,039	557,775	114,264	20.5
7500 - 10000	53	596,982	465,657	131,325	28.2
10000 - 25000	66	1,098,651	1,096,460	2,191	0.2
25000 - 50000	37	1,129,732	1,157,353	-27,621	-2.4
TOTAL	711	4,953,002	4,308,148	644,854	15.0

River Crossing Screenline Validation

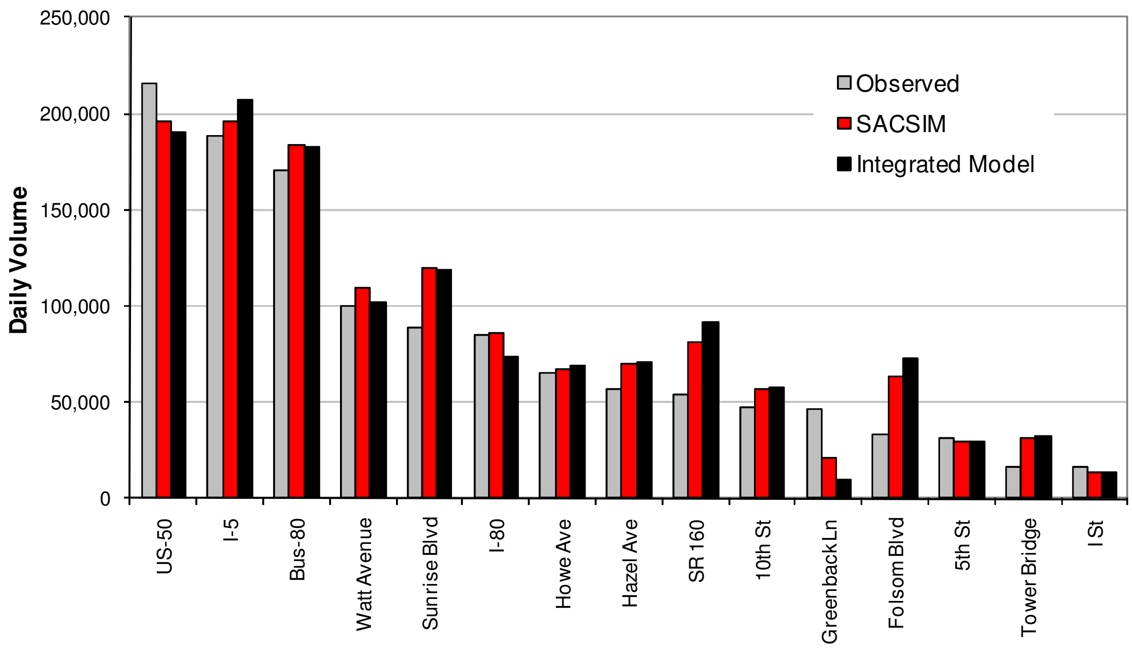
The SACOG region is divided by two major rivers, the Sacramento River and the American River which have their confluence just northwest of downtown Sacramento. The rivers act as an important natural barrier to travel. Since the city center is bounded on two sides by these rivers, confirming river crossing estimates provided a good check of the predicted traveler flows into and out of the Sacramento city center. The SACSIM model uses screenline codes 5, 6, 7, 15 and 16 for the facilities that cross the Sacramento River and American River. The highway links which make up these screenlines are highlighted in blue in Figure 29. There are 15 bridges which have observed count data resulting in 30 separate comparisons between estimated model volumes and observed daily counts for this aggregated screenline.

Figure 29. Sacramento and American River Crossing Count Locations



The total relative error for the 30 links that make up the Sacramento River and American River crossing screenline is 8.9 percent. Figure 30shows observed volumes versus estimated volumes from SACSIM and the integrated model.

Figure 30. River Crossing Daily Validation by Facility



To finalize the calibration of the Integrated Model we compared the estimated link volumes against those generated by the official 2005 SACSIM base year model. Table 12 through Table 16 below compare the Daily, AM, MD, PM, and EV time period validation ratios by facility type, the r-squared, average percent error and RMSE for the Integrated Model against the same measures extracted from the SACSIM model. These tables illustrate some interesting differences between the performance of the two model systems, both across facility types and across time periods. The tables indicate the Integrated Model appears to better represent volumes on lower level facilities such as minor arterials and collectors, which the SACSIM model appears to systematically under-assign. Higher level facilities, such as freeways and expressways are better represented by the SACSIM model during some time periods and by the Integrated Model during others. Overall, the %RMSE for the SACSIM model is consistently lower than the Integrated Model, suggesting that this model is overall better performing. However, it should be noted that network assignment performance is often significantly impacted by the degree of scrutiny and revision to the network assumptions. Although the Integrated Model networks pivot off of the SACSIM networks, they also incorporate more operational and geometric details, and have not received the same review and revision as the SACSIM networks. It is also worth noting that the Integrated Model network assignment performance degrades with each successive time period, which is an artifact of the "cascade" effect of trips into later time periods due to the suppression of time constraint effects, as described in Section 3.3.2.2.

Table 12. Comparison of SACSIM and Integrated Model Daily Validation

	SACSIM Model	**Integrated Model**
Facility Type	Validation Ratio	Validation Ratio
Freeway	1.04	1.01
Expressway	1.02	0.98
Major Arterial	1.00	1.14
Minor Arterial	0.82	1.01
Collector	0.81	1.04
Ramp	0.96	1.01
TOTAL	0.99	1.05
R-squared	0.97	0.91
Ave Link Error	21%	25%
RMSE	35%	41%

Table 13. Comparison of SACSIM and Integrated Model AM Validation

	SACSIM Model	**Integrated Model**
Facility Type	Validation Ratio	Validation Ratio
Freeway	1.04	0.96
Expressway	1.03	0.86
Major Arterial	1.06	1.12
Minor Arterial	0.90	1.04
Collector	0.84	1.03
Ramp	-	-
TOTAL	1.02	1.01
Ave Link Error	23%	28%
RMSE	39%	43%

Table 14. Comparison of SACSIM and Integrated Model Midday Validation

	SACSIM Model	**Integrated**
Facility Type	Validation Ratio	Validation Ratio
Freeway	1.15	1.05
Expressway	1.07	0.95
Major Arterial	0.96	1.03
Minor Arterial	0.76	0.92
Collector	0.76	0.98
Ramp	-	-
TOTAL	1.01	1.02
Ave Link Error	24%	25%
RMSE	40%	38%

Table 15. Comparison of SACSIM and Integrated Model PM Validation

	SACSIM Model	**Integrated Model**
Facility Type	Validation Ratio	Validation Ratio
Freeway	1.05	1.06
Expressway	1.06	0.90
Major Arterial	0.95	1.04
Minor Arterial	0.81	0.93
Collector	0.77	0.94
Ramp	-	-
TOTAL	0.97	1.03
Ave Link Error	21%	25%
RMSE	35%	40%

Table 16. Comparison of SACSIM and Integrated Model Evening Validation

	SACSIM Model	**Integrated Model**
Facility Type	Validation Ratio	Validation Ratio
Freeway	0.93	1.12
Expressway	0.98	0.98
Major Arterial	1.01	1.26
Minor Arterial	0.86	1.17
Collector	0.88	1.26
Ramp	-	-
TOTAL	0.95	1.17
Ave Link Error	22%	25%
RMSE	37.0%	47.0%

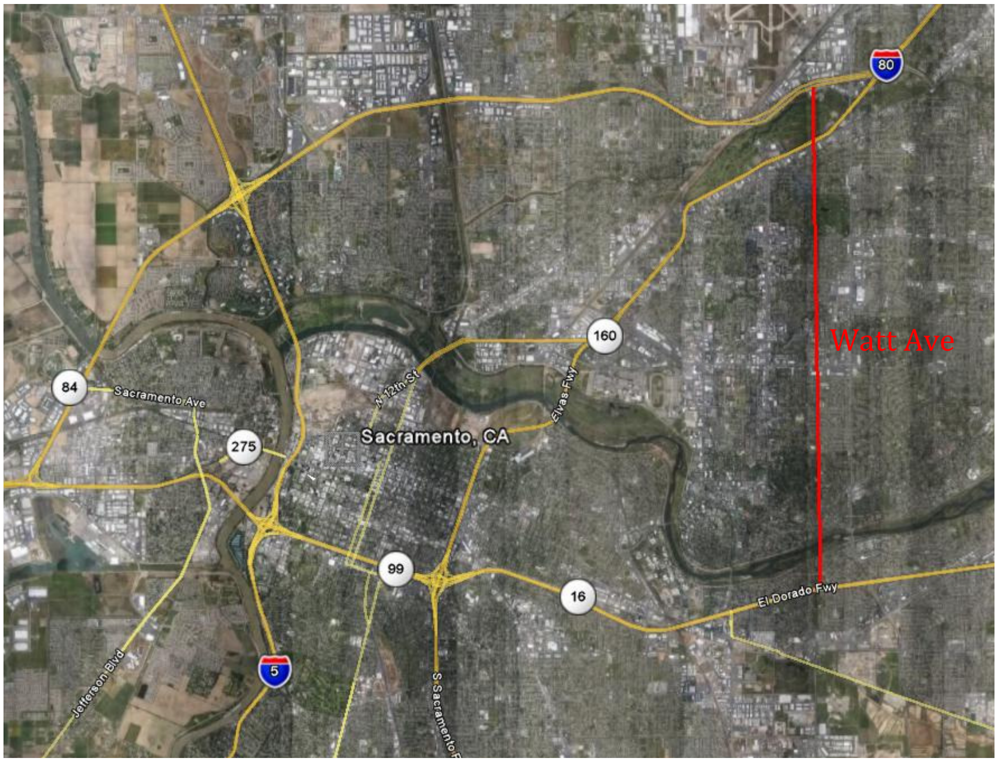
6.0 POLICY TEST: WATT AVE BRIDGE

A policy testing was conducted using the Integrated Model to evaluate peak spreading on the river crossings that are described in the model calibration section above. Based on guidance and feedback from SACOG staff a before and after case study of the Watt Avenue Bridge project was developed. The case study analyzed the Watt Avenue Bridge project using both the SACSIM model as well as the DaySim-TRANSIMS Integrated Model. The goal of the policy testing was to qualify and quantify the differences between the different sets of model results. In addition, it was hoped that the Integrated Model would provide additional insights related to the impacts of the project given the spatial and temporal resolution of the Integrated Model relative to SACSIM.

6.1 Watt Avenue Bridge Improvements

The Watt Avenue Bridge is located a few miles east of the Sacramento city center. Watt Avenue is a major north-south artery that connects the El Dorado Freeway (SR 16/50) in the south to Interstate 80 in the north.

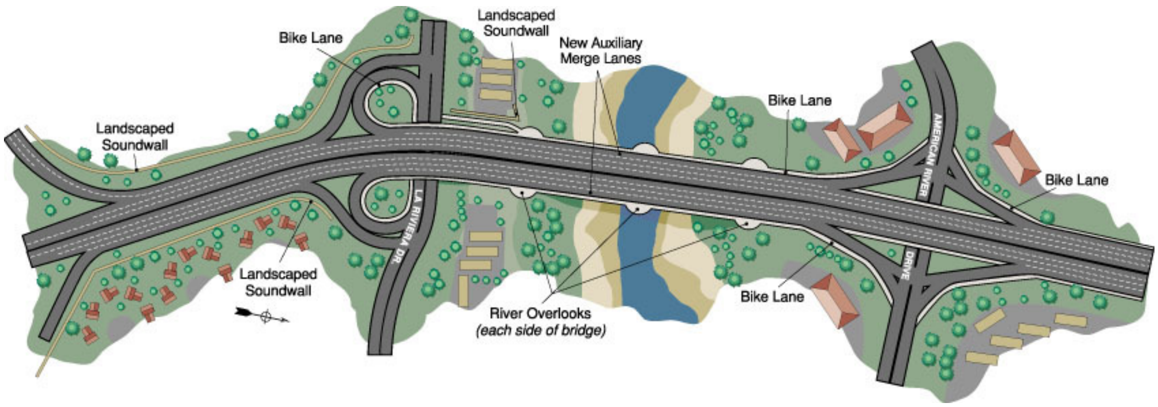
Figure 31. Watt Avenue Location



The Watt Avenue Bridge which crosses the American River, carries in excess of 100,000 vehicles per day and had become one of the most congested roadways in the Sacramento area. The County needed to improve mobility, safety and seismic response, and wanted to make the area more aesthetically pleasing for motorists, bicyclists, pedestrians, and area residents, all with minimal environmental impact to the American River while keeping the bridge open to traffic throughout construction.

The project widened the existing bridge and two street under-crossings, improved circulation from US 50 to nearby neighborhoods, added one lane in each direction on the bridge, added auxiliary merge lanes between the two local collector roads on either side of the river and improved connectivity to the American River Parkway. The bridge redesign can accommodate a future transit line in the median. Safety features and amenities to accommodate pedestrians and bicyclists include: two large cantilevered overlooks with benches; low-profile fiber optic lighting in the pedestrian railings; passive video detection of pedestrians and bicyclists that activates advance warning indicators; 8' wide sidewalks and raised medians that separate pedestrians and bicyclists from vehicle traffic; and improved bicycle connections to the American River Parkway. Artistic design elements adorn exterior bridge girders, railings, benches, and retaining walls. The Watt Avenue Bridge Improvement Project was completed in 2001.

Figure 32. Watt Avenue Bridge Improvements



To analyze the Watt Avenue Bridge as a before and after case study, a Build and No-Build roadway network were developed. In the 2005 Base SACSIM network the Watt Avenue Bridge is represented as three-lanes in each direction. For the No-Build scenario, the bridge is modeled as two-lanes in each direction. For the Build scenario, the bridge is modeled as four-lanes in each direction. Coding up the TP+ networks for use in SACSIM simply involves changing the number of lanes and the total link capacity. Coding up the TRANSIMS networks also involves modifying the number of lanes and total capacity along with the required modifications to the Lane Connectivity files to account for the lane removal and additions. Varied land-uses were not studied as part of the before and after case study.

6.2 Model System Comparisons

The before and after Watt Avenue Bridge case study will be evaluated using three separate and distinct models. The three models are: 1) the new Integrated Model , 2) the “classic” SACSIM model and 3) the “adjusted” SACSIM model. Each model will be described in detail below.

The Integrated Model is the name of the DaySim-TRANSIMS system developed as part of this project. The Integrated Model relies on DaySim to provide detailed, disaggregate estimates of travel demand, though the version used is different than that used in SACSIM in that it incorporates a shadow pricing enhancement. The Integrated Model is distinctly different than SACSIM, however, in that the estimates of travel demand are not aggregated to matrices prior to assignment, but rather are assigned to the network in a completely disaggregate framework using the TRANSIMS Router. Like SACSIM, a complete model run involves multiple successive runs of the demand simulation and network assignment. As in SACSIM, link volumes from previous iterations are combined to develop estimates of network level of service used in subsequent iterations. However, unlike SACSIM, in the Integrated Model, the entire synthetic population is simulated in every global iteration. In addition, as currently configured, the network assignment is run for a fixed number of iterations rather than some predetermined closure criterion. This is due primarily to the fact that although the Router is configured to emulate a user equilibrium solution, it does not incorporate all of the logic embedded in a traditional assignment algorithm, by design.

"Classic" SACSIM is the name of the model system currently used by SACOG. DaySim is a component of SACSIM that provides detailed, disaggregate activity-based estimates of travel demand. This demand is then aggregated to matrices, integrated with auxiliary demand such commercial vehicles and airport travel, and assigned to transportation networks using TP+ travel demand software. A complete model run involves multiple successive runs of the demand simulation and network assignment. In each successive run, the portion of the synthetic population whose choices are simulated is increased, and the convergence criteria for network assignment closure are made more stringent. This structure allows system iterations early in the model run to be performed more quickly, though the results are inherently less stable, and allows system iterations late in the model run to be stable, but require longer runtimes. When iterating, link volumes from the most recent iteration are combined with link volumes from previous iterations to calculate new level of service estimates for subsequent iterations. The core DaySim component is enhanced on a regular basis, and the current version of DaySim used in SACSIM does not include the shadow pricing of destinations for mandatory purposes (work and school) that subsequent versions have incorporated like the one included in the Integrated Model.

As the earlier sections describing the two model systems illustrate, although there are a number of commonalities between the two model systems, there are also a number of differences. Ideally, a number of actions could to be undertaken to make the "classic" SACSIM and the Integrated Model systems more comparable in terms of their core components and overall system flow. The "adjusted" SACSIM model will include modifications to the "classic" SACSIM model to make the components more comparable and enhance the policy sensitivity testing. The "adjusted" SACSIM model will be revised to use the DaySim version that incorporates shadow pricing capabilities like the Integrated Model. The adjusted model system will simulate the choices of the entire synthetic population in each global iteration. The adjusted system will use a simplified global iteration methodology where averaged link delays from previous iterations are feedback to subsequent iterations and will finally run a fixed and consistent number of global iterations. When these revisions to the model system are completed we will be able to compare results from the Integrated Model against both the "classic" and "adjusted" SACSIM models.

6.3 Watt Avenue Bridge Validation

As of this writing, the Watt Avenue Bridge before and after case study has only been evaluated using the "classic" SACSIM model and the Integrated Model. Following the feedback we receive from the Peer Review panel and more thorough investigation of the results presented below we anticipate performing the Build and No-Build scenario runs with the "adjusted" SACSIM model as well.

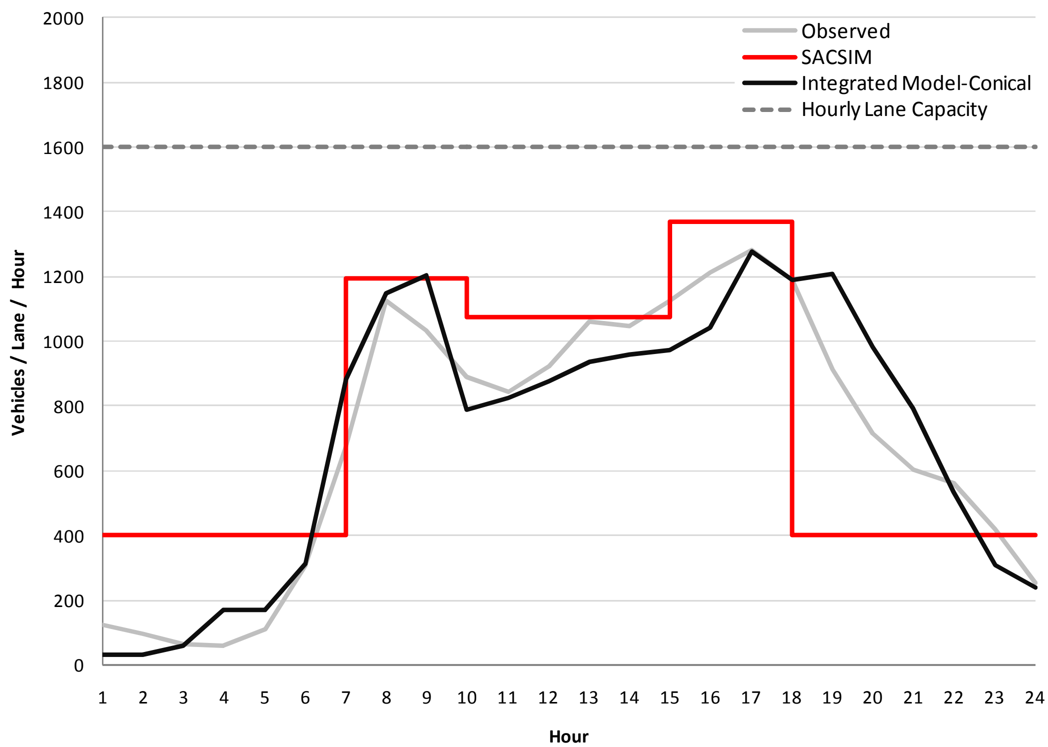
In the calibration section of this report, both the "classic" SACSIM model and Integrated Model have been shown to be well calibrated regionally. Model performance on the Watt Avenue Bridge was illustrated for the river crossing screenline analysis. However, model estimated volumes were only compared against daily observed counts. Below, the performance by both models by time of day is illustrated. The 2005 count by direction as well as the validation ratios (volume/count) for each model by direction are presented in Table 17.

Table 17. Watt Avenue Bridge Validation

2005 Observed Volumes				Classic SACSIM Est/Obs			DaySim-TRANSIMS Est/Obs		
Period	NB	SB	Total	NB	SB	Total	NB	SB	Total
AM	8,800	9,400	18,200	1.3	1.1	1.2	0.9	0.8	0.8
MD	14,800	15,200	30,000	1.1	1.0	1.1	0.9	0.8	0.8
PM	11,800	10,400	22,200	1.0	1.2	1.1	0.9	1.0	0.9
EV	13,300	16,000	29,300	1.2	0.9	1.1	1.4	1.0	1.2
Total	48,700	51,000	99,700	1.2	1.1	1.1	1.0	0.9	1.0

One advantage of using the Integrated Model is that we can examine the results at a much finer level of temporal disaggregation. Figure 33 shows model volumes by hour compared against an hourly count for the Watt Avenue Bridge. Since the "classic" SACSIM model only generates an AM, MD, PM, and EV volume the plot is fixed during the time range represented by those periods (3 hours, 5 hours, 3 hours, 13 hours). The volume by hour presented for the "classic" SACSIM model is the total period volume divided by the number of hours in the period. Note that in the baseline configuration there are three lanes in each direction on the bridge. In the "nobuild" and "build" alternatives described in this analysis, there are two lanes and four lanes in each direction, respectively.

Figure 33. Watt Avenue Bridge Volumes by Hour (baseline)



6.4 Results

The Build and No-Build scenarios for the Watt Avenue Bridge case study have been run in both the "classic" SACSIM model and the new Integrated Model. Build and No-Build scenario bridge volumes are presented in Table 18 below. With the "classic" SACSIM model the additional roadway capacity, increasing from 2 lanes in each direction to 4 lanes in each direction, increases the daily bridge volume by 7,350 vehicles with each time period seeing an increase in both southbound and northbound volume. In contrast, the Integrated Model only shows a slight increase in bridge volume, about 1,700 vehicles, with the added bridge capacity. Furthermore, some time periods actually have a decrease in bridge volume in the Build scenario. Use of the conical volume delay function in the Integrated Model assignment process shows an increase of 3,300 vehicles due to the additional capacity, and no counter-intuitive results by time period.

Table 18. Watt Avenue No-Build vs. Build Comparison

Classic SACSIM		**No-Build**			**Build**	
Period	NB	SB	Total	NB	SB	Total
AM	9,346	10,477	19,823	10,210	11,696	21,906
MD	15,010	15,736	30,746	15,941	16,655	32,596
PM	11,500	10,576	22,076	13,166	12,014	25,180
EV	15,020	16,113	31,133	15,212	16,457	31,669
Total	50,876	52,902	103,778	54,529	56,822	111,351
					Diff	**7,573**
DaySim-TRANSIMS (BPR)						
Period	NB	SB	Total	NB	SB	Total
AM	8,854	9,733	18,587	9,046	9,668	18,714
MD	13,033	13,883	26,916	13,269	14,200	27,469
PM	10,456	10,167	20,623	10,769	10,579	21,348
EV	16,329	17,900	34,229	16,558	17,962	34,520
Total	48,672	51,683	100,355	49,642	52,409	102,051
					Diff	**1,696**
DaySim-TRANSIMS (conical)						
Period	NB	SB	Total	NB	SB	Total
AM	8,458	9,761	18,219	8,743	10,304	19,047
MD	13,017	13,418	26,435	13,233	13,748	26,981
PM	10.099	9,317	19,416	10,705	9,672	20,377

EV	16,693	17,216	33,909	17,201	17,707	34,908
Total	48,267	49,712	97,979	49,882	51,431	101,313
					Diff	**3,334**

Figure 34 and Figure 35 show the change in link volumes between the Watt Avenue Bridge build and nobuild scenarios forecast by SACSIM and by the new Integrated Model. In both figures, red indicates increased volumes and green indicates decreased volumes. Figure 34 indicates that SACSIM estimates a pronounced increase in volumes on the bridge and on the roads leading to the bridge, as well as decreases on nearby bridges. In contrast, Figure 35 shows that the Integrated Model shows less dramatic increases in volumes, and little diversion from adjacent river crossings.

Figure 34. Change in Volumes due to Watt Ave Bridge Improvement-SACSIM

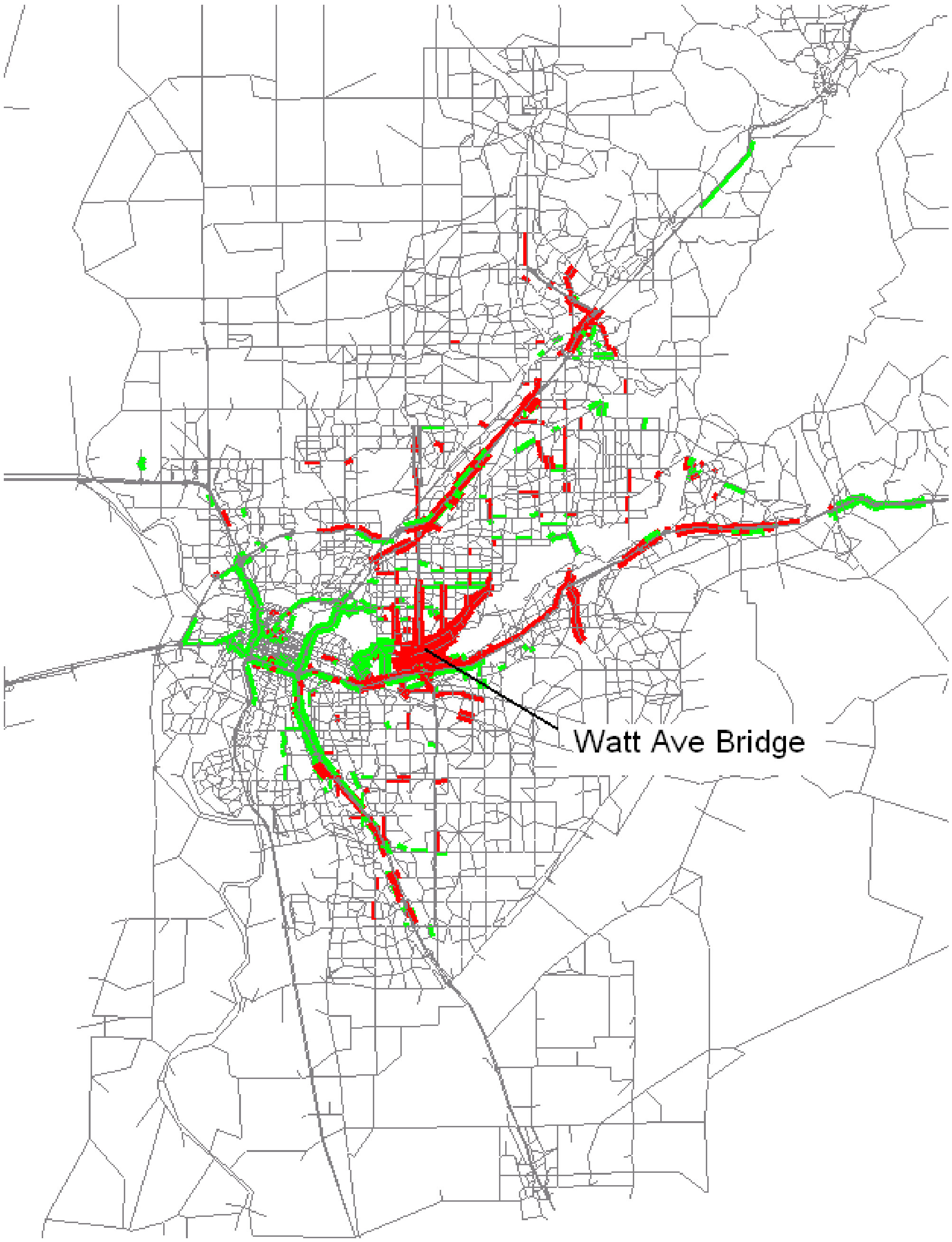


Figure 35. Change in Volumes due to Watt Ave Bridge Improvement-Integrated Model (conical)

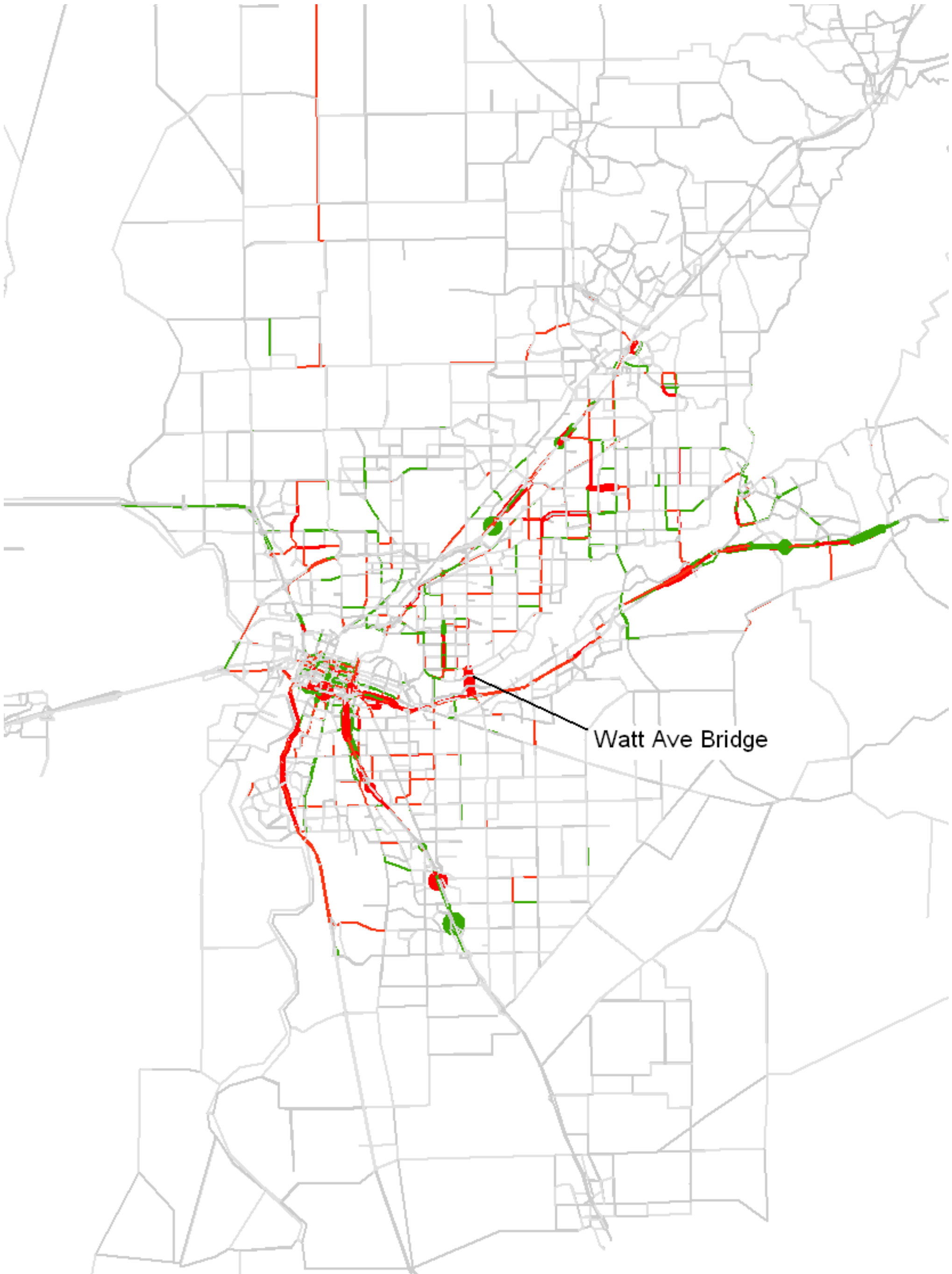
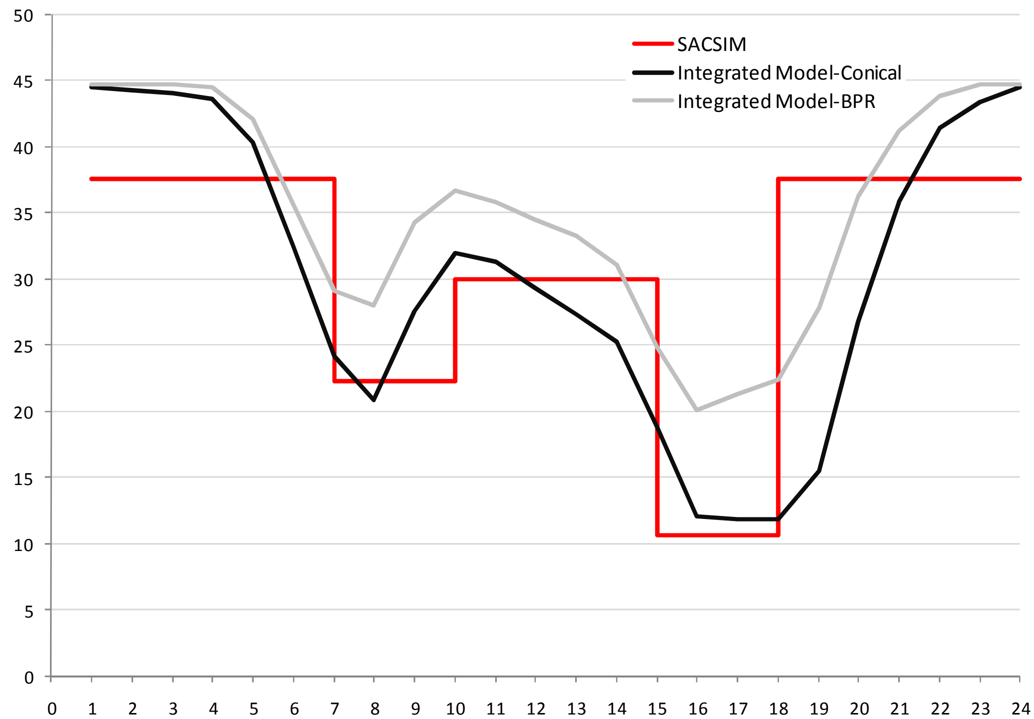


Figure 36 shows average northbound speeds by hour on the Watt Avenue Bridge in the nobuild alternative, and illustrates the level of temporal detail produced by the Integrated Model. In addition, this figure also illustrates the significant difference in congested speeds between conical and BPR volume delay functions.

Figure 36. Average Speed by Hour Watt Ave Bridge Northbound (nobuild)



7.0 MODEL PERFORMANCE

7.1 Model Runtimes

Because disaggregate models predict travel behavior for each individual traveler within a household the additional calculations and data requirements can produce very long model run times. In addition, the use of detailed network simulation methods, where individual vehicles may be simulated at a very fine temporal resolution, can also result in excessively long runtimes, making model execution, validation, scenario testing and even model maintenance difficult. Regardless of the analytical complexity and how well the model replicates observed conditions, disaggregate models will be deemed unusable if model run times are measured in days and not hours.

Despite differences in the population sizes being modeled, recent disaggregate model experience in San Francisco, New York, Sacramento, Portland, and Ohio suggest that model run times in excess of 24 hours are the norm. Furthermore, these implementations still utilize aggregate vehicle assignment procedures found in commercially available transportation planning packages such as TransCAD, CUBE, and EMME2. Total run time would likely increase significantly if dynamic vehicle simulation and assignment algorithms such as those available in TRANSIMS and DynusT were used to replace the static assignment in these model systems.

The number of TRANSIMS implementation projects has increased significantly in just the last few years. The user's community has expanded and TRANSIMS based models have now been developed for large urban areas such as Chicago, Washington, D.C. and Los Angeles to name just a few. Table 19 below shows run times from these model implementations.

Table 19. TRANSIMS Runtimes

Region	Total Run Time	Demand	Links	Router Iterations	Cores	Tools
Burlington, VT	4 hours	0.5 million	800	40	1	Router & Microsimulator
Twin Cities, MN	35 hours	1.5 million	5,200	30	1	Router & Microsimulator
Sacramento, CA	**80 hours**	**6 million**	**6,800**	**25**	**4**	**Router & System Feedback**
Phoenix, AZ	15 hours	13 million	13,400	10	1	Router
Washington D.C.	175 hours	25 million	17,000	50-100	4	Router & Subarea Microsim
Chicago, IL	100 hours	28 million	27,000	80	16	Router & Subarea Microsim
Moreno Valley, CA	180 hours	40 million	48,000	80	32	Router & Subarea Microsim
Atlanta, GA	550 hours	20 million	19,000	40	8	Router & Regional Microsim

As demonstrated in Table 19, the TRANSIMS models developed to date have very long runtimes. The Integrated Model developed for the Sacramento area is no exception. The implementations cited in the table above include subarea microsimulation while the Integrated Model does not apply the microsimualtor. However, the Integrated Model is the only system that includes global system feedback where updated level of service was used to re-estimate travel demand, and the travel times reflect four total global iterations. Total run time of the Integrated Model with 25 network assignment iterations and 4 global system iterations is roughly 80 hours. Each global iteration takes about 20 hours with 3 hours of DaySim runtime to generate the activity list, approximately 12 hours of Router Stabilizer runtime with 25 iterations (where all travelers are routed) to produce converged travel plans and link delays, and finally 5 hours for the Skim Development process to generate updated level of service skims that are then fed back to DaySim in the next global iteration.

7.2 Distributed Processing

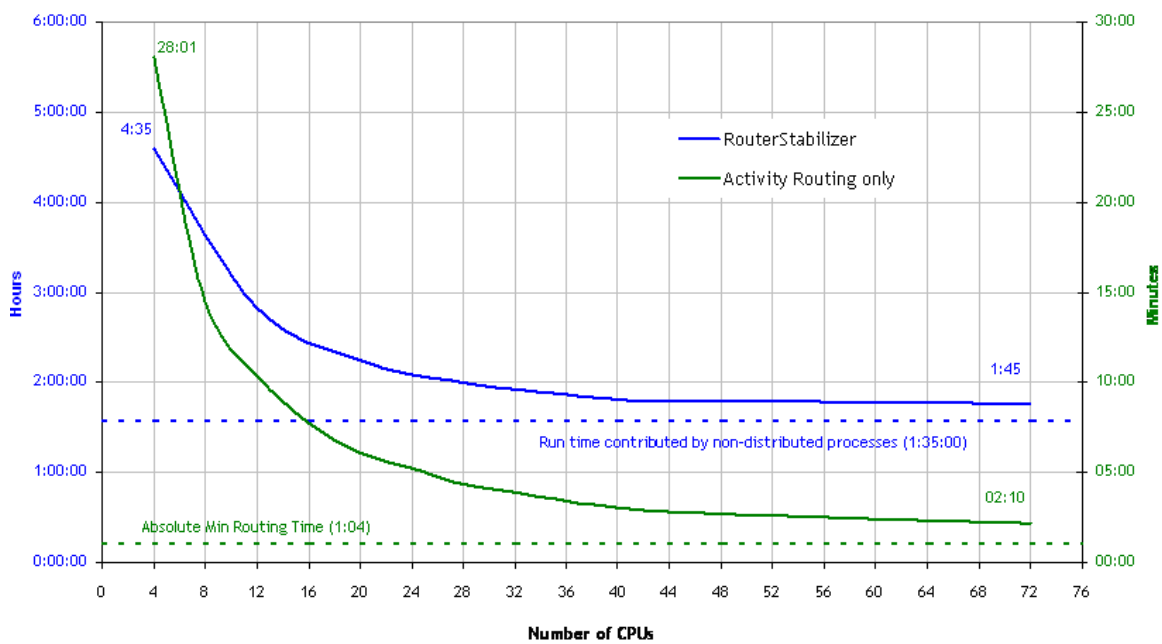
Distributed and parallel processing is one way to reduce runtime by sharing intensive computations among multiple CPU resources concurrently. DaySim does support parallel processing by configuring the control file to simulate portions of the total regional population on specific cores. DaySim was not parallelized in the Integrated Model implementation since the activity generator is not the major bottleneck in the model stream. In addition, this functionality has yet to be fully implemented in a computing environment that effectively employs more than three simultaneous instances of DaySim. DaySim takes roughly 3 hours to run for each global iteration. Therefore, DaySim is contributing only 12 hours to the total 80 hour runtime or roughly 15 percent. Future work will pursue parallelization of the DaySim component since any and all runtime reductions may need to be investigated to demonstrate true feasibility and model transferability.

The TRANSIMS utilities applied in the Router Stabilizer module of the Integrated Model have been fully parallelized. All tools that support parallelization have been split among the 4 cores available on our modeling server. Specifically, the region-wide household list was broken into four partitions so that utilities like the Router, PlanPrep and PlanCompare could be run simultaneously with each CPU working on its own piece of the household list. PlanSum which is called twice during each Router Stabilization iteration cannot not be distributed since it must read in all regional travel plans in order to generate a regional link delay file. That said, runtimes can be significantly improved by writing and reading binary files instead of tab-delimited or Version3 format files. Using binary plans reduced routing time by 30 percent and reduced PlanSum runtime by almost 50 percent.

7.3 TRACC Testing

The Integrated Model was tested on the Transportation Research and Analysis Computing Cluster (TRACC), a high performance computing cluster located at Argonne National Laboratory. The Router Stabilizer process was uploaded to the cluster and a sensitivity testing was conducted to determine runtime reductions that might be observed by utilizing more and more computation nodes on the cluster. In the first test the Router Stabilizer was run on a single computation node with 4 cores to mimic the performance on our own modeling server. The runtime was comparable to what we observe with our quad core desk machine. In the final test, the Router Stabilizer was run on 18 computation nodes with 72 cores. Intermediate tests were conducted with the number of nodes N set equal to N=2, 3, 4, 5, 6, 8, 10, 12, and 15. Figure 37 shows the observed runtimes.

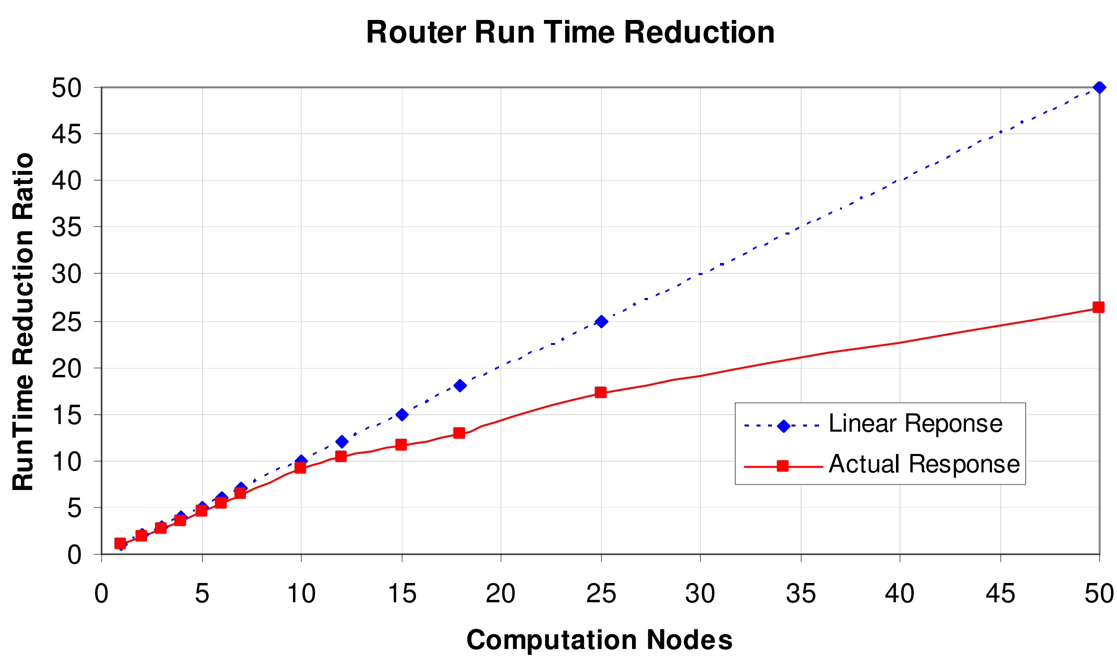
Figure 37. Distributed Process Performance



A runtime floor is approached (represented by blue dashed line) as the number of CPUs requested increases. This is due to the fact that TRANSIMS tools such as PlanSum and LinkDelay, cannot be distributed and therefore contribute a fixed portion of the overall runtime that is not reduced by increasing the number of CPUs. In addition, the response of simply routing the activity list (green line) with more and more processors closely resembles the runtime reduction observed by running the full Router Stabilization process (blue line). This demonstrates that the Router is most responsive to a high degree of parallelization. However, the figure illustrates that a point of diminishing returns is observed around 8 to 10 nodes. This finding suggests that a "mini-cluster" with even 4-5 nodes may be sufficient to develop, maintain, and run complex integrated activity-based demand and dynamic traffic assignment models such as the one developed for this project.

To push this sensitivity testing to its logical conclusion we attempted to route the activity list by requesting all of the TRACC resources. The TRACC is made up of 128 nodes with 512 cores. While attempting to partition the SACOG regional household list into 400 partitions we discovered that the TRANSIMS utilities will not support more than 200 partitions. The TRANSIMS utility HHList that creates household partition list returns an error when the number of split files is outside the range of 1 to 200. So, we routed the activity list using up to and including 50 computation nodes. The reduction in runtime is approximately linear. That is, routing runtime is reduced by a factor of 2 when the number of processors is increased from 4 to 8. However, a linear runtime reduction response is only observed up to about 12 nodes. With the maximum allowed 50 nodes (200 partitions), the routing runtimes was only 27 times faster than using just 1 node. We'd be interested to learn if other researchers have encountered any deterioration in runtime reduction when this degree of parallelization is applied.

Figure 38. Router Runtime Reduction



7.4 Hardware Requirements

Despite transferring this model to the TRACC for testing, a computing cluster is not needed to run the Integrated Model. The model was developed, tested, debugged, and calibrated on a relatively inexpensive off-the-shelf quad core machine. The policy testing and production model runs were likewise performed on this machine. The specifications of the server machine we purpose built for the Integrated Model development and testing project are presented below.

Processor:	Intel Core 2 Quad Q9650 3.0 GHz Quad-Core
Memory:	G-Skill DDR2-1066 PC2-8500 (8GB total Memory, 4 sticks Dual Ch.)
Power:	Corsair 620Watt power supply
Motherboard:	Gigabyte EP-45UD3P
Video:	XFX GeForce 9500GT
Harddrive:	WD1002FBYS 1TB SATA Drive 4 Drives total (RAID 10 Configuration)
OS:	Windows 2003 Server

8.0 LESSONS LEARNED

8.1 Model Integration

- Integrating an advanced activity-based travel demand forecast model with a detailed network assignment model and producing reasonable validation and sensitivity results is an achievable goal.
- Development of skims for aggregate time periods (whether broad or fine-grained) using highly temporally detailed networks and network simulation software involves many complexities and the skim construction process needs to be thoughtfully considered and integrated with the demand model.
- Advanced disaggregate travel demand and network simulation models provide more opportunities as well as more complexities when addressing activity and time scheduling issues. This project team encountered numerous time constraint issues arising from discrepancies between the skims used as input to DaySim demand model and the network times experienced when routing individual activities in the Router.

8.2 Model Calibration and Validation

- Reasonable results were achieved with a “straight transfer” of all DaySim travel demand model coefficients and constants. However it was also clear that the integrated model would benefit significantly from additional calibration efforts, both on the travel demand and the network supply side. For example, using activity locations as the spatial unit for assignment appears to increase volumes on the lower level facilities likely as a consequence that the original demand model intrazonals were calibrated at a zonal rather than activity location level.

- A temporally detailed and comprehensive (geographically, facility type) set of traffic count and speed data is essential for model validation purposes. Count data is relatively easy to get, but detailed hourly speed data is more difficult to acquire.
- The basic capacity increasing sensitivity test performed as part of this project resulted in inconclusive traffic redistributions warrant further consideration. In contrast, the static assignment results for the same sensitivity test looked more plausible.
- More extensive and rigorous sensitivity testing would be valuable. These would include changes to both demand side input assumptions, parameters and inputs as well as network simulation side assumptions, parameters, and inputs

8.3 TRANSIMS

- Keep current with latest TRANSIMS releases to the greatest extent possible. It is possible to spend a lot of time investigating and confirming the existence of problems only to find that a subsequent TRANSIMS release incorporated a bug fix that addressed this issue. In some cases, we experienced problems that were resolved by reducing or turning off reporting options.
- Thoroughly investigate any anomalous results. At minimum, these investigations will usually turn up network problems, though they often identify more fundamental problems with the integrated model configuration or structure.
- Parallelization / partitioning is essential as the spatial and temporal detail and the total demand increases. However, there do seem to be diminishing returns as the number of nodes/processors increases due to the fact that some processes simply cannot be distributed. We found that significant performance gains could be accomplished using 8-16 processors. At minimum, 4 processors should be used. In addition, a significant amount of disk space is recommended due to the large sizes of some outputs (such as plan files), and the usefulness of saving interim outputs due to long model runtimes.
- TRANSIMS would benefit from more explicit documentation of features. Also variations in TRANSIMS version file formats can cause confusion. For example, *.def definition files that contain the header information for all the TRANSIMS text files are created automatically when you use a tool if there is not already one present, but one challenge is that *.def can be totally different depending on the Version (Version3 vs. Version4 vs. Tab vs. DBF).
- Automate control file preparation
- Due to the significant number of TRANSIMS-related network files, it's very easy to make small network coding errors or create inconsistencies between network files that are consequential.
- Network convergence measures and methodologies need to be thoughtfully considered. Network convergence strategies need to address both theoretical and practical (i.e. runtime) concerns.