# BUILDING AN INTEGRATED ACTIVITY-BASED AND DYNAMIC NETWORK ASSIGNMENT MODEL

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## 1. Introduction

This paper describes the integration of DaySim, an activity-based travel demand forecast model developed for the Sacramento region, with the TRANSIMS Router, a disaggregate dynamic network assignment tool. The objective is 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.

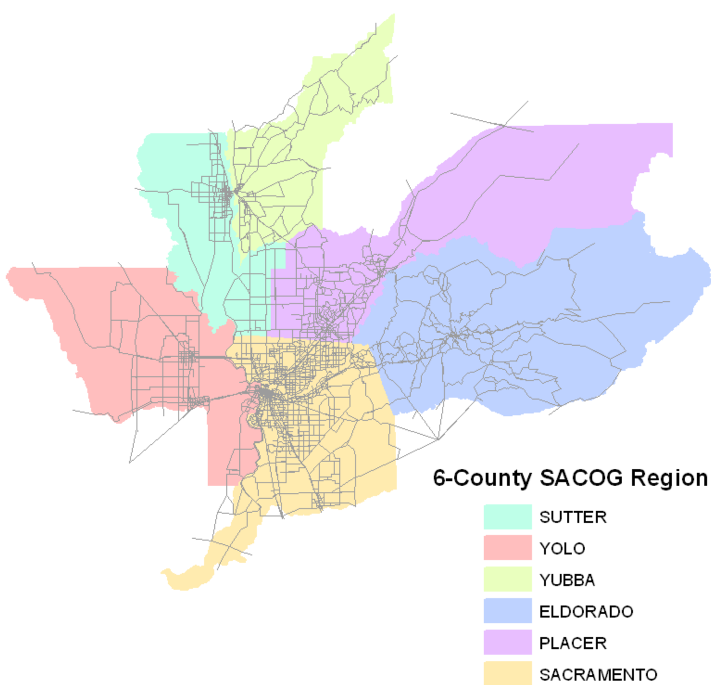
The development of activity-based demand models and TRANSIMS have largely followed separate paths for the last 13 years. Activity-based models have been unable to achieve their full potential because they have been integrated with traditional equilibrium assignment models, which discard the behavioral, 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. DaySim is comprised of a series of submodels that simulate long-term choices such as usual work and school location and household auto availability, as well as short-term choices such as the number and purpose of tours and stops, the parcel-level destinations of these tours and stops, the travel modes used to access these destinations, and the timing of travel. The model system is implemented using Monte Carlo simulation.

TRANSIMS provides sophisticated routing and traffic microsimulation tools, which are sensitive to timing and modal constraints for determining which paths will be chosen by travelers. The TRANSIMS Router and Microsimulator each have unique capabilities, with the Router determining paths for individual vehicle trips using volume-delay functions, and the Microsimulator simulating the interactions of these vehicles on the transportation network. These tools can be used to estimate roadway performance measures at finer spatial and temporal resolution than is possible with the traditional equilibrium assignment. Because using disaggregate demand models in conjunction with dynamic network models is still largely uncharted territory, for this effort we focused on the integration of DaySim with the TRANSIMS Router, and did not address Microsimulator performance.

The Sacramento region represented in the integrated model system is coterminous with the boundaries of the Sacramento Area Council of Governments (SACOG), and includes six counties in northern-central California. In the year 2005, the region contained approximately 1,000,000 jobs and 2,050,000 residents. The model system incorporates over 600,000 parcels and 22,000 TRANSIMS activity locations. One of the fundamental challenges of fully disaggregate models with spatial and temporal detail is the complexity and impact on model run times, which is discussed in a subsequent section.

**Figure 1. SACOG Region**

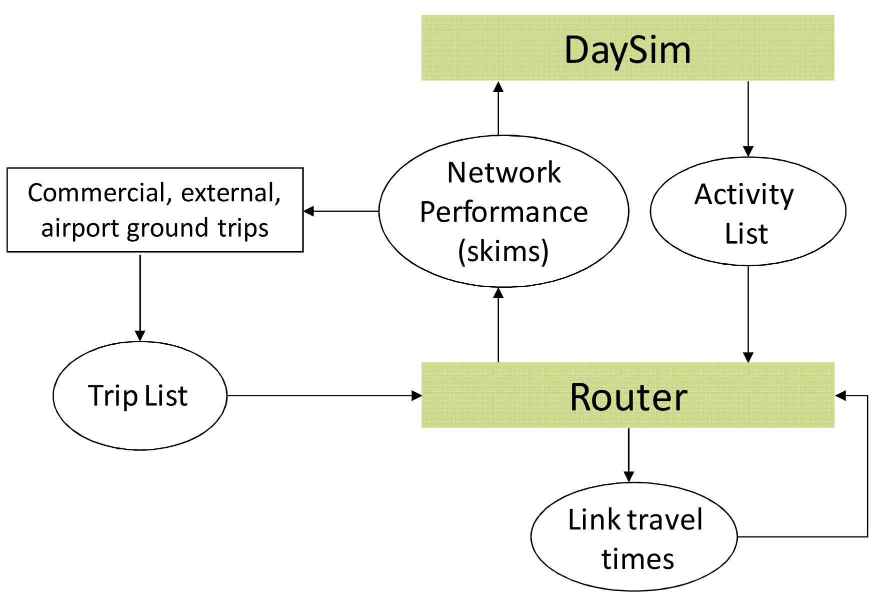


## 2. Integration Design

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.

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. 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 the initial phase of 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 the second phase 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.

**Figure 2. DaySim-TRANSIMS Linkages**

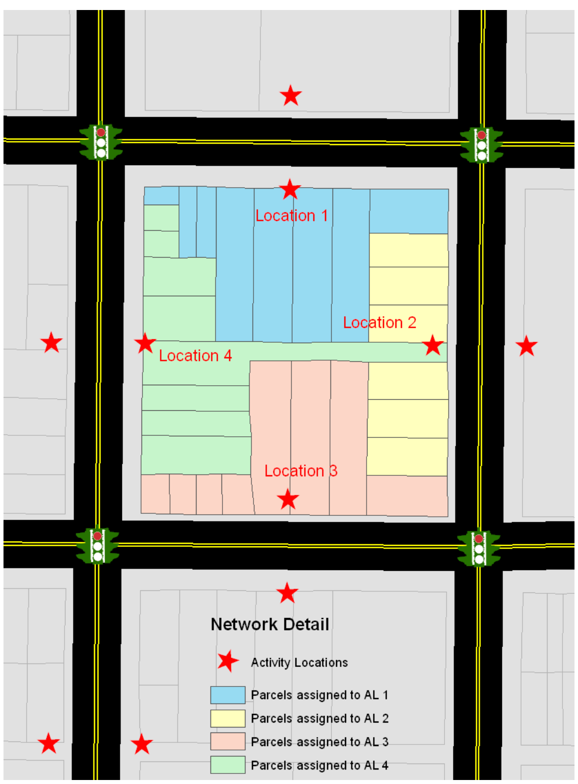


The model system is currently coded to run four global DaySim-TRANSIMS iterations, though it has the capability of iterating until satisfying a pre-specified system convergence metric. In each global iteration, the travel choices of the entire synthetic population are simulated and assigned to the network. The link volumes from each successive iteration are averaged with link volumes from previous iterations to calculate new link delays, which are the basis for the skims and travel simulation in the subsequent iteration. The initial iteration is seeded with skims derived from SACOG's existing DaySim-based model system (SacSim), while subsequent iterations use TRANSIMS-based level of service measures.

## 3. Implementation

Implementation of the Integrated DaySim-TRANSIMS Model was conducted in four phases. The first phase of work focused on the preparation of a TRANSIMS network for the region. The second phase of work was related to the conversion of auxiliary travel demand, such as external and commercial travel, derived from SacSim. This demand comprises almost 20% of regional vehicle trips, and must also be assigned using the TRANSIMS Router. The third phase of work was related to the development of a Router-based iteration scheme using the complement of TRANSIMS tools that would lead to convergent assignment results, as well as implementation of a system convergence scheme. The final phase of model implementation investigated ways to optimize the model stream to both improve efficiency and reduce overall runtime.

**Figure 3. TRANSIMS Network Detail**

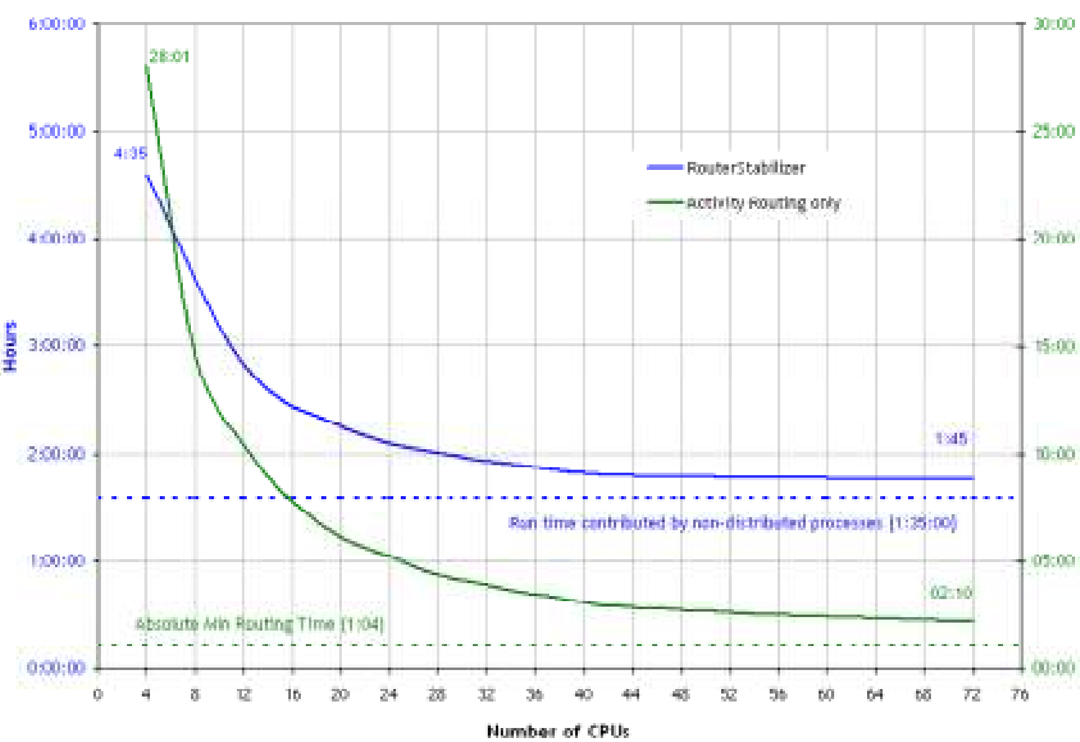


The standard process of converting traditional 4-step regional travel demand model networks to the TRANSIMS format was employed, which uses several utilities such as GISNet and TransimsNet that read link and node data in various software formats and then convert the data to TRANSIMS link and node files. Transit assignment was not explicitly addressed in this effort so conversion of the transit network was not performed. Also, 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.

The SACOG travel model includes auxiliary travel demand that is not predicted by the DaySim model, such as external trips, airport ground access 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.

This effort built upon "Router stabilization" schemes that have been developed as part of other TRANSIMS deployments. Although these schemes are typically implemented in anticipation of use of the Microsimulator, in this work our aim was to develop and evaluate Router stabilization processes that approximate a user equilibrium convergence, as described in the subsequent section. TRANSIMS tools such as PlanSelect, PlanSum, PlanCompare and LinkDelay were all used to pursue convergence.

**Figure 4. Effect of Parallelization on Runtimes**



The integrated model system routes roughly 6.25 million daily vehicle trips, 5 million of which are drive activities produced by DaySim and another 1.25 million vehicle trips representing auxiliary demand. Given this level of demand, the size of the network geography, and convergence strategies that re-route all travelers in each iteration, the integrated model run times are quite long. As a result, the project team is engaged in an ongoing process of identifying and implementing strategies to reduce model runtimes. Specifically, all TRANSIMS tools that support parallelization have been parallelized. In addition, the project team has achieved runtime reductions by saving files in binary as opposed to tab-delimited format. Even after implementing these performance enhancements, runtimes are still long - on the order of roughly 40 hours to complete four global feedback iterations. Finally, the integrated model has been uploaded and tested on the Transportation Research and Analysis Computing Center (TRACC) computing cluster, a high performance computing cluster located at Argonne National Laboratory. Testing the integrated model on the TRACC revealed some interesting findings, such as the fact that runtimes do not generally improve with more than 10 compute nodes (40 processors), which suggests that a "mini-cluster" with 4-6 nodes may be sufficient to develop, maintain, and run complex integrated activity-based demand and dynamic traffic assignment models.

## 4. Convergence

A key goal of the project was to design the integrated model system so that it could achieve some measure of convergence. 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 reached a parameterized solution. Convergence is necessary in order to ensure the behavioral integrity of the model system.

The integrated DaySim-TRANSIMS model system convergence is pursued through iterative feedback. This feedback occurs both within the network assignment phase through the configuration and use of the Router and other TRANSIMS tools, 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. Within the traffic assignment process, a number of methods for achieving convergence and measures of convergence were investigated. One method was intended to replicate a traditional user equilibrium assignment convergence, where all auto driver trips are assigned to the network at each iteration, although only a simple weighting scheme is used to develop the averaged impedance. System convergence is also pursued by averaging, at each global iteration, final link volumes and recalculating link delays for level-of-service skims used in the subsequent iteration.

However, the disaggregate nature of both the demand and supply side simulations also provide unique capabilities and opportunities, such as the ability to reroute subsets of households, persons or trips during network assignment rather than averaging assignment iterations, and the ability to re-simulate consistent subsets of households at both the demand and supply stages. In theory, rerouting subsamples should allow one to achieve convergence more quickly by focusing efforts on those trips, persons, or households that are impeding convergence. A number of tests of subsampling and rerouting alternatives were performed, such as selection based on traversal of links exceeding a critical volume-to-capacity ratio, or by travel costs differences between the current and prior iteration exceeding a threshold. These tests suggested that some level of convergence was achieved using these methods, but that the converged solution was different than that achieved by iteratively re-routing all travelers.

**Figure 5. Disaggregate Trip Gap Measure**

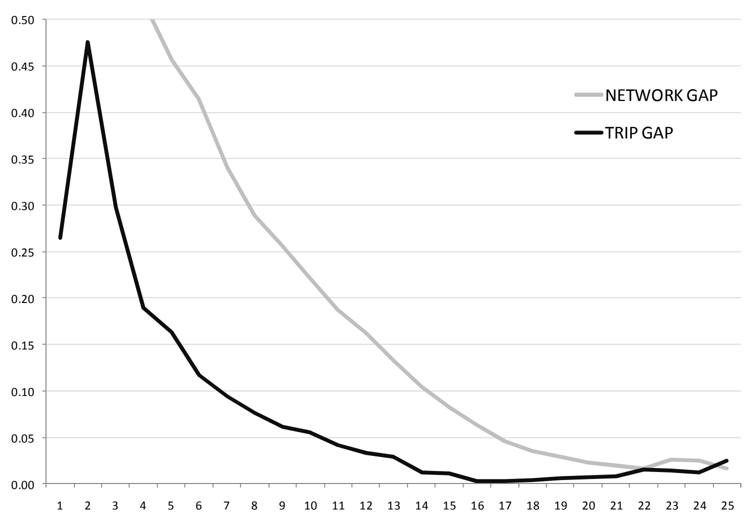
$$\frac{\sum_s (c_{xs}(\{c_{at}\}) - c_{ys}(\{c_{at}\}))}{\sum_s c_{xs}(\{c_{at}\})}$$

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 $\{c_{at}\}$

In order to take advantage of the nature of the Router when evaluating network assignment convergence, a disaggregate trip gap measure was calculated, and compared to a more traditional link-based network gap measure. This disaggregate trip gap measure, shown in Figure 5, is calculated at the trip level, and it captures the difference between the trip cost using the most recent path and most recent link costs and the trip cost using the shortest path and the most recent link costs. This difference is summed across all trips and normalized. Comparison of this measure to network link-based gap measures suggests that person trip-level convergence is achieved before network link volume convergence, which seems consistent with the observation that traditional skim matrices converge more quickly than network link volumes. Measures of overall system convergence were also evaluated, including the % root mean square difference for O/D flows at a district level, and the percent change in trip costs from one iteration to the next.

**Figure 6. Disaggregate Trip Gap and Network Relative Gap Convergence**



## 5. Validation

Once the integrated DaySim-TRANSIMS model system was established and demonstrated to be converging to reasonably stable solutions, a validation of the roadway network assignments was performed. Both daily estimated volumes and estimated volumes by time period were compared to observed counts gathered by SACOG for validation of the SacSim model system. Table 1 summarizes the results of this validation. Daily estimated volumes were higher than observed volumes by approximately 5%, while the validated SacSim model is less than 1% different than observed. Interestingly, the number of auto trips assigned to the networks in the integrated model and in SacSim are comparable, as is the network resolution in the two model systems. The largest errors are on the lowest level facilities which may be related to the use of the more numerous activity locations as network loading points in the integrated model assignment, which reduces the number of intrazonal trips, thereby loading more trips onto the network.

**Table 1. Daily Network Assignment Validation by Volume Class**

| Volume Level | Obs | Est Vol | Obs Vol | Diff | % Diff | % RMSE |
|---|---|---|---|---|---|---|
| 0 to 1000 | 114 | 162,791 | 57,936 | 104,855 | 181.0 | 364.0 |
| 1000 to 2500 | 97 | 277,984 | 166,465 | 111,519 | 67.0 | 143.9 |
| 2500 to 5000 | 160 | 733,336 | 578,475 | 154,861 | 26.8 | 77.5 |
| 5000 to 7500 | 114 | 873,011 | 704,034 | 168,977 | 24.0 | 67.6 |
| 7500 to 10000 | 121 | 1,155,135 | 1,056,927 | 98,208 | 9.3 | 54.2 |
| 10000 to 25000 | 372 | 5,860,437 | 5,736,592 | 123,845 | 2.2 | 36.3 |
| 25000 to 50000 | 100 | 3,551,778 | 3,258,306 | 293,472 | 9.0 | 30.2 |
| 50000 to 75000 | 37 | 2,297,042 | 2,403,531 | -106,489 | -4.4 | 17.9 |
| 75000 to 100000 | 29 | 2,370,851 | 2,440,648 | -69,797 | -2.9 | 18.0 |
| 100000 to 500000 | 10 | 1,052,481 | 1,075,378 | -22,897 | -2.1 | 13.8 |
| TOTAL | 1154 | 18,334,846 | 17,478,292 | 856,554 | 4.9 | 39.9 |

## 6. Next Steps

There are several opportunities for further model development and research. First, further spatial and temporal disaggregation could be added to level-of-service information passed from TRANSIMS to DaySim. Although DaySim's behavior models produce outputs with ½ hour time resolution and parcel-level space resolution, using parcel-level input information about households, employment and accessibility, the network level of service used by DaySim still comes from zone-to-zone skims for only four broad time periods. These have been aggregated from the activity-location-to-activity-location and minute-by-minute information available from the TRANSIMS Router. In the next phase of integrated model development, the spatial and temporal aggregation of network level of service information will be discontinued. However, transitioning to TRANSIMS activity location-level skims for many time periods results in a vast number of level-of-service values that cause storage and computational challenges. The project team is evaluating solutions to this problem, and is moving towards an "on the fly" approach where high resolution LOS is produced on an as-needed basis, with additional logic for sampling and storing of skimmed values.

The TRANSIMS Microsimulator could also be added to the model chain to increase the network sensitivity. As mentioned at the outset, this was always a planned step but was removed in the interest of focusing the research on model integration. Adding the Microsimulator will also significantly impact model runtimes and the team is considering how best to introduce this step. The Microsimulator can produce notably different travel times than the Router and it is felt that the supply side should converge to a stable solution. This is often done through first iterating within the Router and then introducing the Microsimulator. Research should be conducted as to what constitutes a reasonable convergence.

Finally, the integrated model system should be used to support policy sensitivity tests. The intent of the proposed policy sensitivity test could be to compare the outputs of traditional aggregate zone-based assignment methodologies to the outputs of disaggregate DTA-like assignment methodologies such as those embedded in the TRANSIMS' Router. The approach could involve comparing measures that can be derived from both assignment approaches, such as volumes, travel times, and delays across broad time periods, as well as presenting new measures and capabilities that can be produced using the disaggregate Router-based approach, such as volumes, times and delays by detailed time period (down to 15-minute increments), queuing, and individual vehicle routing.