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The Second
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 **SHRP 2 REPORT S2-C10A-RW-1**

Dynamic, Integrated Model System: Jacksonville-Area Application

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The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life*, published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

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SHRP 2 Report S2-C10A-RW-1

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FOREWORD

Stephen J. Andrie, *SHRP 2 Deputy Director*

This report will be of interest to professionals who use travel demand and network assignment models as part of the transportation planning process. The goal of this research was to improve urban-scale modeling and network procedures to address operations or spot improvements that affect travel time choice, route choice, mode choice, reliability, or emissions. Such improvements may include traveler information, pricing, reversible lanes, and improved bottlenecks. Operational improvements like these are difficult to model on an urban-area scale using existing tools. A secondary goal was to facilitate further development and deployment of these or similar procedures. The goals were addressed by building a proof-of-concept dynamic integrated model in two urban areas: Jacksonville, Florida, and Sacramento, California.

The integration of the activity-based demand model DaySim and a Dynamic Traffic Assignment (DTA) model, TRANSIMS, in Jacksonville, Florida, is the subject of this report. Both DaySim and TRANSIMS are open-source products. Integration means that a feedback loop was built between the demand and network assignment model systems. All the demographic and network data required to run the model set were assembled, and the feedback between the demand model and the DTA was tested in Jacksonville, Florida, and Burlington, Vermont. The model set is structured so that it can be run in a long-range planning mode, a short-term operations mode, or a combined mode.

A companion report and model set are available for the application in Sacramento, California. This work has the same objective but uses DynusT for the highway network assignment and adds a schedule-based transit assignment called FAST-Trips. DaySim was also used as the demand model. Both model sets and software start-up guides are available from the Federal Highway Administration.

Travel demand models have been used for more than half a century to determine the need for and estimate the usage of proposed new highway and transit systems. The majority of such models use traffic analysis zones to aggregate demographic data and estimate interzonal travel demand for large time blocks (such as the morning peak period). The interzonal demand is assigned to a link and node network to estimate likely roadway volumes.

Activity-based travel demand models are based on the disaggregate travel activity of individual travelers, not the aggregate behavior of all the travelers in a zone. They have the potential to better simulate behaviors such as time-of-day choice, route choice, mode choice, and trip chaining. As with real travelers, information on the state of the network is needed to make choices. The feedback loop from the network assignment may cause a simulated “traveler” to change route, time of day, or mode in response to network congestion. The model set iterates until convergence is reached; travel volumes and modes are stable after successive iterations.

Activity-based models have been available for some time, but they are not widely used in production planning work. Dynamic Traffic Assignment models are network simulation tools that represent network travel conditions. Such simulation models are used for subarea

traffic analysis but have not been linked to a demographically based demand model and used at the urban-area scale. This project integrated the supply and demand sides of transportation demand forecasting in order to test operational improvements to the highway system as well as capacity enhancements.

A test model set was built for Burlington, Vermont, and then a larger integrated model set was built for four counties in the greater Jacksonville area. The model was used to test transportation alternatives in Burlington and, to some extent, in Jacksonville. The results are proof-of-concept in nature. The integrated model works and demonstrates improved sensitivity to policies that affect regional travel. However, run times are long, which limited the ability to test policy options. The integrated model sets built for this project are available as a basis for implementing a similar approach in other urban areas.

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Executive Summary

Purpose and Need

SHRP 2 Project C10A, Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network, was undertaken to develop a dynamic, integrated model and to demonstrate its performance through validation tests and policy analyses. Key goals of the SHRP 2 C10A model system development effort include providing enhanced representation of travelers' sensitivities to price and incorporating findings from other SHRP 2 Capacity projects.

Modeling Travel

Travel models are used to support decision making by providing information about the impacts of transportation and land-use investments and policies, as well as demographic and economic trends. When applied properly, they can provide a consistent framework for evaluating different alternative scenarios. Transportation decision makers need to have confidence that the tools they use to inform policy and investment decisions, including travel demand forecasting models, produce reasonable results that are appropriately sensitive to the questions at hand.

Most travel models comprise a set of components that address different aspects of traveler choices. The four steps of travel models involve determining (1) the number and purpose of trips to be made, (2) the origins and destinations of those trips, (3) the travel mode (such as driving alone or riding transit), and (4) the specific network routes used. These steps can be broadly grouped into demand and supply categories, with the first three (generation, distribution, and mode choice) describing the demand components and the last one (assignment) describing the supply components. Recent methodological advances have occurred with both model demand components and model supply components. These advances provide the opportunity to develop more robust travel models for use in transportation decision making.

Activity-Based Demand Models

On the demand side, metropolitan planning organizations (MPOs) have increasingly adopted activity-based models. Activity-based travel demand models produce estimates of daily activity patterns including tour and trip generation, destination choice, mode choice, and time-of-day choice. A tour is a chain of trips that begin and end at home or work; it is essential for representing the interrelationships between activities undertaken by travelers. Daily activity pattern models consider the coordinated aspects of travel made by an individual across the entire day, as well as activities potentially coordinated across individuals within a household. In addition, these

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models typically incorporate accessibility measures that allow changes in network performance to influence demand generation.

Agencies generally develop and apply activity-based models to include sensitivities to policies that may be challenging to represent in a traditional, trip-based models. For example, the effects of pricing policies on demand generation, destination, and mode choices can be better captured using activity-based models than trip-based methods. A number of features distinguish activity-based approaches to modeling demand from traditional trip-based approaches. These features include the following:

- Activity-based models represent travel demand in a more intuitive manner than traditional, trip-based demand models because they simulate individual and household travel choices. For example, a traveler decides whether to make a tour or stop to participate in an activity where that activity will take place (such as whether to work at home or journey to work), and when and how to get there, in an intuitive way that captures opportunities and constraints.
- Activity-based models provide more consistency, and potentially more detail, across all dimensions of travel behavior, especially space and time. In turn, that consistency results in more realistic representations of transportation system performance by the network supply model. Significantly, activity-based models do not include non-home-based trips. Those trips frequently make up a large portion of the demand in traditional trip-based models, but trip-based models cannot include potentially relevant information such as prior trip-mode choices and traveler income.
- Activity-based models include significantly more detail on traveler attributes and spatial and temporal constraints, which provides better estimates of the transportation impacts of a given alternative scenario. For example, activity-based models can assign person-specific and purpose-specific values of time to different individuals, which is important for modeling pricing alternatives. Such detailed market segmentation is possible because of the disaggregate nature of most activity-based model implementations and is often intractable in the context of aggregate trip-based travel models.
- Activity-based models produce a wider range of performance measures, with greater detail.

Perhaps most significantly for the C10A project, activity-based demand models explicitly include a detailed representation of time-of-day using temporal units of half-hours and minutes rather than broad multihour time periods. This temporal resolution facilitates the incorporation of changes in network performance by time-of-day that are produced by the dynamic supply model; it also provides an explicit method for reflecting availability constraints (such as time-window accounting), which produces activity patterns that are logically consistent in both time and space.

Dynamic Traffic Assignment Models

On the supply side, metropolitan planning organizations are also increasingly adopting dynamic traffic assignment (DTA) approaches. Traffic assignment is the fourth and final step of the traditional four-step planning process. Until the past decade, virtually all travel models incorporated static traffic assignment methods, which produce estimates of travel times, costs, and volumes across relatively broad time periods. However, the analysis and management of transportation network performance require information about time-varying network times, costs, and flows, and transportation policies increasingly incorporate time-varying assumptions. Static-based assignment approaches cannot represent time-varying flows and congestion or the impacts on travel times and costs with sufficient detail. In contrast, dynamic network models do have the ability to represent time-varying network time and costs; in addition, they can provide

more information on network performance by detailed time of day, which can be used as input into travel model demand components. Features that distinguish dynamic network methods from static network approaches include the following:

- DTA models incorporate more complete representations of transportation network attributes and configurations, including better representations of intersection controls such as signal synchronization and other advanced network control schemes.
- DTA models use more realistic flow models to propagate traffic on links, rather than using simplified volume-delay functions, which may produce unrealistic estimates of network times and volumes.
- DTA models provide more detailed estimates of network system performance, which is essential for accurately evaluating the impacts of different transportation policy, systems management, and funding alternatives.

Integrated Models

Transportation policy and investment questions have become increasingly complex. At the same time, existing models have been made more behaviorally descriptive, and new models have been developed. Separate models that had been viewed as independent are now often viewed as interdependent. The purpose of the C10A project was to make operational a dynamic, integrated model and to demonstrate its performance through validation tests and policy analyses. An integrated model system is essential because most current travel models are not sufficiently sensitive to the dynamic interplay between travel behavior and network conditions; they are unable to reasonably represent the effects of transportation policies, such as variable road pricing and travel demand management strategies. The availability and capabilities of activity-based demand models and dynamic network supply models provide the opportunity to address the shortcomings of current tools and provide decision makers with more complete information.

Project Objectives

As stated, the primary objective of the C10A project was to make operational a dynamic, integrated model—an integrated, advanced travel demand model with a fine-grained, time-dependent network. The model's performance would then be demonstrated through validation tests and policy analyses. Secondary project goals included producing a transferrable process and sample data for use in other regions, demonstrating an effective interface with the Environmental Protection Agency's (EPA's) motor vehicle emission simulator (MOVES) model, addressing travel time reliability in travel models, and incorporating knowledge from other SHRP 2 efforts. These include Project C04, Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand (pricing), and Project C05, Understanding the Contribution of Operations, Technology, and Design to Meeting Highway Capacity Needs (operations). This report describes the tools incorporated into the integrated model system, the data required to implement the tools, modifications to the tools that were necessary to achieve the integration, and results of sensitivity tests of the integrated model system.

The C10A project team envisioned implementing the project in a region with limited choices of nonhighway modes; as such, the dynamic, integrated model represents behavioral changes in response to roadway conditions. To meet this objective, the model system was designed to capture changes in demand, such as time-of-day choice (i.e., peak spreading), and route choice in response to capacity and operational improvements, such as signal coordination, freeway management, variable tolls, and capacity improvements.

While the primary project objective called for the development of a dynamic, integrated model with advanced policy analysis capabilities, the project team also noted that advanced practitioners

have to be able to implement the model system in other regions without excessive costs or undue complexity. The resulting model system has the following features:

- The model is scalable. While the model system implemented for C10A can exploit distributed computing to reduce model system runtimes, it does not require a large hardware cluster or complex computing environment.
- The model is relatively easy to implement and maintain. Although the model system is inherently complex because of its advanced capabilities, it can be easily and flexibly configured to operate with different levels of temporal and spatial detail and in different computing environments.
- The model system does not require a multiyear, multi-million-dollar implementation and maintenance effort. The model system was implemented in two regions and subjected to a set of initial calibration and sensitivity tests in approximately 1 year.

This report documents the implementation of the model system in both Burlington, Vermont, and Jacksonville, Florida; the calibration and validation of the model system; and the application of the model system to a set of initial sensitivity tests.

Model System Components

The proposed model system comprises three primary components: DaySim, the Transportation Analysis and Simulation System (TRANSIMS) Router and Microsimulator, and MOVES. DaySim is a travel demand forecast model that predicts household and personal travel choices at a parcel level on a minute-by-minute basis. The TRANSIMS Router and Microsimulator are dynamic traffic assignment and network simulation software that can perform regional traffic microsimulation on a second-by-second basis. MOVES is the EPA's latest software for estimating emissions and air-quality impacts. The C10A integrated model links these three components in an equilibrated model system that provides enhanced policy sensitivities at significantly higher levels of spatial and temporal resolution than are found in traditional regional travel demand forecasting systems.

DaySim

The travel demand model used for this project is coded in a software framework called DaySim. DaySim is one of the two main families of activity-based model systems now being used by MPOs in the United States. DaySim was initially implemented in Sacramento, California, and has been enhanced to interface effectively with the TRANSIMS tools.

DaySim 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 into dynamic traffic simulation. DaySim's predictions in all dimensions (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 (O-D) path, and time of day; thus it can, in turn, effectively use as inputs the improved network travel costs and times output from a dynamic traffic simulator. DaySim is structured as a series of hierarchical or nested choice models. The general hierarchy places the long-term models (such as auto availability) at the top of the choice hierarchy and the short-term models (such as trip-mode and time-of-day choice) at successively lower levels in the hierarchy. More details of the DaySim structure and capabilities and a description of the DaySim-TRANSIMS linkage are provided in Chapter 1.

TRANSIMS

TRANSIMS network and travel assignment processes are used to represent the performance of the transportation networks in the integrated model system. TRANSIMS assigns a sequence

of trips or tours for individual household persons between specific activity locations (smaller than travel analysis zones but larger than individual parcels) to roadways, walkways, and transit modes on a second-by-second basis for a full travel day. The TRANSIMS networks include detailed information regarding the operational characteristics of the transportation facilities that may vary by time of day and by vehicle or traveler type. This information includes the number of lanes; the lane-use restrictions; the traffic controls, signal timing, and phasing plans; turning restrictions; and tolls.

TRANSIMS implements a dynamic user equilibrium network assignment for trip and activity files that defines the demand by detailed time of day. The primary demand input to TRANSIMS is an activity file produced by DaySim that contains information on each individual's activity locations, timing, and mode of travel. In addition, trip list files are used to represent non-household-related travel such as trucks, external trips, and other commercial travel in the network demand. TRANSIMS tools also generate zone-to-zone network impedance measures by detailed time of day for use in subsequent DaySim demand simulations. A description of this TRANSIMS-DaySim linkage can be found in Chapter 1.

MOVES

The MOVES software was developed by the EPA to provide estimates of emissions and greenhouse gases. MOVES uses detailed information about the distribution of vehicle miles traveled (VMT) by source type, facility type, area type, time of day, day of week, and 5-mph-average-speed bins to calculate emissions for an array of pollutants. In addition to travel data, MOVES uses information about fleet-age and fuel-type distributions, inspection maintenance programs, and monthly temperatures and humidity for each county in the analysis area. These are used to calculate county-based emissions inventories or custom domains that combine counties into aggregate estimates. TRANSIMS tools have been developed to interface with MOVES to support the generation of these estimates. A detailed description of the TRANSIMS-MOVES linkage is provided in Chapter 1.

Regional Implementations

As part of the C10A project, the DaySim-TRANSIMS-MOVES model system was implemented in two regions: Burlington, Vermont, and Jacksonville, Florida.

Small-Scale Regional Test Bed

The integrated model system was first implemented in Burlington, Vermont. The purpose of this implementation was to establish a test bed for developing and refining model system capabilities and configurations. The Burlington modeling area comprises a single county (Chittenden) of approximately 620 mi², and was home to 55,000 households in the base year of 2005 (Figure ES.1). These households generate approximately 525,000 daily person trips.

From a development perspective, the primary advantage of implementing the model system in a smaller region is that it allows researchers to more rapidly test alternative model configurations and to debug model processes because the model system runtimes are shorter. Shorter runtimes are associated with both the DaySim demand component of the model system and the TRANSIMS supply component.

In the DaySim model, runtimes relate directly to the amount of demand, so regions with a smaller population can be simulated more quickly. However, the DaySim demand model is not the primary performance bottleneck in the model system. The overall model system runtimes are primarily driven by the performance of the TRANSIMS Router and Microsimulator network assignment tools. Like DaySim runtimes, TRANSIMS runtimes are related to the amount of demand being simulated, but they are also significantly influenced by the level of transportation

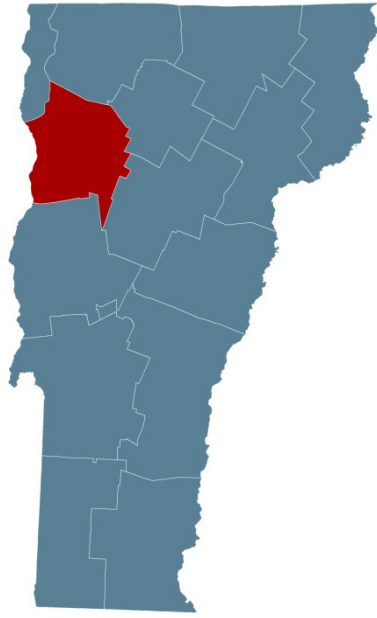


Figure ES.1. Burlington model area.

network detail—specifically the number of links in the network. In the Burlington implementation, the TRANSIMS network is relatively coarse, and the small modeling area limits the number of network links. However, because the levels of congestion in the region are relatively low, this smaller region cannot support the full range of model system sensitivity testing required by the C10A project and the model system’s responses to a number of policies and improvements are limited.

Large-Scale Regional Demonstration

Subsequent to the initial model implementation in the Burlington region, the integrated model system was implemented in Jacksonville, Florida. The purpose of the second implementation was to provide a more robust and challenging context for testing the model system capabilities. The Jacksonville region comprises four counties in northeast Florida covering 3,100 mi² (Figure ES.2). The regional population includes more than 525,000 households and 1.25 million people and generates more than 4 million daily person trips.

From the perspective of model application and sensitivity testing, the purpose of implementing the model system in the larger region was to subject the model system to a broader and more rigorous set of policy sensitivity tests. The region’s higher levels of network congestion made this possible. The primary disadvantage of using this larger model region is that the additional demand and network detail result in significantly longer model system runtimes, primarily attributable to the TRANSIMS Microsimulator. Use of this larger area for model development would have resulted in a longer model development phase. The longer runtimes associated with the Jacksonville integrated model implementation also necessitated the development and testing of a number of alternative application modes, as described in the following section.

Application Modes

The primary driving force behind the SHRP 2 C10A project is the need to address transportation policies being considered by MPOs around the country that are not adequately addressed by current state-of-the-practice travel-forecasting models. The integrated, time-sensitive

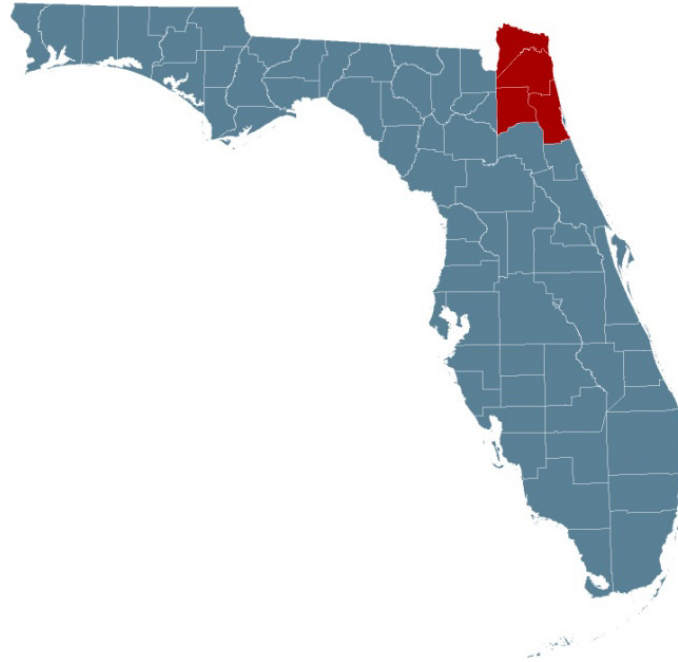


Figure ES.2. Jacksonville model area.

model developed for this project seeks to address the following broad categories of policies and strategies:

- Pricing policies;
- Capacity enhancements;
- Transportation system management (TSM) (and operations) improvements;
- Travel demand management policies; and
- Greenhouse gas reduction strategies.

Each of the three primary components of the integrated model system—DaySim, TRANSIMS, and MOVES—provides unique capabilities and can be flexibly configured to address the different analysis needs associated with the different policies and strategies. The project team developed different methods of combining and linking the model system components in application as a result of practical experience in working with and testing the model system. Specifically, some policies or improvements (such as roadway pricing) require regional-scale analysis, but regional-scale microsimulation can result in excessively long runtimes while adding little policy-specific sensitivity. Conversely, smaller-scale policies or improvements (such as signal coordination in a corridor) may not be expected to affect overall regional travel patterns, but they may require the local sensitivities of a traffic microsimulation model.

To balance policy analysis needs against practical runtime considerations, the project team developed a set of model system application modes: planning, operations, and planning + operations. Table ES.1 illustrates some typical Jacksonville model system runtimes for these application modes when implemented and distributed on the Transportation Research and Analysis Computing Center (TRACC) computing cluster at Argonne National Laboratory. Note that runtimes are highly dependent on the particular hardware being used, the specific versions of the software tools employed (which are updated frequently), and the level of convergence required for a particular analysis. As computing power increases, runtimes are expected to decrease. The following sections describe the configuration of these application modes and identify the types of policies or improvements that each might most effectively test.

Table ES.1. Application Mode Runtimes

Mode	Planning	Operations	Planning + Operations
Runtime for Operations			
DaySim demand estimation (hours)	4.0	4.0	4.0
Assignment iteration (hours)	0.5	5.0	5.0
Convergence checking (hours)	1.0	1.0	1.0
Skimming procedures (hours)	1.0	0.0	1.0
Total (hours)	6.5	10.0	11.0
Iterations			
Assignment	40	40	40
System	3	1	3
Total	120	40	120
Total System Runtime			
Hours	195	244	735
Days	8	10	31
Weeks	1.2	1.5	4.4

Planning Mode

The planning application mode can be used when the analysis needs are expected to result in regional-scale changes in overall levels of travel demand or changes in regional travelers' destination, mode, or time-of-day choices but are not expected to be significantly affected by local-scale traffic dynamics. The planning mode integrates the DaySim demand model with the TRANSIMS supply model in an iterative feedback loop in which DaySim outputs estimates of travel demand at the level of individual minutes for routing within the TRANSIMS Router. Temporally detailed network impedance skims based on these Router assignments are then generated and fed back as input to DaySim. A full-scale regional TRANSIMS microsimulation may be optionally run as a post process after the integrated DaySim-TRANSIMS Router application.

Planning Mode Configuration

The distinguishing feature of the planning application mode is that only the TRANSIMS Router is used in an integrated way with DaySim; the TRANSIMS Microsimulator is available for post-processing. The TRANSIMS Router operates at detailed temporal resolutions (such as 5 min or 15 min) and incorporates important features (such as time-dependent, shortest path building), but it uses traditional volume-delay functions (VDFs) to convert assigned volumes into 5-min or 15-min measures of link delay. These VDFs are inferior to Microsimulator-based delays in which the travel times and costs experienced by individual travelers are used to directly generate the times and delays used in path building. The Router also lacks some key functionalities of the Microsimulator, such as using actual signal timings to estimate delays at intersections instead of relying on fixed delays derived from prior assignment iterations. A critical advantage of using only the Router in the planning mode is that it runs relatively quickly even at a regional scale because it can be partitioned across multiple processing cores. By incorporating the Microsimulator as a postprocess, the impact of strategies and policies on regional and local traffic dynamics can also be assessed, albeit not in an integrated way. Figure ES.3 illustrates the configuration of the model system components in the planning mode, including network impedances based on VDFs and measures of effectiveness (MOEs) for MOVES.

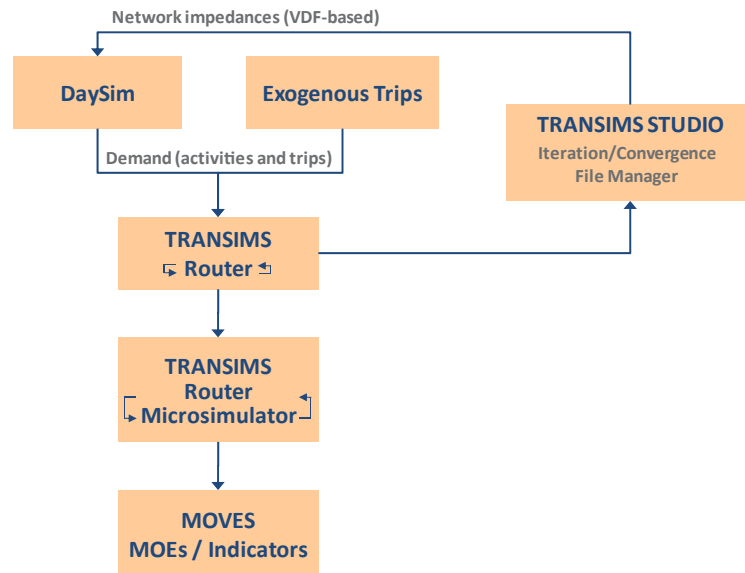


Figure ES.3. Planning mode system configuration.

Planning Mode Applications

The planning mode can be used when the policies or strategies being considered are expected to result in regional-scale changes in overall levels of travel demand or changes in regional travelers' destination, mode, or time-of-day choices, but are not expected to be significantly affected by local-scale traffic dynamics. The planning mode can be applied to the following primary policy and strategy analyses:

- *Pricing.* Pricing strategies are the costs imposed on travelers using certain roads, traversing certain screenlines, or traveling to certain areas (tolling, cordon pricing, or area pricing). These costs may either be fixed or vary by time of day or by response to congestion. Additionally, these costs may vary by user to reflect discounts or subsidies provided to some users. Pricing strategies are most effectively addressed in the context of a regional-scale model given the potential responses to pricing strategies. Responses may include changes in the overall level of activity and trip generation, changes in the destinations for these activities, changes in the travel modes used to access these destinations, and changes in the specific routes on the roadway or transit networks given the selected mode.
- *Capacity.* Capacity strategies involve adding, modifying, or deleting capacity on the roadway system. This may include the addition of new roads or lanes to the travel model networks, or it may involve adjusting existing capacity, such as the implementation of reversible lanes, auxiliary lanes, or turn lanes at intersections. The impacts of local capacity enhancements may be better captured using traffic microsimulation tools, but significant increases in capacity (such as the addition of new roads or lanes) are better addressed using regional-scale models because the enhancements have potentially broad impacts on regional network levels of service, which could influence generation, distribution, mode choice, and route assignment.
- *Travel demand management.* Travel demand management strategies typically aim to change travel behavior to reduce congestion and improve mobility. For example, these policies may seek to increase the number of people who work at home and their frequency of doing so; to induce workers to adjust their schedules to travel during off-peak, less-congested conditions; or to increase the number of people who carpool to work. Such policies are most appropriately addressed at a regional scale because of their expected impact on performance on regionally significant or congested facilities. However, a detailed model of traffic dynamics is not necessarily required to capture the impact of these policies.

Operations Mode

The operations mode can be used when the analysis requires an assessment of the impacts of a policy or strategy on local traffic dynamics and when these improvements are not expected to result in changes in overall levels of travel demand or in destination, mode, or time-of-day choices.

Operations Mode Configuration

The distinguishing features of the operations mode are that it incorporates a full regional traffic microsimulation but does not include an iterative feedback loop in which microsimulator-based network simulation impedance measures are fed back to DaySim. The elimination of this feedback loop reflects the fact that some operational improvements may greatly improve local traffic dynamics but have only marginal effects on the other travel dimensions; it also acknowledges that regional microsimulation is computationally intensive and results in extremely long runtimes. Figure ES.4 illustrates the configuration of the model system components in the operations mode.

Operations Mode Application

The operations mode is most appropriate when the policies or strategies under consideration are not expected to result in significant changes in overall levels of travel demand or in destination, mode, or time-of-day choices. The operations mode can be applied to the following primary policy and strategy analyses:

- *Capacity.* Some capacity improvements or enhancements to existing capacity may be evaluated using more local, operationally focused tools. These may include changes such as turn lanes at intersections, other geometric changes such as lane connectivity or lane widths, and the presence of shoulders.
- *Operations.* The operations model may support the analysis of bottleneck improvements, such as the addition of new signals or signs, adjustment of signal timing and phasing, or implementation of ramp meters. These are often most appropriately tested at a local scale using network assignment tools while holding the other choice dimensions fixed. However, more extensive bottleneck or other operational improvements—such as those applied across an extensive, coordinated signal system within a corridor or at a regional scale—may be appropriately tested using the planning + operations application mode described as follows.

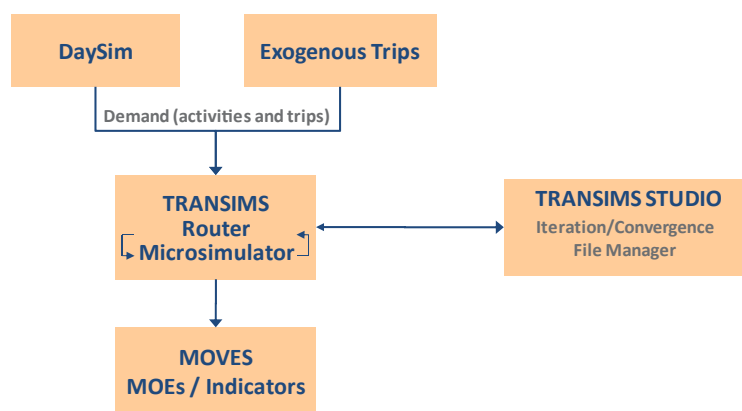


Figure ES.4. Operations mode system configuration.

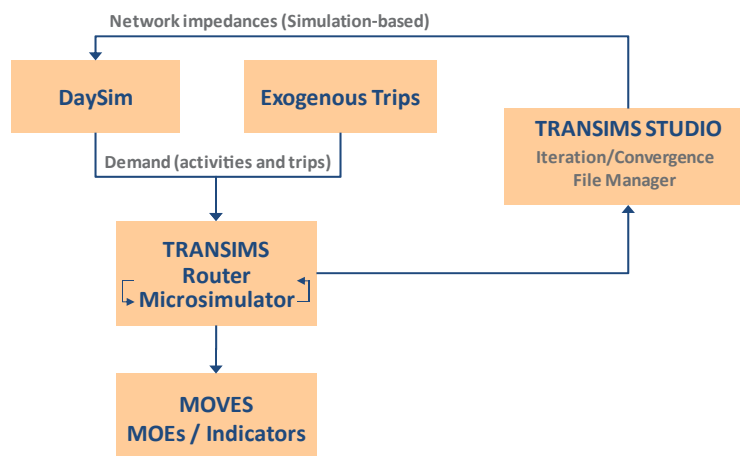


Figure ES.5. Planning + operations mode system configuration.

Planning + Operations Mode

The planning + operations mode represents the fully integrated DaySim and TRANSIMS model system. In this application mode, the TRANSIMS Router and Microsimulator are used to perform a regional traffic microsimulation as part of every model system global iteration; microsimulation-based network impedance measures are fed back and used as input to DaySim. The advantage of this application mode is that it provides the full range of sensitivities to changes in both regional demand and local and regional traffic dynamics. However, these extensive sensitivities come with the significant disadvantage of extremely long model system runtimes. Figure ES.5 illustrates the configuration of the model system components in the planning + operations mode.

Planning + Operations Mode Applications

The planning + operations mode can be used when the proposed policies or strategies are expected to result in regional-scale changes in the overall level of travel demand, or changes in regional travelers' destination, mode, or time-of-day choices and are expected to be significantly affected by local-scale traffic dynamics. The planning + operations mode can be applied to the following primary policy and strategy analyses:

- *Pricing.* Pricing strategies are the costs imposed on travelers using certain roads, traversing certain screenlines, or traveling to certain areas (tolling, cordon pricing, or area pricing). The costs may be fixed or vary by time of day, or they may respond to congestion. Additionally, the costs may vary by user to reflect discounts or subsidies provided to some users. Pricing strategies are most effectively addressed in the context of a regional-scale model given the potential responses to pricing strategies. Responses may include changes in the overall level of activity and trip generation, changes in the destinations for these activities, and changes in the travel modes used to access these destinations. The planning + operations mode is necessary when the pricing policies are also expected to have regionally significant impacts on traffic dynamics.
- *Capacity.* Capacity strategies involve adding, modifying, or deleting capacity on the roadway system. This may include the addition of new roads or lanes to the travel model networks, or it may involve adjusting existing capacity, such as the implementation of reversible lanes, auxiliary lanes, or turn lanes at intersections. Significant increases in capacity (such as the addition of new roads or lanes) are most effectively addressed using regional-scale models.

These models have potentially broad impacts on regional network levels of service, which could influence generation, distribution, mode choice, and route assignment. The use of regional traffic microsimulation within the integrated model provides a more robust platform for estimating these impacts.

- *Travel demand management.* Travel demand management strategies typically aim to change travel behavior to reduce congestion and improve mobility. For example, these strategies may seek to increase the frequency and numbers of people who work at home; to induce workers to adjust their schedules to travel during off-peak, less-congested conditions; or increase the number of people who carpool to work. Such policies are most appropriately addressed at a regional scale because of their expected impact on performance on regionally significant or congested facilities. Although a detailed regional-scale model of traffic dynamics is not necessarily required, the microsimulation may provide a better tool for assessing the impact of these policies.
- *Operations.* The planning + operations model can support the analysis of bottleneck improvements, such as the addition of new signals or signs, adjustment of signal timing and phasing, or implementation of ramp meters. These are often tested at a local scale using network assignment tools while the other choice dimensions are held fixed. However, more extensive bottleneck or other operational improvements—such as those applied across an extensive, coordinated signal system within a corridor or at a regional scale—may be appropriately tested using the fully integrated planning + operations application mode.
- *Greenhouse gas.* Strategies to reduce greenhouse gases (GHGs) may include both land-use and transportation improvements. In this case, the project team focused on transportation strategies. Using the microsimulator integrated with DaySim in the planning + operations mode provides the greatest sensitivity to GHG reduction strategies; these include pricing strategies to reduce VMT or increased fuel-efficiency standards. In addition, integration produces the most detailed estimates of transportation measures used as inputs to the MOVES and GHG estimation tools.

Before using the model system in an application, the DaySim and TRANSIMS model components had to be implemented and linked. In the Jacksonville region, the model system was then calibrated and validated. These efforts, as well as the initial sensitivity testing of the model system in Burlington, are the focus of this report.

Conclusions

Model Implementation

Demand Model Data Development

Developing the parcel-level inputs to the activity-based model (ABM) was relatively straightforward. Cleaning the employment data by the North Florida Transportation Planning Organization (NFTPO) and the Florida Department of Transportation (FDOT) significantly reduced the amount of time required to implement the model, although relatively crude updates to the employment data in one of the counties were still necessary. The parcel file required some additional cleaning to establish reasonable totals of housing units and to address inconsistencies in the parcel geography. School enrollment, transit stops, intersection types, and parking data were all relatively easy to assemble from existing data sources. In addition, developing the synthetic population was relatively straightforward given the availability of the data and tools; however, the overall effort still required approximately 6 months.

Accommodating auxiliary demand within the integrated DaySim-TRANSIMS model system was achieved using readily available static methods from the region's trip-based model; however, revisions to these auxiliary demand components are necessary for a more spatially and temporally consistent integrated demand-supply model system. A drawback of the current

implementation is that the auxiliary demand is fixed for each forecast year. That is, although this demand varies by forecast year, it is not affected by changes in network impedances. Ideally, the auxiliary models will be revised to provide sensitivity to changes in network performance.

Network Model Data Development

Developing detailed and usable networks for microsimulation requires significant effort. The TRANSIMS software comes with a wide array of tools to perform many network development tasks, and spatially detailed network data are widely available. However, users should expect to spend hundreds of hours debugging simulation networks, by correcting topological errors, resolving attribute discontinuities, and coding intersection controls. The time-consuming effort involves iteratively evaluating, adjusting, and testing the networks by running simulations. In addition, users face numerous challenges when attempting to develop future-year or alternative network scenarios, a topic discussed in subsequent sections.

Model Integration

Configuring DaySim to generate temporally, spatially, and behaviorally detailed travel demand information for use in TRANSIMS was straightforward. Configuring TRANSIMS to generate the skims for input to DaySim was also straightforward. More sophisticated methods of providing TRANSIMS-based impedances to DaySim could potentially be implemented. These could include implementing efficient multistage sampling of destinations (and corresponding impedances) at strategic points in the DaySim looping process, or tightly integrating DaySim and TRANSIMS so that DaySim can call TRANSIMS to extract the required measures quickly. However, the project team decided that the runtime implications and resources required for development were prohibitive, and concluded that the current methods provide sufficient spatial and temporal detail. The network convergence equilibration effort revealed that the most effective convergence strategies were often the least acceptable to the larger DTA community, but they were necessary to ensure sufficiently converged assignments within reasonable runtimes. Schedule consistency was identified as another measure of the soundness of a model solution. Extensive testing of the model system was necessary to determine the number of network assignment and model system iterations required to ensure that differences between alternative scenario model results were attributable to these policies and investments and were not obscured by noise in the model system.

Model Enhancements

The enhancements made to the model system were necessary to improve the model system's sensitivity and to fulfill the goals of the SHRP 2 C10A project. Updates to the DaySim model system were relatively straightforward, although the updates were not fully completed until a new DaySim software architecture was implemented, which took significantly longer than expected. The updates to the TRANSIMS model components were much more extensive and involved much more time to implement; many of these enhancements were under development during the C10A project. While these enhancements were necessary to fulfill project goals, they undoubtedly also resulted in schedule delays.

Model Application

The challenges in interacting with the model are primarily associated with debugging the model system. As already mentioned, the network simulation model is very sensitive to small-scale network coding and parameter assumptions, and the network simulation is subject to frequent failures as input assumptions are refined. Users must be able to understand and mine which data generated by the model system can illuminate the source of simulation problems and also be able

to make informed decisions about how to modify model inputs to achieve the proper model sensitivity. Model users must also have a basic understanding of Python programming language to understand the overall model system flow, as well as robust data manipulation, statistical analysis, and geographic information system (GIS) skills. Model users are not required to know C# or C++, the development platforms used for DaySim and TRANSIMS, respectively.

The types of analysis that can be performed with the new model system are fundamentally different and more expansive than can be performed with a traditional model system, and the application and interpretation of model outputs must be thoughtfully considered. The fully integrated model system is most valuable when the proposed policies or strategies are expected to result in regional-scale changes in the overall level of travel demand or changes in regional travelers' destination, mode, or time-of-day choices, and are expected to be significantly affected by local-scale traffic dynamics.

The model system software can be flexibly deployed on hardware running either Windows or Linux, and the implementation can be scaled or configured to reflect available hardware resources. To avoid long runtimes, the model can be used in different application modes, as described earlier in this chapter. Although many DaySim and TRANSIMS tools exist to assist in data preparation and coding, the model system is highly sensitive to alternative configurations of the model system and to small-scale coding issues; anywhere from an hour to many weeks may be needed to generate plausible alternative scenarios.

Model System Calibration and Validation

Transferring the DaySim activity-based demand component from Sacramento (where DaySim was initially implemented) to Jacksonville radically reduced the amount of time needed to implement the activity-based demand model component of the model system. Additional calibration and validation of some of the subcomponents of the model—such as the daily activity pattern component of DaySim or the refinement of TRANSIMS networks—was necessary to improve model performance. However, a number of the models required little, if any, recalibration.

The project team used the National Household Travel Survey (NHTS) as the primary observed data source for developing demand model calibration targets, although the survey's limited weekday sample size in the Jacksonville region and other data completeness issues created some challenges. Ultimately, more time was spent refining and validating the roadway networks than refining the calibration of the DaySim demand model components. Network microsimulation models are significantly more sensitive to network coding assumptions, so identifying and resolving those issues simply require more time.

Model Sensitivity Testing

Travel demand forecasting model systems are only able to test the effects of policies and assumptions that have been explicitly included in the design and implementation of the model system; they are not intrinsically sensitive to the increasingly broad range of transportation policies and improvements of interest to decision makers. While most regional models are sensitive to large-scale assumptions about land use and demographics, few are sensitive to more detailed assumptions about pricing policies, or to traffic or travel demand management strategies. Even when models have the capability to address these types of policies, they are typically not sufficiently sensitive to the dynamic interplay between travel behavior and network conditions by time of day to do so, nor can they reasonably represent the effects of road pricing, travel demand management, and other policies. Sensitivity testing of model systems involves the evaluation of the effects of changes in model inputs on model outputs. The Burlington implementation of the C10A model system was subjected to a set of sensitivity tests designed to illustrate the unique capabilities of the model system, including pricing, travel demand management, and operations.

Pricing

Two types of pricing tests were evaluated as part of this effort. In the first, a number of scenarios were defined in which freeway tolls varied by time of day. In the second, scenarios were defined in which auto operating costs were modified from the baseline condition. For the first type of sensitivity tests, three scenarios were evaluated and compared with the baseline. In the baseline alternative, no costs were assessed at any time; in the three scenarios, different fixed, per-mile charges that varied by time of day were evaluated. The expected responses to these policies—that travel would decline during tolled periods and on tolled facilities and that the changes would vary by activity purpose—were all observed in the model system outputs. Interestingly, all three pricing scenarios resulted in pronounced increases in travel demand during the evenings, suggesting that travelers will reschedule activities to occur when tolls are absent and when they have fewer scheduling constraints such as are present during midday. The team also observed in these tests that tolls have different effects on different trip purposes. For example, work-related travel was relatively unaffected, but social- and recreation-related travel shifted noticeably out of the peaks and into the evening. Finally, the network-based total delay was higher than the base in all scenarios, as tolling induces travelers to shift onto more capacity-constrained surface facilities.

For the second set of pricing sensitivity tests, three auto operating cost scenarios were evaluated and compared with the baseline. The baseline alternative assumed a cost of \$0.12/mi, while the alternatives assumed charges as low as \$0.06/mi and as high as \$0.60/mi. These tests confirmed that when auto operating costs decline, the share of households choosing to maintain zero vehicles also declines; and as the costs increase, the share of zero-vehicle households also increases. However, these changes were relatively modest. The results also showed small changes in regional tour frequency by purpose, although these shifts did not result in significant changes in network performance or congestion.

Travel Demand Management

Travel demand management (TDM) approaches incorporate a wide range of strategies aimed at changing travel behavior to reduce congestion and improve mobility. The sensitivity testing for Project C10A focused on assessing the impacts of a flexible work schedule in which all workers worked fewer days but longer hours on those days. The overall time spent on work activities was held fixed. The model results were consistent with expectations based on the structure and linkages of the DaySim and TRANSIMS model. In general, overall levels of activity generation were lower, although the declines in work-related travel were offset by increases in travel for discretionary purposes. The model produced shifts in the distribution of travel by time of day because of the lengthened workday; as expected, changes in the destination and mode choices were relatively small. This test did reveal noticeable changes in network performance, with reduced congestion across all facility types throughout most of the day. A slight increase in congestion in the evening reflects both the later return times from work and increased participation in discretionary activities in the evening.

Operations

The sensitivity testing focused on a scenario in which signals were coordinated using TRANSIMS tools along three primary regional corridors, with the goal of reducing bottlenecks and improving the overall traffic flow. The DaySim-TRANSIMS model system provides sensitivity to these improvements. (Traditional travel demand forecast models cannot typically represent such improvements because of their linkage with traditional static network assignment methods; those methods lack detailed network operation attributes and have coarse temporal resolution.) The initial model results showed some reductions in delay by facility type, particularly during peak periods. However, closer inspection of the speed profiles along the three targeted corridors

showed more mixed results, with the signal progression producing better speeds in some corridor directions and worse speeds in other corridor directions. As others have noted, the sensitivity of DTA and traffic microsimulation models to these detailed inputs suggests distinct challenges when attempting to incorporate these assumptions into a forecasting mode, especially at a regional scale. Of all the scenarios evaluated as part of this sensitivity testing, the signal progression scenario required the greatest amount of time and resulted in the least interpretable results.

Disaggregate Framework

Because both the demand and the supply components of the model system are fully disaggregate, users can trace the impacts of policies and investments on individual travelers from long-term choices (such as usual work locations) all the way down to the specific paths taken by each individual traveler on a second-by-second basis. Although disaggregate model results are not reported, this framework provides tremendous flexibility for aggregating model results for specific travel markets or communities of concerns; and it is useful for debugging, calibrating, and refining model sensitivity. Also, note that random simulation variation did not compromise the ability to use the model system, provided that sufficient convergence was achieved both within the network assignment and for the model system overall.

Overall, the new model system is more sensitive to a wider range of policies than a traditional travel demand model system. This sensitivity is further enhanced by the detailed representation of temporal dimension, as well as the increased behavioral and spatial detail. In addition, the model system produces a wider range of statistics of interest to decision makers. Extracting, managing, and interpreting the results was not difficult; however, the level of effort required to effectively test different types of improvements varied widely, from as little as 1 hour to more than a week. Using the model to evaluate the pricing and TDM scenarios was relatively easy, requiring straightforward adjustments to network coding or to model coefficients. Using the model to evaluate the operational scenarios required significantly more effort because of the sensitivity of the network simulation to different signal coordination and timing assumptions. This level of effort would undoubtedly increase if more extensive changes to operational assumptions were required. In addition, even with the additional effort, the results produced by the model system did not seem as intuitive as the results of the other scenario tests.

CHAPTER 1

Model Implementation

SHRP 2 Project C10A, Partnership to Develop an Integrated, Advanced Travel Demand Model and a Fine-Grained, Time-Sensitive Network: Jacksonville-Area Application was undertaken to develop a dynamic, integrated model and to demonstrate its performance through validation tests and policy analyses. This chapter describes the data requirements and steps necessary to implement the integrated model system. First, all key data inputs and tools are identified and described. The DaySim model requires data that reflect a wide variety of factors that influence travel decisions. Much of the data is developed and applied at the detailed parcel level.

Data Development

The DaySim model requires data that reflect a wide variety of factors that influence travel decisions, including socioeconomic, employment, and school information; transportation network level of service; and urban form attributes. Much of the data is developed and applied at the detailed parcel level, which enhances the model's sensitivity but which also increases the data development, maintenance, and update requirements. The DaySim data inputs are discussed in the following sections.

Synthetic Population

DaySim was initially implemented in Sacramento, California. Before applying the DaySim models in Jacksonville and Burlington, the project team first had to develop a *synthetic population* of these regions' residents. This synthetic population is a list of households and persons that is based on observed or forecast distributions of socioeconomic attributes and created by sampling detailed Census Bureau microdata. This list functions as the basis for all subsequent choice-making simulated in the model system. The base year 2005 data used to develop the synthetic population with the DaySim population generation component are available from three sources: (1) the Census Bureau's American Community Survey (ACS) Public Use Microdata Sample (PUMS) and Decennial PUMS,

(2) Northeast Florida Regional Planning Model (NERPM) inputs, and (3) the National Household Travel Survey (NHTS).

PopGen

PopGen, a synthetic population generator developed at Arizona State University, was chosen for synthesizing the Jacksonville and Burlington populations. Synthetic population generators typically use Census-based marginal distributions on household attributes to generate joint distributions on variables of interest using standard iterative proportional fitting (IPF) procedures. Households are then randomly drawn from an available sample in accordance with the joint distribution such that household-level attributes match perfectly. However, these traditional procedures typically operate at the household level and do not control for person-level attributes and joint distributions of personal characteristics. PopGen incorporates a heuristic approach to generate synthetic populations while matching both household-level and person-level characteristics of interest.

PopGen is a Python-based software with an easy-to-use and flexible graphical user interface (GUI). Its wizard-based project setup process allows users to choose the region for population synthesis and specify the required inputs. Figure 1.1 shows the PopGen project setup wizard. It accommodates sample and control inputs from Census, ACS, and region-specific sources such as household surveys and land-use model outputs. Populations can be synthesized with controls at various geographic resolutions such as Census-block groups or travel analysis zones (TAZs). For Jacksonville and Burlington, the populations were synthesized at the TAZ level and subsequently allocated to individual parcels.

Once the required inputs have been specified, PopGen imports them into tables in a MySQL database and works from those tables to draw a synthetic population. After a population synthesis run, the match between the synthetic population and control data can be checked using visualization features in PopGen. Figure 1.2 shows one such

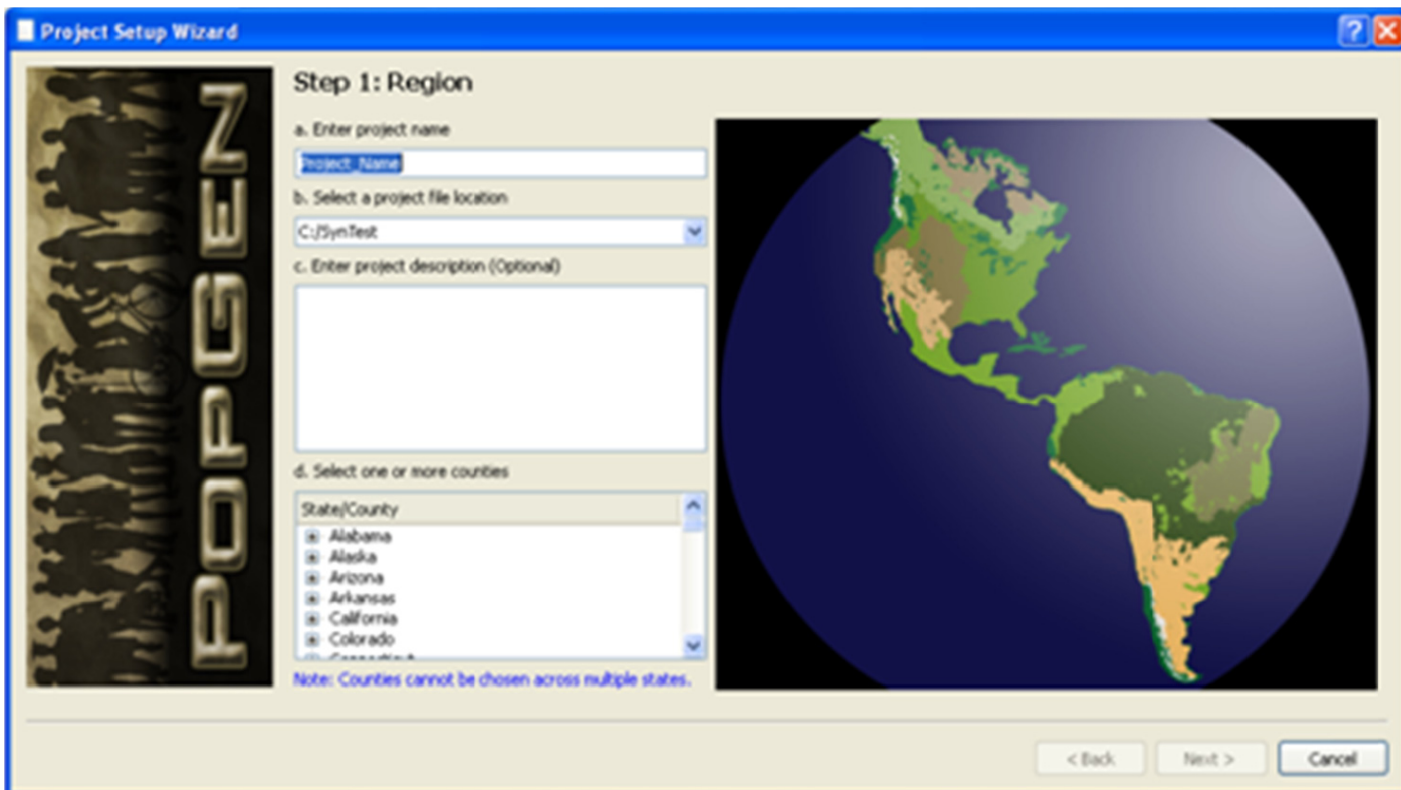


Figure 1.1. PopGen project setup wizard.

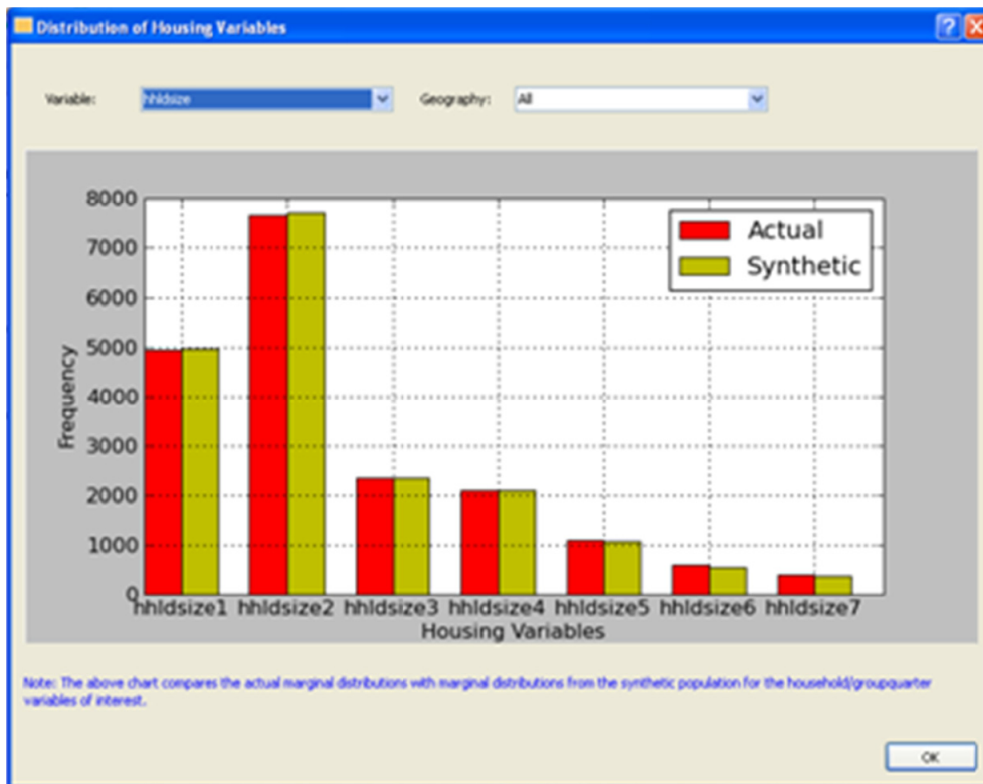


Figure 1.2. PopGen visualization.

feature. If the synthetic population is found to be appropriate, PopGen tools can export it to specific file formats for use in travel demand microsimulation applications, such as DaySim.

Preparing a synthetic population for microsimulation using DaySim involves four basic steps. Each of the steps is described in detail in the following sections.

1. Prepare the control data.
2. Prepare the sample data.
3. Synthesize the population.
4. Process the synthetic population for use in DaySim.

The Jacksonville synthetic sample population comprises three segments: permanent households and population, seasonal households and population, and the group quarters population. The segments were established to reflect the differences in travel patterns associated with these subpopulations as well as to support seasonal analyses. For example, the seasonal population is generally older than the permanent population, has lower levels of workforce participation, and clusters in certain geographic areas. All of these attributes influence travel patterns and the demand for travel.

The Burlington synthetic sample population comprises two segments: permanent households and population and the group quarters population. Burlington does not have a significant seasonal population; thus a separate seasonal segment was not necessary. However, Burlington does have a significant group quarters population comprising University of Vermont students, so this segment was maintained.

Jacksonville Synthetic Population

Control Data

This section identifies the data sources and steps to prepare the control data for all three of the subpopulations that make up the synthetic population: permanent resident households and population, seasonal households and population, and noninstitutionalized group quarters (GQ) residents.

ESTIMATE THE DEMOGRAPHIC DISTRIBUTIONS

The first step is to identify specific control variables of interest and derive demographic distributions for them. The control variables are attributes based on demographic distributions that are relevant to travel demand patterns. Control variables are specified for each of the three segments.

PERMANENT HOUSEHOLDS. Table 1.1 and Table 1.2 show the control categories and data sources for households and for persons, respectively. The PopGen program uses this information

to synthesize the permanent household population. For households, the categories include the following:

- Age of the head of household;
- Household size;
- Number of workers;
- Household income; and
- Presence of children.

For persons, the categories include gender and age.

The attributes are based primarily on Census Transportation Planning Products (CTPP) distributions; the presence of children attribute is obtained from the Census Summary File 1 (SF1). Before working with the data, CTPP tables at the Census TAZ level were mapped to corresponding NERPM TAZs using the following steps:

- A NERPM parcel centroid file was created from the parcel boundary shape file. This file also contains the NERPM TAZ for each parcel.
- The parcel centroid shape file was intersected with the Census TAZ shape file in ArcGIS, and centroids of NERPM parcels were matched with Census TAZs. This step creates a many-to-many correspondence between Census and NERPM TAZs.
- Using the total number of housing units in all the parcels in a NERPM TAZ and the total number of housing units in all the parcels in a Census TAZ, the project team calculated the proportion of housing units from a Census TAZ that belong to a particular NERPM TAZ.

The numbers of households in various categories of control variables were aggregated at the Census TAZ level and distributed to NERPM TAZs on the basis of the calculated proportions. The data were aggregated again at the NERPM TAZ level.

Similarly, because SF1 data are at the Census-block level, centroids for Census-block polygons were mapped to NERPM TAZs using ArcGIS to obtain a block-TAZ correspondence table. By combining appropriate fields in the data tables, distributions of the various categories among the control variables chosen were obtained at the NERPM TAZ level.

SEASONAL HOUSEHOLDS. The control categories for the seasonal population are the same as for permanent households. However, the base year control values come directly from the seasonal households in the statewide NHTS survey sample, conducted in 2008 and 2009, which includes 530 households that reported living in Florida for 8 months or less per year. Of those households, 463 provided income information. The demographic distribution of this statewide sample is assumed to apply to all TAZs in the model area because reliable seasonal population attributes at detailed geographic levels are

Table 1.1. Household Control Data for Permanent and Seasonal Households

Household Attribute	Control Column	Categories	Source Data
Householder age	1	18–44	CTPP 1-70
	2	45–64	
	3	65+	
Household size, number of workers, and income		Size categories 1–4: 1, 2, 3, 4+; Workers categories 1–3: 0, 1, 2+; Income categories 1–4: Under \$30,000, \$30,000–\$59,999, \$60,000–\$99,999, \$100,000 & over (Specified as joint distribution using a composite attribute):	CTPP 1-75
	4	Size1 Workers1 Income1	
	5	Size1 Workers1 Income2	
	6	Size1 Workers1 Income3	
	7	Size1 Workers1 Income4	
	8	Size1 Workers2 Income1	
	9	Size1 Workers2 Income2	
	10	Size1 Workers2 Income3	
	11	Size1 Workers2 Income4	
	12	Size2 Workers1 Income1	
	13	Size2 Workers1 Income2	
	14	Size2 Workers1 Income3	
	15	Size2 Workers1 Income4	
	16	Size2 Workers2 Income1	
	17	Size2 Workers2 Income2	
	18	Size2 Workers2 Income3	
	19	Size2 Workers2 Income4	
	20	Size2 Workers3 Income1	
	21	Size2 Workers3 Income2	
	22	Size2 Workers3 Income3	
	23	Size2 Workers3 Income4	
	24	Size3 Workers1 Income1	
	25	Size3 Workers1 Income2	
	26	Size3 Workers1 Income3	
	27	Size3 Workers1 Income4	
	28	Size3 Workers2 Income1	
	29	Size3 Workers2 Income2	
	30	Size3 Workers2 Income3	
	31	Size3 Workers2 Income4	
	32	Size3 Workers3 Income1	
	33	Size3 Workers3 Income2	
	34	Size3 Workers3 Income3	
	35	Size3 Workers3 Income4	
	36	Size4 Workers1 Income1	
	37	Size4 Workers1 Income2	

(continued on next page)

Table 1.1. Household Control Data for Permanent and Seasonal Households (continued)

Household Attribute	Control Column	Categories	Source Data
	38	Size4 Workers1 Income3	
	39	Size4 Workers1 Income4	
	40	Size4 Workers2 Income1	
	41	Size4 Workers2 Income2	
	42	Size4 Workers2 Income3	
	43	Size4 Workers2 Income4	
	44	Size4 Workers3 Income1	
	45	Size4 Workers3 Income2	
	46	Size4 Workers3 Income3	
	47	Size4 Workers3 Income4	SF1-p19
Presence of children under 18	48	Yes	
	49	No	

not available. However, the seasonal population is clustered in certain areas, such as along the coast.

For population synthesis, all dollars are normalized to represent 1999 dollars as closely as possible; that value was used in the 2000 Census, which supplies PUMS and control table data. The NHTS survey data are recorded in categories of nominal 2007 or 2008 dollars (\$5,000 increments to \$80,000, then \$80,000 to \$100,000, then above \$100,000); each of these categories must be placed within one of the four 1999 income categories used

for population synthesis (under \$30,000, \$30,000 to under \$60,000, \$60,000 to under \$100,000, and \$100,000+). To do this the gross domestic product (GDP) deflator (0.817) was used to inflate the 1999 synthesis categories to 2007 values (under \$36,700; \$36,700 to under \$73,400; \$73,400 to under \$122,400, and \$122,400+), so that the recorded category of each household could be placed in the best synthesis category. Because the NHTS survey data's top category is only \$100,000+ (2007 dollars), high-income survey respondents could not be accurately assigned to the top two synthesis categories given that the threshold (\$100,000 in 1999 dollars) falls between them (\$73,400 to under \$122,400 and \$122,400+ in inflated 1999 dollars). The best option was to assign all such respondents to the top income category of \$100,000+ (1999 dollars).

Table 1.2. Person Control Data for Permanent and Seasonal Households

Person Attribute	Control Column	Categories	Source Data
Gender and age		Gender categories 1&2: male/female; age categories 1-5: 0-15, 16-20, 21-44, 45-64, 65+	CTPP 1-51
	1	Male age 0-15	
	2	Male age 16-20	
	3	Male age 21-44	
	4	Male age 45-64	
	5	Male age 65+	
	6	Female age 0-15	
	7	Female age 16-20	
	8	Female age 21-44	
	9	Female age 45-64	
10	Female age 65+		

NONINSTITUTIONALIZED GROUP QUARTERS. Table 1.3 shows the proposed control categories for the Group Quarters (GQ) residents.

The distribution is extremely simple because of limited Census data for GQ residents. However, the age distribution helps PopGen properly locate two important GQ subpopulations: college students and retirement center residents. The

Table 1.3. Control Data for Noninstitutionalized Group Quarters Residents

Household/Person Attribute	Control Column	Category	Source Data
Age	1	Under 18	2000 SF1-p38
	2	18-64	
	3	65+	

control information is so simple that an IPF procedure is not necessary. However, if using PopGen to generate the sample, it can be set up to run only the household-level IPF, which will converge quickly, and avoid entirely the person-level iterative proportion fitting (IPF) and the iterative proportion updating (IPU) procedures.

*ESTIMATE THE NUMBER OF HOUSEHOLDS
AND PERSONS IN EACH TAZ*

The numbers of households and persons living in each TAZ in 2005 are required as control totals for both the permanent and seasonal populations. The final control total required to synthesize the population is the number of GQ residents.

The total number of permanent households and seasonal households for 2005 at the TAZ level were obtained by combining NERPM model data on permanent and seasonal housing occupancy with parcel-level estimates of housing units. The development of the parcel-level estimates of housing units is described in the section on DaySim parcel data. The NERPM model demographic data include TAZ-level data on the number of housing units in a TAZ, the proportion of those households that are seasonally occupied or vacant, and the proportion that are vacant. The following formulas (see Equation 1.1) were used to derive the number of households. They produced a total of 479,250 permanent households and 35,339 seasonal households.

$$\text{PHHP} = \left(\frac{\text{SFDU} * (1 - \text{SFSEAS}/100)}{+ \text{MFDU} * (1 - \text{MFSEAS}/100)} \right) / (\text{SFDU} + \text{MFDU})$$

$$\text{PHH} = \text{ParcelHU} * \text{PHHP}$$

$$\text{SHHP} = \left(\frac{\text{SFDU} * (\text{SFSEAS} - \text{SFVAC})/100}{+ \text{MFDU} * (\text{MFSEAS} - \text{MFVAC}/100)} \right) / \left(\frac{\text{SFDU}}{+ \text{MFDU}} \right)$$

$$\text{SHH} = \text{ParcelHU} * \text{SHHP} \quad (1.1)$$

where

- PHHP = permanent household proportion;
- SFDU = single-family dwelling units (NERPM data);
- SFSEAS = percentage of seasonal or vacant single-family dwelling units (NERPM data);
- MFDU = multifamily dwelling units (NERPM data);
- MFSEAS = percentage of seasonal or vacant multifamily dwelling units (NERPM data);
- PHH = permanent households;
- ParcelHU = housing unit estimates from parcel data;
- SHHP = seasonal household proportion;
- SFVAC = percentage of vacant single-family dwelling units (NERPM data);
- MFVAC = percentage of vacant multifamily dwelling units (NERPM data); and
- SHH = seasonal households.

The permanent population controls are based on the total number of persons by county from the Census population estimated data. According to these data, the July 1, 2005, population of the four-county Jacksonville model area was 1,223,279. That number includes GQ residents but is assumed not to include seasonal residents. GQ residents were separated out by estimating their 2005 population—interpolating between the number of GQ residents according to the 2000 Census (20,122) and the number according to the 2006–2008 ACS (21,047)—which gives 20,783 GQ residents. The total permanent population according to the Census is 1,202,496. The county-level permanent population totals were used to calculate an average household size for the highest household size category (4+ people) for each county. That number was applied to the TAZ-level household-size distribution (from CTPP Table 1-62) and the number of permanent households to calculate the number of permanent residents in each TAZ.

The average seasonal household size was calculated from the NHTS data using the ratio of the total number of seasonal persons in the sample and households in the sample. To calculate the total number of persons in the seasonal population, this average household size was multiplied by the total number of seasonal households in each TAZ. This calculation resulted in 63,611 seasonal residents.

The total number of noninstitutional GQ residents for the base year was estimated using the total GQ population and data from Census 2000 SF1 (Table P37) which identified the proportion of GQ residents classed as noninstitutional. (This distinction is important for travel modeling because institutionalized GQ residents, such as prisoners in jails, do not travel outside of their institution.) The number of noninstitutional GQ residents is 10,813. The county-level estimates were assigned to TAZs on the basis of the number of GQ housing units according to parcel data.

The demographics distributions were rescaled to match the estimated number of households and persons living in each TAZ.

REFORMAT CONTROL DATA TO POPGEN SPECIFICATIONS

For permanent residents, two PopGen “marginals” files are needed, with 49 household controls in one file and 10 personal controls in another, as shown in Table 1.1 and Table 1.2. The layout of the marginal input file required by PopGen is shown in Table 1.4. The file begins with four mandatory fields: state, county, tract, and bg, with bg interpreted as TAZ. After that is a column for each control category, with entries representing the number of households (or persons) within the category for each TAZ. Two header rows (the column name in Row 1 and the data type in Row 2) are followed by one of control data items for each TAZ. The control data items are represented here as dots.

Household and person marginals files with the same control categories are needed for seasonal residents. For the GQ

Table 1.4. PopGen Household Marginal File Layout

State	County	Tract	Bg	<hhvar1cat1>	<hhvar1cat2>
<variabletype>	<variabletype>	<variabletype>	<variabletype>	<variabletype>	<variabletype>
<data>	<data>	<data>	<data>	<data>	<data>
...

Note: ... = control data.

population, the three controls in Table 1.3 need to be included in a household marginals file, but no person marginals file is required.

All of these steps have been coded in an R-script. The R Project (<http://www.r-project.org/>) provides open-source software for statistical computing and graphics. It is also an efficient tool for data manipulation and processing. The inputs required for the R-script are correspondences between Census TAZs, NERPM TAZs (for Jacksonville), and DaySim TAZs (DaySim TAZs are renumbered NERPM TAZs since the DaySim software requires that external zones be listed first), CTPP tables in comma-separated values (CSV) format, SF1 data with NERPM TAZ mapped (also in CSV format), NERPM zonal data (database file, dbf, format), demographic distributions of seasonal households from NHTS, and GQ population totals by county from Census SF1.

On synthesizing the population, the project team found a considerable overestimation in the total number of workers compared with the employment in the region, accounting for in- and out-commuting. The household distribution by number of workers was found to be influencing the higher number of workers. Thus, the demographic distributions obtained from Census data were adjusted at the county level to match those obtained from ACS 2005–2007, which had different proportions of households by workforce participation.

Sample Data

The household sample provides the household and person records that will be drawn into the synthetic population. It also provides the multidimensional attribute seed distribution for the IPF procedures used in PopGen. Because the distribution does not depend primarily on the household sample, but rather on the controls, the sample need not exactly represent the distribution. However, preferably, the sample should include many households of the types found in the region included in the synthetic distribution. Thus, a large sample from which to draw is preferred. Typically, the Census PUMS of each Public Use Microdata Area (PUMA) serves as the sample for all smaller geographical units included in the PUMA. Now that the ACS PUMS is available, either the 2000 Census PUMS or ACS PUMS—or both—can be used; the PUMA definitions and the

definitions of the PUMS data items used by DaySim are essentially the same for the 2000 Census and for ACS PUMS. Both data sources have been combined to create the sample file.

Table 1.5 lists the PUMAs that cover the model area. The PUMS for permanent and seasonal households include all occupied-housing and person records from these PUMAs. The sample for noninstitutionalized GQ residents includes only the occupied-housing and person records, from these PUMAs, that represent the noninstitutionalized GQ population. For 2000 PUMS, these have housing record UNITTYPE=2; and for 2006–2008 ACS, they have housing record TYPE=3. If the resulting sample is quite small, then all the GQ records may need to be combined into a single sample that is used for all PUMAs, and even GQ records from other PUMAs in the state may need to be added.

Table 1.6 lays out the data elements needed for the PopGen input sample files, including the items required by PopGen, the items corresponding to control variable categories, and the items needed by DaySim. These elements include data items corresponding to the controls required for the generation of all three synthetic subpopulations.

Table 1.7 shows the exact format of the input sample file as required by PopGen. An input sample file contains four mandatory fields (state, pumano, hhid, serialno) followed by population attributes. The serial number and household ID are identical IDs for the sample housing unit, indexed at 1. (The duplication is a legacy of an earlier version of PopGen. The

Table 1.5. Jacksonville PUMAs

PUMA ID	Description
1300	Clay County
1101	Parts of Duval and Nassau Counties
1102	Part of Duval County
1103	Part of Duval County
1104	Part of Duval County
1105	Part of Duval County
1106	Part of Duval County
1107	Part of Duval County
1200	St Johns County

Table 1.6. PopGen Input Sample File Data Items

Data Item and Description	Values	Control Variable	ACS 2006–2008 Item	Census 2000 5% PUMS Item
Household Sample File				
State			ST	STATE
Pumano			PUMA	PUMA5
Hhid (same as serialno)				
Serialno				
Household size			NP	PERSONS
Number of people in related family			NPF	NPF
Household income ^a	In dollars		HINCP (PINCP for GQ)	HINC (INCTOT for GQ)
CTPP1-70 category: age of householder		HH		
CTPP 1-75 category: household size, income ^a , and number of workers		HH		
SF1-P19 category: presence of children in household		HH		
SF1-P38 category: age		GQ		
Person Sample File				
State			ST	STATE
Pumano			PUMA	PUMA5
Hhid (same as serialno)				
Serialno				
Pnum				
Gender	1-male, 2-female		SEX	SEX
Age	Years		AGEP	AGE
Grade in school	1:Pre-K 2:K 3:Grade 1–4 4:Grade 5–8 5:Grade 9–12 6:Undergrad 7:Grad/Prof school		SCHG	GRADE
Hours worked per week			WKHP	HOURS
CTPP1-51 category: gender and age		HH		

^a Income data from separate years are deflated to 1999 dollars, used by 2000 CTPP 1-75 and by DaySim. Household income is not available in PUMS for GQ residents, but total personal income is available in the person record and was used instead.

Table 1.7. PopGen Household Sample File Layout

State	Pumano	Hhid	Serialno	<hhvariable1>	<hhvariable2>	...
<variabletype>	<variabletype>	<variabletype>	<variabletype>	<variabletype>	<variabletype>	
<data>	<data>	<data>	<data>	<data>	<data>	
...	

Table 1.8. PopGen Geographic Correspondence File Layout

County	Tract	Bg	State	Pumano	Stateabb	Countyname
<vartype>	<vartype>	<vartype>	<vartype>	<vartype>	<vartype>	<vartype>
<data>	<data>	<data>	<data>	<data>	<data>	<data>
...

current version requires only one unique ID, but the code still requires that two fields be present in the input file.)

Population Synthesis

In this step, PopGen is run separately for each of the three sub-populations, using the specified input control and sample files. In addition to the control and sample files, PopGen requires a geography correspondence file (shown in Table 1.8). This file has one row per TAZ and associates the TAZ with the PUMA (and other larger geographies) to which it belongs. For Jacksonville, the correspondence file has been prepared and is named Geocorr.csv.

After PopGen is run, output population files are exported. Table 1.9 lays out the data elements needed for the PopGen synthetic population output files. Compared with the sample input data items, this step drops the items required for sampling and adds the identification numbers required by PopGen.

Synthetic Population DaySim Integration

DaySim currently generates and reads the synthetic population in the form of person records, with household data repeated in every person record. In addition, DaySim operates at the parcel level, while PopGen creates the synthetic population at the larger TAZ level. Therefore, a DaySim population conversion/parcel allocation utility has been created that reads PopGen population files, associates household attributes with persons, and allocates the households in the synthetic population to parcels. It then outputs a combined synthetic population file (dbf) in the format required by DaySim. The primary inputs to this utility are six PopGen output files (household and person files for three population groups), a TAZ controls file, and DaySim's regular parcel data input file. The TAZ controls file is an input of permanent households, seasonal households, and noninstitutionalized GQ residents living in each TAZ. The file format is shown in Table 1.10.

Table 1.11 shows the format of the PopGen population household files that are needed by the DaySim utility. Whether one, two, or three input files are required depends on the segmentation of the synthetic population and the associated

Table 1.9. PopGen Synthetic Population Output File Data Items

Data Item and Description	Values
Household Characteristic	
State	
County	
Tract	
Bg (TAZ)	
Hhid	
Serialno	
Frequency	
HhuniqueID	
Household size	
Number of people in related family	
Household income	In dollars
Person Characteristic	
State	
County	
Tract	
Bg (TAZ)	
Hhid	
Serialno	
Pnum	
Frequency	
PersonuniqueID	
Gender	1-male, 2-female
Age	Years
Grade in school	1:Pre-K (age 3+) 2:K 3:Grade 1-4 4:Grade 5-8 5:Grade 9-12 6:Undergrad 7:Grad/Prof school
Hours worked per week	

Table 1.10. DaySim Synthetic Population Input Data Items

Label	Format	Definition
TAZ	Integer	Zone number
HHPPerm_ZC	Float	Permanent households living in TAZ
HHSeas_ZC	Float	Seasonal households living in TAZ
GQUnitsZC	Float	Noninstitutionalized GQ residents in TAZ

Note: These data must be in CSV format (.csv), with a header row, in the order specified. DaySim reads them as integers.

settings in the control file. For Jacksonville, three files are used, one for each population segment.

Table 1.12 shows the formats of PopGen population person files that are needed by the DaySim utility. A PopGen population person file is required for each of the population segments; three in the case of Jacksonville.

The utility also creates three additional data items (shown in Table 1.13) required by DaySim during microsimulation. It creates binary variables for each person, indicating whether or not that individual is a worker and/or a student. It then assigns the household to the specific parcel within the TAZ to which the synthetic household was assigned by PopGen. Permanent and seasonal households in a TAZ are combined into one large group and allocated to parcels on the basis of the availability of dwelling units. GQ residents are allocated to parcels containing GQ dwelling units, which are identified in the parcel data input file separately from dwelling units for permanent and seasonal households.

Table 1.11. Input Files Format of Households Generated from PopGen: Permanent, Seasonal, or GQ

Label	Definition
State	State of residence
County	County of residence
Tract	Tract of residence
Bg	TAZ of residence
Hhid	Household ID (generated by PopGen; DaySim reassigns household number)
Serialno	Serial number (generated by PopGen)
Frequency	Number of households represented (DaySim assigns this number of households)
HINC	Household income (dollars)
Hhsize	Number of persons in household
NPF	Number of persons part of family

Note: These data must be in CSV format (.csv), without a header row, in the order specified. DaySim reads them as integers.

Table 1.12. Input Files Format of Persons Generated from PopGen: Permanent, Seasonal, and/or GQ

Label	Definition
Pstate	State of residence
Pcounty	County of residence
Ptract	Tract of residence
Pbg	TAZ of residence
Phhid	Household ID (generated by PopGen; DaySim reassigns household number)
Pserialno	Serial number (generated by PopGen)
Pnum	Person number within household (DaySim reassigns person number)
Pfrequency	Number of households represented (DaySim assigns this number of households)
Age	Age in years
Gender	Gender: 1-male, 2-female
GradeCat	0:Non-student 1:Pre-K (age 3+) 2:K 3:Grade 1-4 4:Grade 5-8 5:Grade 9-12 6:Undergrad 7:Grad/Prof school
Hours	Hours worked per week

Note: These data must be in CSV format (.csv), without a header row, in the order specified. Each person file must be in the same household order as its corresponding household file. DaySim reads the data as integers.

Synthetic Population Validation

For Jacksonville, the synthetic population generated using PopGen was validated across the different control dimensions (both household and person) used to ensure that the population matched the control variables. The validation was done separately for the three population groups. Table 1.14 summarizes the differences in the total number of households and

Table 1.13. DaySim Synthetic Population Derived Data Items

Data Item and Description	Value	ACS 2006-2008 Item	Census 2000 5% PUMS Item
Household Characteristic			
Parcel	Parcelid		
Person Characteristic			
Worker indicator	Yes/no	WKHP>0	HOURS>0
Student indicator	Yes/no	SCHG not blank	Grade>0

Table 1.14. Synthetic Population Validation Summary

Population Group	HH Obs.	HH Syn.	HH Diff.	Per Obs.	Per Syn.	Per Diff.
Permanent	479,250	479,298	0.01%	1,202,855	1,184,800	-1.50%
Seasonal	35,339	35,367	0.08%	63,611	64,185	0.90%
Group Quarters	10,813	10,823	0.10%	10,813	10,823	0.10%
Total	525,402	525,488	0.02%	1,277,279	1,259,808	-1.37%

Note: HH = households; Obs. = observed; Syn. = synthesized; Diff. = difference; Per = persons.

persons in the synthetic population and observed controls. Overall, the synthetic population has about 1.4% fewer persons. That can be considered reasonable given the total population of about 1.2 million persons in the modeling region.

Figure 1.3 shows a comparison of the household size distribution from the control data and synthetic population to illustrate the degree of match achieved. Table 1.15 and Table 1.16 show the comparison of household size distributions further disaggregated to the county level. Since the population was synthesized at the TAZ level, the county level match is close, as expected. Note that the proportion of seasonal households is quite low.

The distributions of household workers for both permanent and seasonal populations are shown in Figure 1.4. At a county level, household workers distributions are given in Table 1.17 and Table 1.18 for permanent and seasonal populations, respectively. The level of match is similarly close to that of the household size distribution.

The household income distributions for both permanent and seasonal population are shown in Figure 1.5. Table 1.19 and Table 1.20 illustrate that, for both permanent and seasonal households, the income distribution in the synthetic population is close to that of the observed control data at the county level.

In addition to evaluating the household validation, users should also look at the matches among person attributes. Person-level attributes are one of the distinguishing features of the PopGen tool. Figure 1.6 shows that the person-level attribute distribution of age in the synthesized population is a close match to the controls. Table 1.21 and Table 1.22 split the distributions of age further, by counties. Note that both the distributions and the county-level total of number of persons fit well.

Table 1.23 illustrates that for the GQ population, the age distribution in the synthetic population is representative of the observed marginal numbers in each of the four counties.

Burlington Synthetic Population

Control Data

ESTIMATE THE DEMOGRAPHIC DISTRIBUTIONS

The first step is to identify specific control variables of interest that are relevant to the travel demand forecasting process. The control variables or attributes are identified for each of the two population segments, permanent households and the group quarters population, separately. Because the choice of attributes for Jacksonville was not based on reasons specific to the geographic area, the same attributes were used for Burlington.

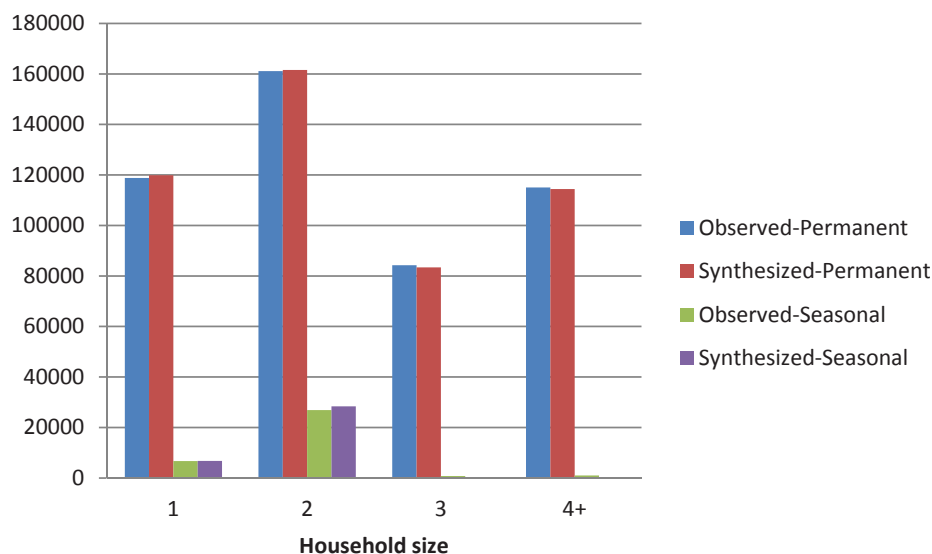


Figure 1.3. Jacksonville regional household size distribution comparison.

Table 1.15. Jacksonville Household Size Distributions for Permanent Households, by County

Household and County		Household Size				
		1	2	3	4+	Total
Observed	Clay	10,489	20,296	12,058	18,508	61,352
	Duval	87,640	107,388	57,993	75,330	328,350
	Nassau	4,900	8,940	3,971	5,720	23,531
	St Johns	15,812	24,489	10,212	15,509	66,022
Synthesized	Clay	10,583	20,394	11,965	18,427	61,369
	Duval	88,402	107,661	57,412	74,877	328,352
	Nassau	4,974	8,992	3,914	5,665	23,545
	St Johns	15,942	24,548	10,103	15,439	66,032

Table 1.16. Jacksonville Household Size Distributions for Seasonal Households, by County

Household and County		Household Size				
		1	2	3	4+	Total
Observed	Clay	583	2,331	66	86	3,066
	Duval	4,840	19,358	550	715	25,463
	Nassau	499	1,996	57	74	2,626
	St Johns	795	3,182	90	118	4,185
Synthesized	Clay	561	2,504	2	0	3,067
	Duval	4,934	20,406	120	23	25,483
	Nassau	493	2,104	21	8	2,626
	St Johns	797	3,370	18	6	4,191

PERMANENT HOUSEHOLDS. The household and person controls and their categories shown in Table 1.1 and Table 1.2 for Jacksonville were also used for PopGen synthesis of the permanent household population in Burlington. The tables also show the specific data sources used to derive distributions for each of the variables. The household-level control attributes include the following:

- Age of the head of household;
- Household size;
- Number of workers;
- Household income; and
- Presence of children.

The person-level control attributes include gender and age.

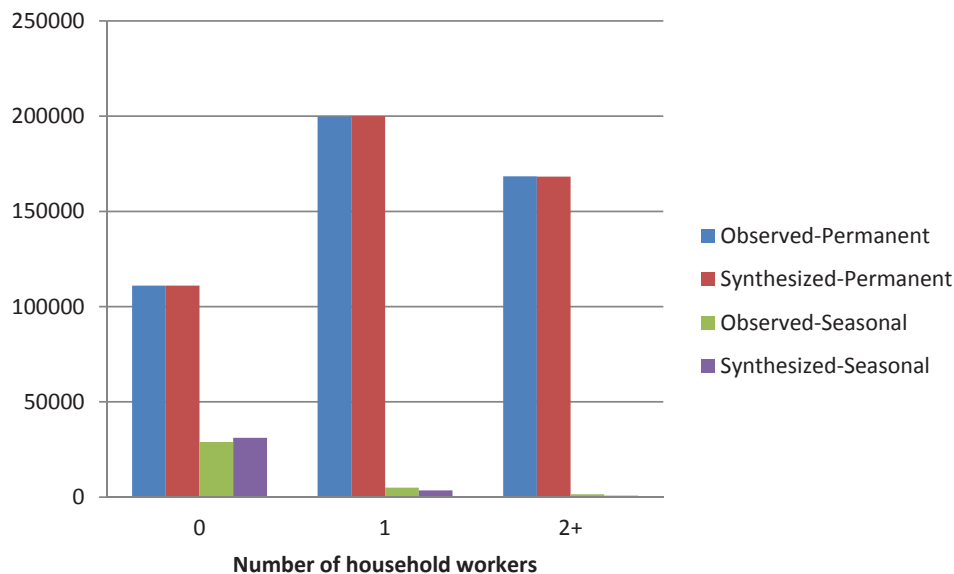


Figure 1.4. Jacksonville regional household workers distribution comparison.

Table 1.17. Jacksonville Household Workers Distributions for Permanent Households, by County

Household and County		Household Workers			
		0	1	2+	Total
Observed	Clay	12,231	24,171	24,949	61,352
	Duval	74,193	141,661	112,496	328,350
	Nassau	6,783	8,053	8,695	23,531
	St Johns	17,824	25,939	22,259	66,022
Synthesized	Clay	12,233	24,154	24,982	61,369
	Duval	74,116	141,841	112,395	328,352
	Nassau	6,810	8,053	8,682	23,545
	St Johns	17,871	25,963	22,198	66,032

Table 1.18. Jacksonville Household Workers Distributions for Seasonal Households, by County

Household and County		Household Workers			
		0	1	2+	Total
Observed	Clay	2,510	430	126	3,066
	Duval	20,843	3,575	1,045	25,463
	Nassau	2,149	369	108	2,626
	St Johns	3,426	588	172	4,185
Synthesized	Clay	2,750	268	49	3,067
	Duval	22,335	2,618	530	25,483
	Nassau	2,315	258	53	2,626
	St Johns	3,703	400	88	4,191

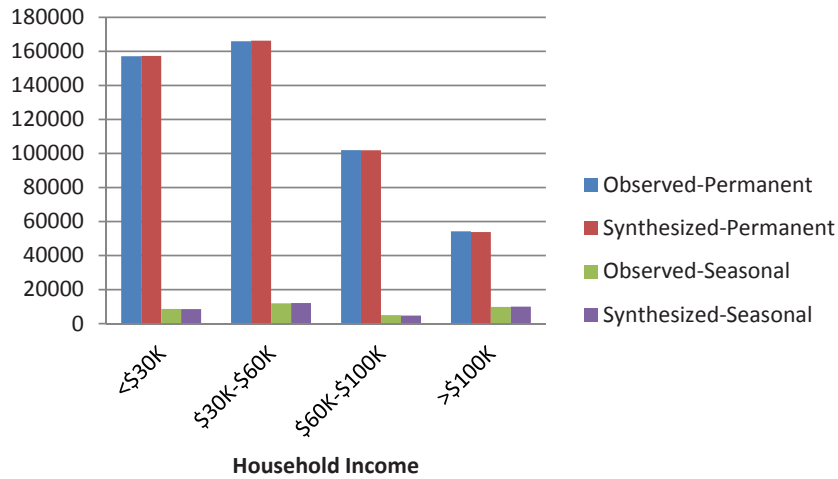


Figure 1.5. Jacksonville regional household income distribution comparison.

Table 1.19. Jacksonville Household Income Distribution for Permanent Households, by County

Household and County		Household Income				Total
		<\$30K	\$30K-\$60K	\$60K-\$100K	>\$100K	
Observed	Clay	16,165	22,164	15,995	7,028	61,352
	Duval	112,892	115,895	66,066	33,497	328,350
	Nassau	7,560	7,917	5,454	2,601	23,531
	St Johns	20,515	19,976	14,448	11,082	66,022
Synthesized	Clay	16,146	22,239	16,005	6,979	61,369
	Duval	113,047	116,117	65,979	33,209	328,352
	Nassau	7,570	7,948	5,460	2,567	23,545
	St Johns	20,556	19,967	14,435	11,074	66,032

Table 1.20. Jacksonville Household Income Distribution for Seasonal Households, by County

Household and County		Household Income				Total
		<\$30K	\$30K-\$60K	\$60K-\$100K	>\$100K	
Observed	Clay	748	1,033	430	854	3,066
	Duval	6,214	8,579	3,575	7,094	25,463
	Nassau	641	885	369	732	2,626
	St Johns	1,021	1,410	588	1,166	4,185
Synthesized	Clay	738	1,061	405	863	3,067
	Duval	6,149	8,718	3,412	7,204	25,483
	Nassau	643	896	353	734	2,626
	St Johns	998	1,450	566	1,177	4,191

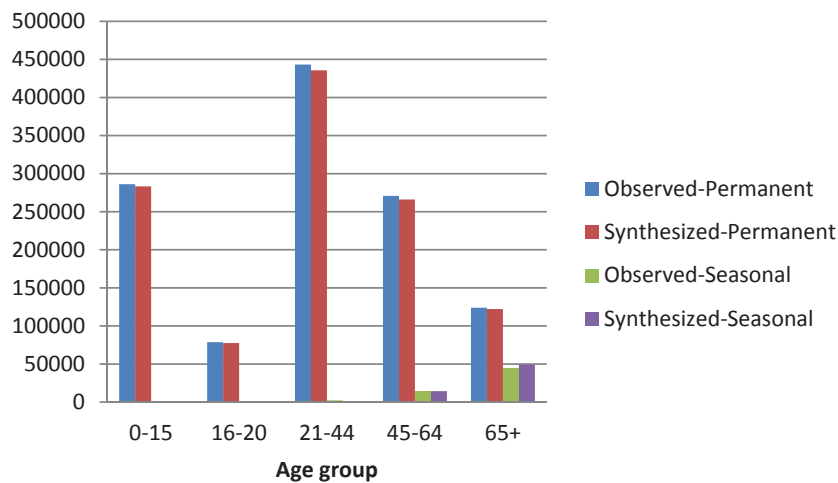


Figure 1.6. Jacksonville regional age distribution comparison.

Table 1.21. Jacksonville Age Distribution Comparison for Permanent Population, by County

Household and County		Age Group (years)					Total
		0-15	16-20	21-44	45-64	65+	
Observed	Clay	43,330	11,951	59,705	39,152	14,317	168,454
	Duval	192,099	53,689	309,132	174,889	80,396	810,204
	Nassau	14,250	3,956	21,236	16,526	7,741	63,709
	St Johns	36,389	9,073	53,278	40,333	21,414	160,487
Synthesized	Clay	42,868	11,733	58,806	38,741	14,179	166,327
	Duval	190,461	52,956	303,452	171,421	79,067	797,357
	Nassau	13,426	3,715	19,795	15,583	7,295	59,814
	St Johns	36,493	9,107	53,681	40,325	21,696	161,302

Table 1.22. Jacksonville Age Distribution Comparison for Seasonal Population, by County

Household and County		Age Group (years)					Total
		0–15	16–20	21–44	45–64	65+	
Observed	Clay	98	58	202	1,267	3,893	5,518
	Duval	817	480	1,682	10,521	32,333	45,833
	Nassau	84	50	173	1,085	3,334	4,726
	St Johns	134	79	276	1,729	5,315	7,534
Synthesized	Clay	0	1	33	1,200	4,341	5,575
	Duval	23	26	447	10,424	35,278	46,198
	Nassau	10	5	59	1,050	3,672	4,796
	St Johns	8	3	71	1,690	5,844	7,616

Distributions for all of the control attributes except those for presence of children were derived from CTPP tables. The distributions for the presence of children attribute was obtained from the Census SF1. Because the CTPP distributions were at the Census TAZ level, they needed to be converted to the Chittenden County Metropolitan Planning Organization (CCMPO) model TAZ level. (Chittenden County encompasses Burlington.) The following steps were used to create a correspondence between the Census and CCMPO model TAZs:

- A CCMPO model parcel centroid file was created from the parcel boundary shape file. This file also contains the CCMPO model TAZ for each parcel.
- The parcel centroid shape file was intersected with the Census TAZ shape file in ArcGIS, and centroids of CCMPO parcels were matched with Census TAZs. This creates a many-to-many correspondence between Census and CCMPO TAZs.
- Using the total number of housing units in all the parcels in a CCMPO TAZ and total number of housing units in all the parcels in a Census TAZ, the project team calculated

the proportion of housing units from a Census TAZ that belong to a particular CCMPO TAZ.

The numbers of households in various categories of control variables were aggregated at the Census TAZ level and distributed to CCMPO TAZs on the basis of the calculated proportions. The data were aggregated again at the CCMPO TAZ level.

SF1 data are at the Census-block group level. A block group–CCMPO TAZ correspondence was similarly created using parcels as the go-between. Parcel centroids were mapped to Census-block groups using ArcGIS, and the block group–level households in each category of the presence-of-children attribute were distributed in the same proportion to the parcel level. Aggregating the data to CCMPO TAZ level at that point resulted in the required distributions.

For population synthesis, all dollars are normalized to represent 1999 dollars as closely as possible; that value was used in the 2000 Census which supplies PUMS and control table data.

NONINSTITUTIONALIZED GROUP QUARTERS. The control categories used for GQ population synthesis in Jacksonville were also used for Burlington (see Table 1.3). As in Jacksonville, the distribution is extremely simple because of limited Census table data for GQ residents. However, the age distribution helps PopGen properly locate two important GQ subpopulations: college students and retirement center residents. No IPF is required, and simple scaling suffices to match this one-dimensional control. However, PopGen was run in a simplified mode to synthesize the GQ population.

ESTIMATE THE NUMBER OF HOUSEHOLDS AND PERSONS IN EACH TAZ

The total number of permanent households for 2005 at the TAZ level was obtained from the CCMPO model data. Because a separate population for seasonal households was not being synthesized, the additional step for estimating the total number of households at the seasonal level was not required.

Table 1.23. Jacksonville Noninstitutional GQ Population Age Distribution

Household and County		Age Group (years)			Total
		18–44	45–64	65+	
Observed	Clay	0	121	638	758
	Duval	233	7,841	646	8,720
	Nassau	0	199	33	233
	St Johns	37	943	122	1,102
Synthesized	Clay	0	120	639	759
	Duval	235	7,847	648	8,730
	Nassau	0	199	33	232
	St Johns	37	945	120	1,102

Permanent population controls were estimated in a straightforward manner. An approximate average of 4.5 persons was assumed for the highest household size category (households with four or more persons). That average along with the number of households in each size category resulted in an estimate of total number of persons by TAZ.

The total number of noninstitutional GQ residents for the base year was estimated using parcel-level data from the CCMPO model. Specific parcels belonging to educational institutions were identified, and number of GQ units on each was aggregated up to the TAZ level.

These demographic distributions were rescaled to match the estimated number of households and persons residing in each TAZ.

REFORMAT CONTROL DATA TO POPGEN SPECIFICATIONS

The process for reformatting the control data in Burlington was similar to that performed in Jacksonville. For permanent residents, two PopGen marginals files were needed, with 49 household controls in one file and 10 personal controls in another, as shown in Table 1.1 and Table 1.2. The layout of the marginal input file required by PopGen is shown in Table 1.4. The file begins with four mandatory fields: state, county, tract, and bg, with bg interpreted as TAZ. After that is a column for each control category, with entries representing the number of households (or persons) within the category for each TAZ. Two header rows (the column name in row 1 and the data type in row 2) are followed by one row of control data items for each TAZ.

For the GQ population, the three controls in Table 1.3 need to be included in a household marginals file, but no person marginals file is required.

All of these steps have been coded in an R-script for Burlington similar to that used for Jacksonville. The inputs required for the R-script are correspondences between Census TAZs, CCMPO TAZs, and DaySim TAZs (DaySim TAZs are renumbered CCMPO TAZs since the DaySim software requires that external zones be listed first), CTPP tables in CSV format, SF1 data with CCMPO TAZ mapped (also in CSV format), CCMPO zonal data (dbf format), and GQ population totals by parcel from CCMPO data.

Sample Data

The sample data represent household samples with detailed demographic attributes and are used to draw individual households to form the synthetic population. The sample data are also used to provide a seed matrix of multidimensional control attributes for the IPF procedure in PopGen. A large and socio-demographically diverse sample from which to draw the synthetic population is desirable. For this reason, as in the case of Jacksonville, PUMS samples from both ACS and Census 2000 were combined to prepare the sample for population synthesis.

Only one PUMA covers the model area: PUMA 100. The PUMS sample for permanent households includes all occupied housing and person records from this PUMA. The sample for noninstitutionalized GQ residents includes only those housing and person records, from this PUMA, that represent the noninstitutionalized GQ population. For 2000 PUMS, these have housing record UNITTYPE=2; and for 2006–2008 ACS, they have housing record TYPE=3.

Table 1.6 lays out the data elements needed for the PopGen input sample files, including the items required by PopGen, the items corresponding to control variable categories, and the items needed by DaySim. The data items are the same for the two population segments developed in Burlington.

Table 1.7 shows the exact format of the input sample file as required by PopGen for both Burlington and Jacksonville. An input sample file contains four mandatory fields (state, pumano, hhid, serialno) followed by population attributes. The serial number and household ID are identical IDs for the sample housing unit, indexed at 1. (As noted in the Jacksonville case, the duplication is a legacy of an earlier version of PopGen. The current version requires only one unique ID, but the code still requires that two fields be present in the input file.)

Population Synthesis

In addition to the control and sample files, PopGen requires a geography correspondence file (shown in Table 1.8). As in the Jacksonville case, this file has one row per TAZ and associates the TAZ with the PUMA (and other larger geographies) to which it belongs. For Burlington, which has only one PUMA, the TAZs are simply mapped to PUMA 100.

Using all these input files, PopGen was run separately for the two population subgroups: permanent and noninstitutionalized GQ. After PopGen was run, output population files were exported. The data elements needed for the PopGen synthetic population output files are identical in both Burlington and Jacksonville and are shown in Table 1.9.

Synthetic Population DaySim Integration

As described in the Jacksonville population synthesis section, DaySim requires a synthetic population in the form of persons records, with the household information attached to each person record. Also, DaySim operates at the parcel level; thus, the population synthesized at the TAZ level by PopGen has to be allocated to individual parcels within a particular TAZ. For this purpose, a utility was created in Delphi to randomly allocate households within a TAZ to individual parcel units. It then outputs a combined synthetic population file (dbf) in a format required by DaySim. The primary inputs to this utility are four PopGen output files (household and person files for two population groups), a TAZ controls file, and DaySim's regular parcel data input file. Because the utility was created

Table 1.24. Burlington Synthetic Population Validation Summary

Population Group	HH Obs.	HH Syn.	HH Diff.	Per Obs.	Per Syn.	Per Diff.
Permanent	59,975	59,975	0.00%	150,263	147,909	-1.57%
Group quarters	5,474	5,477	0.05%	5,474	5,477	0.05%
Total	65,449	65,452	0.00%	155,737	153,386	-1.51%

Note: HH = households; Obs. = observed; Syn. = synthesized; Diff. = difference; Per = persons.

for Jacksonville, which has three population segments, the TAZ controls file is an input of permanent households, seasonal households, and noninstitutionalized GQ residents living in each TAZ. The file format is shown in Table 1.10. The project team was able to use the utility in Burlington by specifying the number of seasonal households in all TAZs as zero.

Table 1.11 and Table 1.12 show the formats of PopGen population household and person files, respectively, that are needed by the DaySim utility. A pair of PopGen population household and person files is required for each of the two population segments in Burlington.

The utility also creates three additional data items (shown in Table 1.13) required by DaySim during microsimulation. It creates binary variables for each person, indicating whether or not that individual is a worker and/or a student. It then assigns the household to a specific parcel within the TAZ to which PopGen assigned the synthetic household. Permanent households in a TAZ are allocated to parcels on the basis of the availability of dwelling units. GQ residents are allocated to parcels containing GQ dwelling units, which are identified in the parcel data input file separately from dwelling units for permanent households.

Synthetic Population Validation

The Burlington synthetic population generated using PopGen was validated across the different control dimensions (both household and person) to ensure that the population matched

the control variable distributions. The validation was done separately for the two synthesized population groups. Table 1.24 summarizes the differences in the total number of households and persons in the synthetic populations and observed controls. Overall, the synthetic population has about 1.5% fewer persons than the observed data.

Figure 1.7 shows a comparison of the household size distributions from the control data and synthetic population to illustrate the degree of match achieved. Because the model region has only one county (Chittenden County), the match can be interpreted as occurring at the county level. Because the population was synthesized at the TAZ level, the county level match is close, as expected.

Similarly, Figure 1.8 and Figure 1.9 show comparisons of distributions for number of household workers and household income between observed and synthetic permanent populations. At the household level, the synthetic population attributes seem to match the observed distributions closely.

In addition to evaluating the match among household attributes, comparing the distributions of person attributes in the synthetic populations and observed data is also important. Figure 1.10 shows that the distribution of person age in the synthetic population matches well with that observed from Census data.

Finally, Figure 1.11 makes clear that the distribution of age of the GQ population is almost the same as that in the observed data.

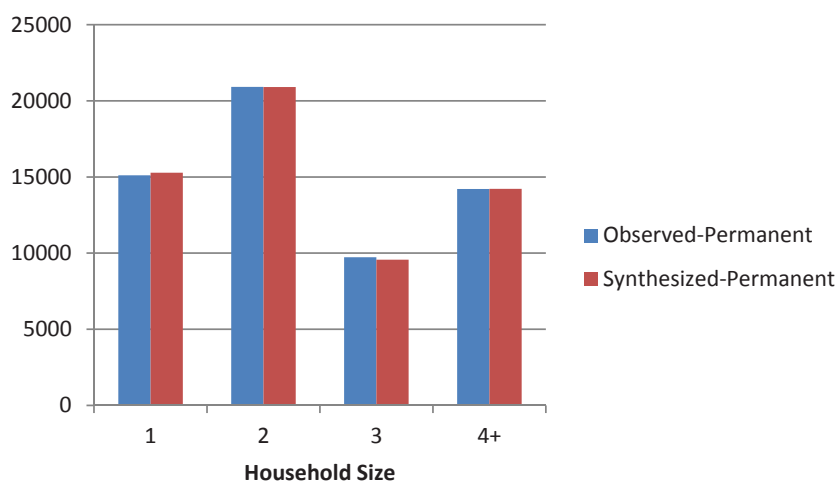


Figure 1.7. Burlington household size distribution comparison.

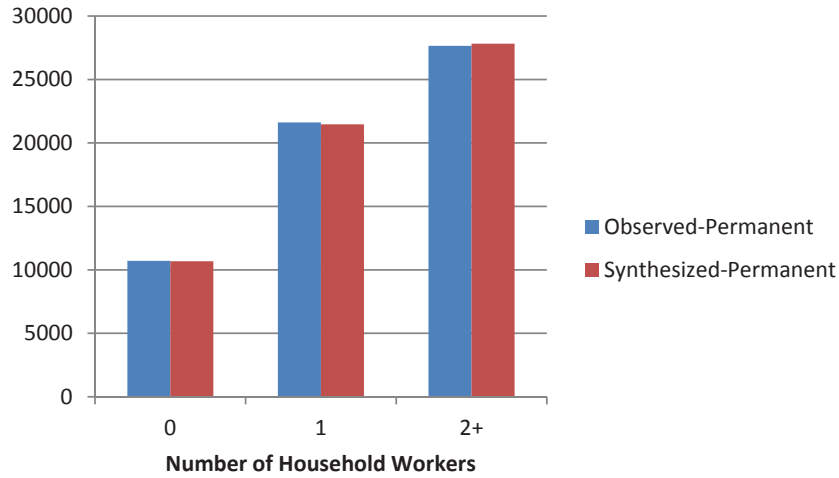


Figure 1.8. Burlington household workers distribution comparison.

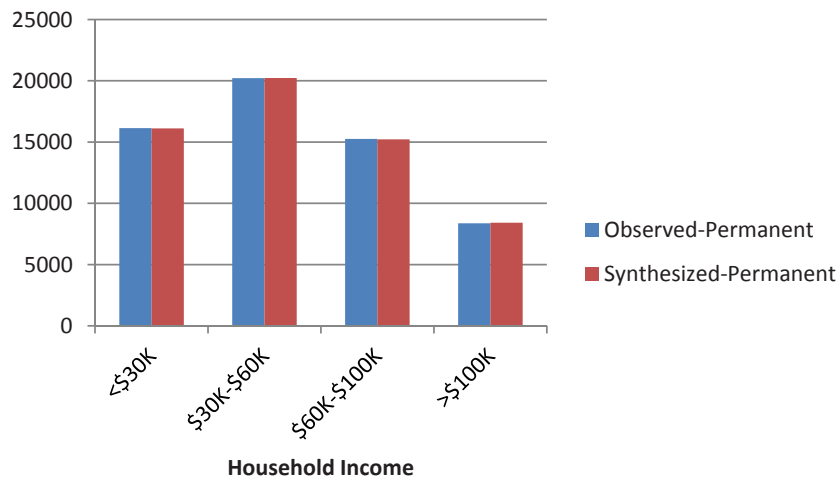


Figure 1.9. Burlington household income distribution comparison.

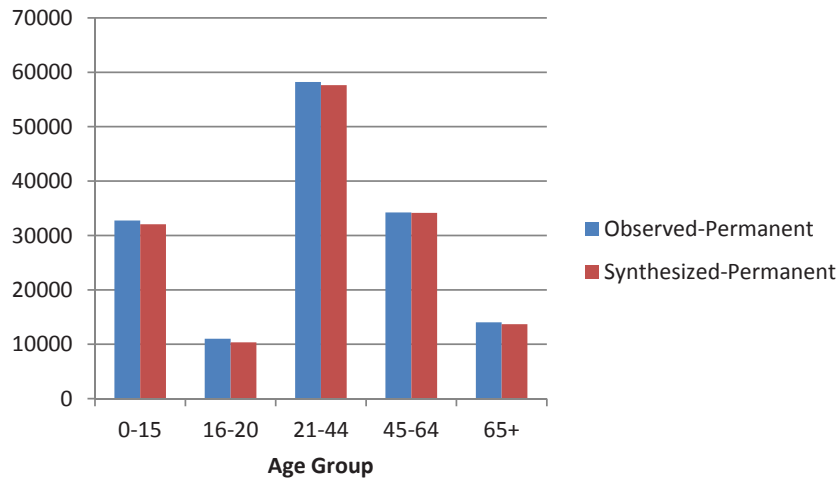


Figure 1.10. Burlington person age distribution comparison.

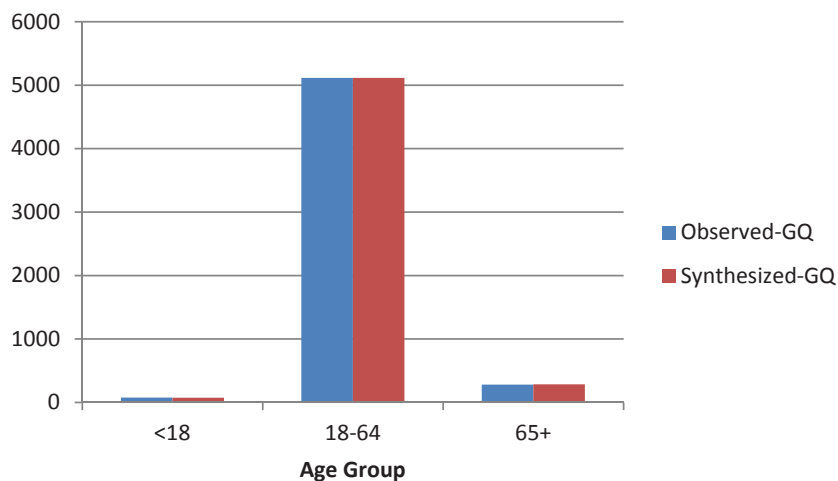


Figure 1.11. Burlington GQ population age distribution comparison.

DaySim Parcel Data

A distinguishing feature of DaySim is that it uses parcels as one of the fundamental spatial units. The parcel data input file contains input data at the parcel level of detail, the more detailed of the two spatial levels at which DaySim input data are prepared. The less detailed spatial level uses TAZs; the TAZ input file is described in the section on DaySim TAZ data. Figure 1.12 shows the relationship between TAZs (TAZ boundaries are shown in red) and parcels. The parcel polygons, which show the physical extent of the parcel, are shown in gray with the parcel boundaries shown as thin white lines. The area of the parcel is

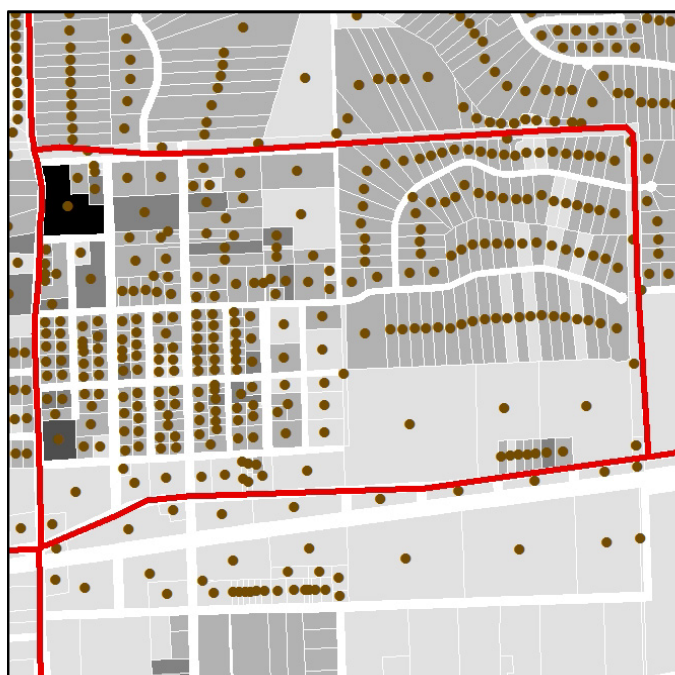


Figure 1.12. TAZ boundaries, parcel polygons, and parcel centroids.

included in the parcel data input file in units of square feet in the AREA_SQF field. In this figure, darker gray colors indicate increasing numbers of housing units in the parcel; housing units numbers are recorded in the HOUSESP variable in the parcel data input file. The parcel centroids are shown as brown dots. The locations of the parcel centroids are described in the parcel file in the X_COORD and Y_COORD fields. Omitted from the parcel file (and shown as thick white lines) are highway and other rights of way. Parcels clearly allow a far more detailed, spatially disaggregate description of the land use in a region than do TAZ-based models; but, consequently, it necessitates the development and management of larger quantities of data.

The parcel data input file is a dBase IV format file (.dbf) with one row of data per parcel. Table 1.25 shows the fields contained in the parcel data input file. The file begins with several fields that identify the parcel and describe the physical location and size of the parcel; the file also contains fields that describe the quantity of housing, school enrollment, and employment on the parcel and within a quarter-mile and a half-mile of the parcel. In addition, the parcel file contains information about urban form and the transportation system on and close to the parcel, including the proximity to transit stops and the price and supply of parking. The data sources and the development process for these fields are discussed in the following sections.

Parcel Files

Housing Units—Jacksonville

Parcel-level information on housing units is used to allocate the synthetic population to individual parcels and to influence destination choices. The data are available in the model area from parcel-level databases maintained in each county for tax assessment purposes. This section provides an overview of the steps required to take four separate parcel databases, combine them to create a consistent regional database,

Table 1.25. Parcel Data Input File Format

Label ^a	Definition	Label ^a	Definition
PARCELID	Parcel ID number	PPRICHRH	Avg. price hourly parking – half mile (cents)
X_COORD	X coordinate – state plane feet	EMPEDU_P	Education jobs – parcel (× 100)
Y_COORD	Y coordinate – state plane feet	EMPFOODP	Food service jobs – parcel (× 100)
AREA_SQF	Area – square feet	EMPGOV_P	Government jobs – parcel (× 100)
TAZ	TAZ number	EMPOFC_P	Office jobs – parcel (× 100)
HOUSESP	Housing units – parcel (× 100)	EMPOTH_P	Other jobs – parcel (× 100)
HOUSESQ	Housing units – quarter-mile radius (× 100)	EMPRET_P	Retail jobs – parcel (× 100)
HOUSESH	Housing units – half-mile radius (× 100)	EMPSVC_P	Service jobs – parcel (× 100)
STUDK12P	Students K–12 – parcel (× 100)	EMPMED_P	Medical jobs – parcel (× 100)
STUDK12Q	Students K–12 – quarter-mile radius (× 100)	EMPIND_P	Industrial jobs – parcel (× 100)
STUDK12H	Students K–12 – half-mile radius (× 100)	EMPTOT_P	Total jobs – parcel (× 100)
STUDUNIP	Students University – parcel (× 100)	EMPEDU_Q	Education jobs – quarter-mile radius (× 100)
STUDUNIQ	Students University – quarter-mile radius (× 100)	EMPFOODQ	Food service jobs – quarter-mile radius (× 100)
STUDUNIH	Students University – half-mile radius (× 100)	EMPGOV_Q	Government jobs – quarter-mile radius (× 100)
NODES1Q	1 link nodes – quarter-mile radius	EMPOFC_Q	Office jobs – quarter-mile radius (× 100)
NODES1H	1 link nodes – half-mile radius	EMPOTH_Q	Other jobs – quarter-mile radius (× 100)
NODES3Q	3 link nodes – quarter-mile radius	EMPRET_Q	Retail jobs – quarter-mile radius (× 100)
NODES3H	3 link nodes – half-mile radius	EMPSVC_Q	Service jobs – quarter-mile radius (× 100)
NODES4Q	4+ link nodes – quarter-mile radius	EMPMED_Q	Medical jobs – quarter-mile radius (× 100)
NODES4H	4+ link nodes – half-mile radius	EMPIND_Q	Industrial jobs – quarter-mile radius (× 100)
DIST_LRT	Distance to nearest LRT stop (miles × 100, –1 if none)	EMPTOT_Q	Total jobs – quarter-mile radius (× 100)
DIST_BUS	Distance to nearest bus stop (miles × 100, –1 if none)	EMPEDU_H	Education jobs – half-mile radius (× 100)
PARKDY_P	Daily paid parking spaces – parcel	EMPFOODH	Food service jobs – half-mile radius (× 100)
PARKDY_Q	Daily paid parking spaces – quarter-mile radius	EMPGOV_H	Government jobs – half-mile radius (× 100)
PARKDY_H	Daily paid parking spaces – half-mile radius	EMPOFC_H	Office jobs – half-mile radius (× 100)
PPRICDYP	Avg. price daily parking – parcel (cents)	EMPOTH_H	Other jobs – half-mile radius (× 100)
PPRICDYQ	Avg. price daily parking – quarter mile (cents)	EMPRET_H	Retail jobs – half-mile radius (× 100)
PPRICDYH	Avg. price daily parking – half mile (cents)	EMPSVC_H	Service jobs – half-mile radius (× 100)
PARKHR_P	Hourly paid parking spaces – parcel	EMPMED_H	Medical jobs – half-mile radius (× 100)
PARKHR_Q	Hourly paid parking spaces – quarter-mile radius	EMPIND_H	Industrial jobs – half-mile radius (× 100)
PARKHR_H	Hourly paid parking spaces – half-mile radius	EMPTOT_H	Total jobs – half-mile radius (× 100)
PPRICHRP	Avg. price hourly parking – parcel (cents)	USED	(unused)
PPRICHRQ	Avg. price hourly parking – quarter mile (cents)	COUNTY	County (used only for usual work validation)
		GQUnitsP	Noninstitutionalized group quarters units – parcel (× 100) (used only with PopGen population)

^a DaySim can read these variables in any order, but the variable names must remain the same as shown. All values from the file are read as integers, with no decimal.

impute housing units for land-use types such as condominium and multifamily housing developments (because housing unit numbers were not necessarily present in the parcel database), and verify that the resulting housing unit numbers were reasonable.

The county-level databases were each structured differently and contained different data items. The following steps were applied to each database before they were combined:

- Identify and remove non-travel-generating parcels such as highway rights of way, bodies of water, or other extraneous parcels. This step did not remove currently undeveloped land that could be developed in the future.
- Merge into a single parcel any parcels that are the same parcel but are spread across separate GIS shapes with multiple database rows. This step involved summing some fields, such as land areas, if they were divided across multiple polygons.
- Develop a set of common fields across the four databases such as land-use type, effective year, land area, building area, and number of buildings.

Ultimately, a combined database of 618,981 parcels was developed. The parcel database does not specify the number of housing units on a parcel; that number must be imputed based on the data included in the database. The following steps were taken to impute the number of housing units:

- The databases varied depending on when they were last updated. Buildings with an effective year (the year the structure was built) after 2005 (the model base year) were not included in the analysis.
- Parcels with a single-family or mobile-home land-use type were assumed to contain one unit.
- Parcels with a condominium land-use type typically contain one unit. Generally, the parcel database shows large condominium buildings or developments as a grid of small

parcels, with each parcel representing a single unit. Some exceptions to this rule were identified on the basis of a scan of land area, building area, and numbers of buildings. In those cases, the parcels were treated in a way similar to other types of multifamily housing parcels.

- Multifamily housing presented the largest challenge when imputing a number of housing units.
 - The available data were identified as a development of either fewer than 10 units or 10 or more units, and typically a number of buildings and a total building area.
 - An initial imputation was made to assign one unit for every 1,000 square feet of floor area in each building and to assign an extra unit to any remainder in excess of 500 square feet.
 - All parcels in the fewer-than-10-units category were then constrained to a minimum number of units of 2 and a maximum of 9; those in the 10-or-more-units category were constrained to a minimum number of units of 10.
 - At this point, outliers were identified by considering the largest developments in terms of imputed units. This step identified issues such as large developments that were split across parcels but for which the total building area for the whole development was assigned to each parcel. Following manual identification and corrections, the housing unit numbers were recalculated.
 - The number of multifamily units was then compared at a county level with data from the NERPM model to check for aggregate consistency. The 1,000 ft² of floor area per unit was increased to 1,275 ft² to match the regional multifamily unit total contained in the NERPM model for 2005.

Table 1.26 shows a summary of the housing unit numbers developed using the parcel databases, by unit type and by county. The numbers compare reasonably closely to the county level totals by unit type used in the NERPM model shown in Table 1.27.

Table 1.26. Summary of Housing Unit Numbers, by Type and County (DaySim parcel file)

Description	Clay	Duval	Nassau	St Johns	Grand Total
SINGLE FAMILY	50,990	236,138	19,170	50,340	356,638
MOBILE HOMES	10,183	11,768	5,941	5,594	33,486
CONDOMINIA	11	18,576	2,493	3	21,083
MULTI-FAMILY (≥10)	6,632	97,143	742	8,490	113,007
MULTI-FAMILY (<10)	851	11,031	1,076	12,676	25,634
Total Single Family	61,173	247,906	25,111	55,934	390,124
Total Multi Family	7,494	126,750	4,311	21,169	159,724
Total Units	68,667	374,656	29,422	77,103	549,848

Table 1.27. Summary of Housing Unit Numbers, by Type and County (NERPM model, 2005)

Unit Type	County				Grand Total
	Clay	Duval	Nassau	St Johns	
Single Family Units	57,477	251,373	26,190	54,588	389,628
Multi Family Units	9,662	124,499	6,348	19,568	160,077
Total	67,139	375,872	32,538	74,156	549,705

Parcel-level calculations of proximity to total housing units within quarter-mile and half-mile buffers are also important urban form measures used in DaySim. They are calculated using a script, as described in the section on parcel-level buffers.

Housing Units—Burlington

In the Burlington region, most of the parcel-level data on housing, enrollment, and employment were obtained from the CCMPO regional travel demand model. The parcel data geodatabase (year_built_to_share.mdb) contained the table *Parcels_yrbuilt*; the fields in the table included parcel ID, location data, town, and area. The table was processed to remove non-travel-generating parcels such as highway rights of way, bodies of water, or other extraneous parcels. This resulted in polygon data for 50,052 parcels, covering the CCMPO model area.

The data on Burlington housing units were obtained from the CCMPO regional travel demand model. The data for the model were originally collected by the Chittenden County Regional Planning Commission (CCRPC) based on the 2005 municipal Grand List. These data had been compared with data from other sources—such as existing parcel data, 2000 Census data, and building permits—to ensure their accuracy. The data were in the form of a point shape file (e.g., 20080612_rpc_2005_housing_points.shp) which contained points for 42,142 residential locations covering the CCMPO model area. The data fields included parcel ID, town, address, dwelling unit type (e.g., single-family, multifamily, GQ), dwelling unit count, and TAZ. Total dwelling units, including GQ, came to 65,449.

Some data cleaning was done, such as removing non-travel-generating parcels which include highway rights of way, bodies of water, and other extraneous parcels. Table 1.28 summarizes the housing unit numbers developed using the parcel databases, by unit type for Chittenden County.

Employment by Type—Jacksonville

Parcel-level information on the total number of jobs by employment type on each individual parcel is one of the most essential model inputs. In DaySim, the number of workers attracted to each employment site is calibrated to the number

of jobs at that site. Detailed information on employment by type was acquired for the Jacksonville area. The employment data for Clay, Duval, and Nassau counties—prepared by FDOT, NFTPPO, and the consulting firm PBS&J—were obtained from PBS&J. PBS&J provided a GIS file of employment location points with records for individual businesses, including number of employees and six-digit standard industrial classification (SIC) codes. The firm had made extensive efforts to clean and verify the raw employment database, so it required minimal additional cleaning for use in this model.

The employment data for St. Johns County were obtained in the form of an InfoUSA database that had not been cleaned or processed in any way. (InfoUSA is a commercial data provider.) These data were similar in format to the data for the other three counties with records for individual businesses, including number of employees and SIC codes. Before processing these data into the format required for the parcel data input file, the data were checked to ensure quality. These checks included reviewing the largest individual points to verify numbers of employees: a common problem is that large employers with many locations in a region allocate all jobs to the home office rather than distribute them across the firm's locations.

Once the employment point databases were obtained and deemed satisfactory, they were processed using the following steps:

1. *Association of DaySim employment types with each business.* DaySim models employment using nine employment types. Table 1.29 shows the correspondence between the aggregated employment categories and the more detailed SIC

Table 1.28. Summary of Chittenden County Housing Unit Numbers, by Type

Description	Chittenden County
SINGLE FAMILY	36,342
MULTI-FAMILY(2-4)	11,510
MULTI-FAMILY(5+)	12,123
GROUP QUARTERS	5,474
Total Units	65,449

Table 1.29. DaySim Employment Sectors and Correspondence with SIC Categories

ID	DaySim Employment Sector	SIC Major Categories/ Generalized 2-Digit Categories	SIC 2-Digit Codes
1	Education	Educational Services	82
2	Food service	Eating and Drinking Places	58
3	Government	Public Administration	91–97
4	Office	Finance and Real Estate, Services (some major categories)	60–67, 73, 81, 86, 87
5	Other	Private Households, Nonclassifiable Establishments	88, 99
6	Retail	Retail Trade	52–59
7	Service	Transportation, Services (some major categories)	40–49, 70, 72, 75, 76, 78, 79, 83, 84, 89
8	Medical	Health Services	80
9	Industrial	Agriculture, Mining, Construction, Manufacturing, Wholesale Trade	01–39, 50, 51

classification. A two-digit SIC code was derived from the six-digit SIC codes in the employment databases (i.e., the first two digits of the six-digit SIC code). Then the correspondence was used to associate the DaySim employment types with each employment location.

2. *Association of employments point with parcels.* The employment points were associated with parcels using GIS to intersect the employment point file and the parcel polygon file. During this process, several checks were carried out to ensure the reasonableness of the association. These included the following:

- Checking that all employment had been assigned to a parcel: Given that the parcel polygon file excludes rights of way and many employment points are geocoded close to the adjacent street, points can fall outside of any parcel. These points were associated with the closest parcel to move them outside of the right of way and into a parcel.
- Checking the land use of the parcels with which employment was associated: The parcel polygon file includes data on the land-use type. Employment associated with residential parcels and vacant parcels was checked. In some cases, residences are legitimate business locations, particularly for individual businesses (i.e., those with one employee who works from home). Association with vacant parcels can indicate poor geocoding (in which case points can be manually repositioned to the appropriate parcel) or inconsistency between the employment data and the parcel database (for example, recently

opened businesses that supersede the latest year built information in the parcel database).

- Aggregation of employment at the parcel level.* DaySim requires that employment data be aggregated from individual points within a parcel to totals for each of the nine employment types on a parcel. Parcels with large numbers of employees were spot checked to ensure that a reasonable number of jobs were assigned to individual parcels.
- Adjustments to employment in military base parcels.* The employment at two military bases was adjusted to reflect data obtained on the number of jobs. For the Naval Air Station Jacksonville, the number of jobs on the parcel was increased by 25,552 to reflect active duty and civilian personnel not accounted for in the employment data, and 10,565 jobs were added to the Naval Station Mayport parcel. Together a total of 36,117 jobs were added.

Table 1.30 summarizes the processed employment data, by county and by employment type. Duval County accounts for the majority of the employment in the region, in excess of 80%, with fewer than 50,000 jobs in the each of the other three counties. The distributions of jobs by employment type are similar in each of the four counties.

Table 1.31 shows a comparison of county-level employment totals used by the NERPM model for the 2005 model year with those derived from employment databases for use in DaySim. The data received from PBS&J and used in DaySim are relatively similar to the NERPM model data for Clay and Nassau counties. Duval County has 56,000 (12%) more jobs according to the updated PBS&J data, including 36,000 additional jobs at the military bases. For St. Johns County, the InfoUSA database contains only 34,000 jobs, significantly fewer than the 53,000 in the NERPM model data. To address this discrepancy, St. Johns

Table 1.30. Cross Tabulation of Employment, by Type and County, from DaySim Parcel File

Employment Type	County				
	Clay	Duval	Nassau	St Johns	Total
Education	3,981	25,632	1,499	2,805	33,917
Food service	5,519	32,233	2,192	4,005	43,949
Government	3,227	65,212	1,980	1,429	71,848
Office	5,210	96,596	2,175	5,118	109,099
Other	95	1,178	9	133	1,415
Retail	10,572	64,647	3,397	5,049	83,665
Service	6,790	78,601	4,614	6,264	96,269
Medical	5,224	57,383	1,681	3,664	67,952
Industrial	6,748	92,779	2,666	5,345	107,538
Total	47,366	514,261	20,213	33,812	615,652

Table 1.31. Total Employment Comparison, by County and Model Type

County	NERPM	DaySim
Clay	41,513	47,366
Duval	458,166	514,261
Nassau	20,579	20,213
St Johns	53,359	33,812
Total	573,617	615,652

County employment was subsequently scaled up to match aggregate NERPM-based totals.

As with housing units, parcel-level calculations of proximity to total employment by sector, within quarter-mile and half-mile buffers, are used in DaySim and calculated using a script, as described in the section on parcel-level buffers.

Employment by Type—Burlington

The parcel-level employment data for Chittenden County were derived from the CCMPO model inputs. The CCMPO originally collected employment land-use data from two distinct sources: InfoUSA and the Vermont Department of Employment and Training (VT DET). Because the VT DET has a privacy agreement and use restrictions, the CCMPO chose to use the InfoUSA data and supplemented gaps in the InfoUSA data using the VT DET data. InfoUSA data contain information such as the name of the employer, the address of the employer, the general number of employees, and the employer's SIC code.

The CCMPO had geocoded the employers according to address. As in the case of housing unit data, the parcel employment data were received in the form of a point shape file. The CCMPO model area encompasses points for 7,478 employment locations. The employment data include schools, with grades and enrollment ranges (for most schools). Two fields in the data contain employment numbers. One of the fields that was supposed to contain the number of jobs—ACTUAL_EMP—was found to have double counted the number of jobs at some major employers (such as IBM) that were based at more than one site. Therefore, a second field—MPO_EMP—was included to resolve these issues; this second field was used to derive the number of jobs at each employment location. The total number of jobs in the region is 102,260. Each employment location was associated with a DaySim employment type on the basis of the correspondence with SIC codes shown in Table 1.29.

In the next step, each employment location was assigned to a parcel by intersecting with the parcel polygon file in GIS. Employment locations that fell outside all parcels were assigned to the nearest parcel. Finally, the number of jobs by employment type were aggregated to the parcel level and appended to the DaySim parcel input data file. Table 1.32

Table 1.32. Number of Jobs in Chittenden County, by Employment Type

Employment Type	Number of Jobs
Education	9,679
Food service	5,967
Government	4,486
Office	16,123
Other	263
Retail	13,779
Service	19,539
Medical	6,686
Industrial	25,738
Total	102,260

summarizes the processed employment data, by employment type, for Chittenden County.

As with housing units, parcel-level calculations of proximity to total employment by sector, within quarter-mile and half-mile buffers, are used in DaySim and calculated using a GIS script.

School Enrollment—Jacksonville

Like workers, the number of students that are attracted to each school location is calibrated to the enrollment by grade level at that school location. As a result, parcel-level information on school enrollment is necessary. DaySim distinguishes school enrollment into enrollment in grades K–12 and then college or university enrollment.

In the Jacksonville region, the Florida Department of Education (FDOE) provides school-level information on enrollment by grade for schools enrolling K–12 students. The schools were then geocoded on the basis of their addresses to obtain enrollment information at the parcel level. Overall, enrollment information was identified for 223 private and 287 public schools. Figure 1.13 shows the distribution of enrollment for both public and private schools. As expected, enrollment in public schools is skewed more toward the higher ranges than in the private schools.

Universities, community colleges, and technical schools are identified in the employment database. The project team identified enrollment for some of these institutions by visiting the institution's website; data on the state university system was obtained from the Florida Board of Governors and on the community college systems from FDOE. In the remainder of cases, enrollment was estimated on the basis of the number of employees at the institution. An average ratio of student enrollment to number of employees was calculated for this purpose, which equals 12.43. Table 1.33 shows the

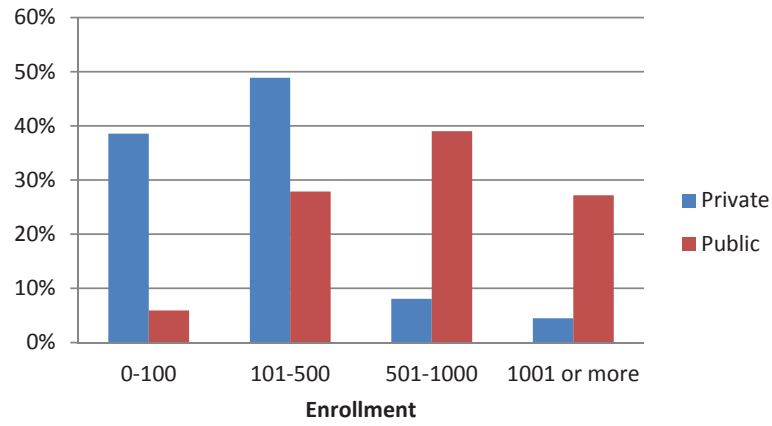


Figure 1.13. K-12 enrollment distribution.

Table 1.33. University-Level Enrollment and Employment

County	School	Employment	Enrollment	Imputed
Duval	Edward Waters College	20	839	
Duval	FCCJ College Administration	20	189	X
Duval	FCCJ Culinary Institute	28	264	X
Duval	Florida Community College	1,970	18,598	X
Nassau	Florida Community College	60	566	X
Duval	Florida Coastal School of Law	95	1,539	
Duval	Florida Metropolitan University	80	994	X
Duval	Florida Technical College	15	186	X
Duval	ITT Technical Institute	45	559	X
Duval	Jacksonville University Campus	20	3,400	
Duval	Jones College	160	650	X
Duval	Logos University	10	124	X
Duval	Remington College	40	497	X
Duval	St Thomas Christian College	20	249	X
Duval	Troy University	20	249	X
Duval	University of Florida College	20	249	X
Duval	University of North Florida	1,233	15,420	
Duval	University of Phoenix Inc	25	311	X
Duval	Webster University	10	124	X
Duval	Conservative Theological Seminary	14	174	X
St Johns	University of St Augustine	30	373	X
St Johns	First Coast Technical Institute	165	734	
St Johns	Flagler College	250	2,716	
St Johns	Flagler's Legacy	12	149	X
St Johns	St Johns River Community College	40	1,091	
Clay	Florida Metropolitan University	10	124	X
Clay	St Johns River Community College	70	941	

Table 1.34. Type of Enrollment, by County

Enrollment Type	County				
	Clay	Duval	Nassau	St Johns	Total
K–12	43,251	195,662	12,188	20,417	271,518
University	1,115	45,349	567	4,764	51,795
Total	44,366	241,011	12,755	25,181	323,313

enrollment and employment information for all of the universities and colleges, with an indication of whether the enrollment was imputed. For brevity, only those institutions with 10 or more employees are shown in this table. The information from the Jacksonville University campus was not used in the calculation of the average enrollment to employment ratio because of the unusually high value (170).

Table 1.34 summarizes the final enrollment numbers by type of school and county.

Table 1.35 compares derived enrollment with that from the NERPM model at a county level. The enrollment input into DaySim matches reasonably closely with that used in the NERPM model.

As with housing units and employment, parcel-level calculations of proximity to school enrollment by sector, within quarter-mile and half-mile buffers, are used in DaySim. They are calculated using a script as described in the section on parcel-level buffers.

School Enrollment—Burlington

As in Jacksonville, DaySim uses two grade levels: K–12 and college or university. For the K–12 grade level, the enrollment numbers were derived using the employment data from CCMPO as described in the following steps:

- All employment locations falling in the primary category of *schools* (about 100) were considered separately.
- Some of these were found to be invalid locations, such as school district administrative offices, dance or martial arts classes, and were filtered out.

Table 1.35. Total Enrollment Comparison, by County and Model Type

County	NERPM	DaySim
Clay	39,582	44,366
Duval	227,964	241,011
Nassau	13,740	12,755
St Johns	32,712	25,181
Total	313,998	323,313

Table 1.36. University Student Enrollment in Chittenden County

College/University	Enrollment
St Michael's College	2,700
Champlain College	2,000
Burlington College	200
University of Vermont	11,704
Vermont Hitec Inc	240

- Each employment location had the number of jobs and a range of student enrollment associated with it. The midpoint of the range of student enrollment at a particular location was used as the estimate of enrollment.
- Using the total estimated enrollment and the total number of jobs at all school locations, an average value of students per (school) employee was computed, which equals 6.0.
- This overall average students-per-employee ratio was then used to estimate the final K–12 student enrollment for each school location.

The total number of students in all the parcels in the region was calculated as 23,706. This value was quite close to the value of 22,403 found in Vermont Public School Enrollment Report for 2008–09.

For university-level enrollment, the numbers were directly obtained from websites of the respective colleges and universities since Chittenden County has only a few of them. Table 1.36 shows the colleges included in the parcel-level college-grade enrollment.

As with housing units and employment, parcel-level calculations of proximity to school enrollment by sector within quarter-mile and half-mile buffers are calculated using a separate script.

Parcel-Level Buffers of Housing Units, Employment, and School Enrollment

Parcel-level calculations of proximity to total housing units, employment by employment type, and school enrollment by school type within quarter-mile and half-mile buffers are important urban form measures used in DaySim, and are calculated using a GIS script. Figure 1.14 shows an example of the buffers around a parcel centroid. The figure shows the parcel centroids of adjacent parcels in brown. All the centroids that fall within a buffer are counted when the various buffer variables are summed.

Figure 1.15 through Figure 1.18 show maps of housing, employment, and school (K–12) enrollment per parcel and within quarter-mile and half-mile buffers. Figure 1.15 and Figure 1.16 compare urban and suburban housing variables.

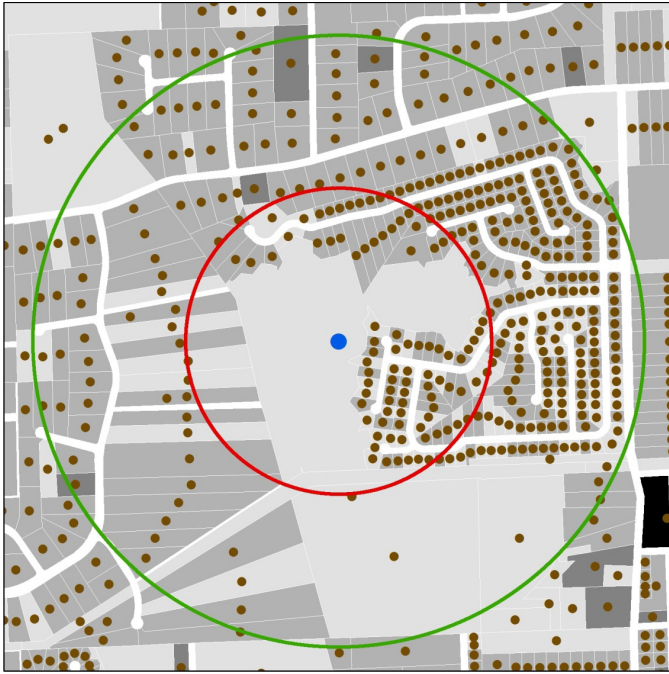


Figure 1.14. Example of quarter-mile and half-mile buffer areas around a parcel centroid.



Figure 1.16. Housing units per parcel and quarter-mile and half-mile housing unit buffers, suburban area.

Transportation Access

In addition to using zone-level information on access times to transit, DaySim also incorporates detailed parcel-level information on the distance to transit, by transit submode. In the case of Jacksonville, two transit modes are included: bus and the JTA Skyway. The Jacksonville Transportation Authority provided GIS data on transit stop locations, and a GIS-based script has been developed to calculate distances to the closest transit stop for every parcel in the region (see Figure 1.19).

Urban Form

A unique parcel-level measure of urban form that DaySim incorporates is the number of intersections or nodes of different types within quarter-mile and half-mile buffers. These intersection types include dead-ends (1 link), T-intersections (3-links), and traditional intersections (4+ links) and help characterize the pattern of urban development. An automated process has been developed to calculate these urban form measures for Jacksonville on the basis of detailed GIS street centerline files. In Burlington, an

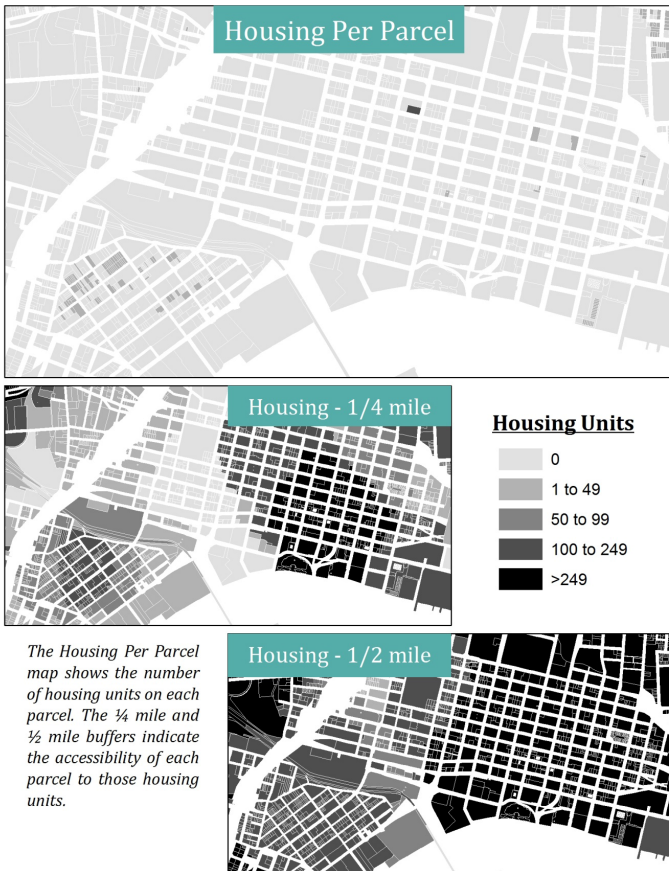


Figure 1.15. Housing units per parcel and quarter-mile and half-mile housing unit buffers, urban area.



Figure 1.17. Total employment per parcel and quarter-mile and half-mile total employment buffers, urban area.

updated Tiger Lines road map for Vermont was downloaded and used for this purpose. Both of these networks are more detailed than the modeled network, which does not include all streets.

The GIS process first analyzes the GIS street centerline file to locate nodes and assign an intersection-type code based on

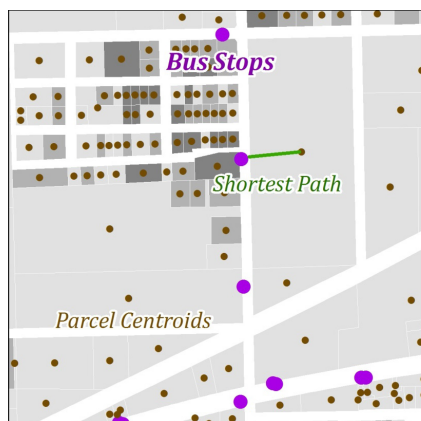


Figure 1.19. Example of closest bus stops to parcel centroids.

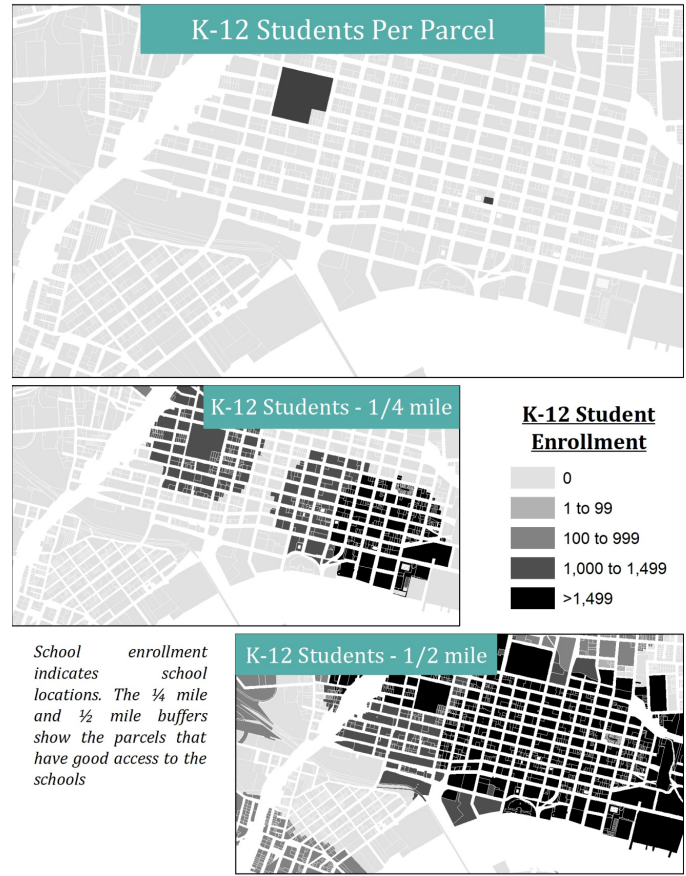


Figure 1.18. K-12 student enrollment per parcel and quarter-mile and half-mile K-12 student enrollment buffers, urban area.

the number of links joined to the node. The process then creates buffer areas around each parcel and counts the number of intersections of each type that fall within the buffers (see Figure 1.20).

Parking

DaySim uses information on the number and prices of both daily and hourly parking spaces on the parcel and within quarter-mile and half-mile buffers of each parcel. The project team has inventoried the location and pricing information for paid off-street locations but has not yet obtained or developed accurate information on capacities.

The point-based parking locations are assigned to individual parcels to develop the parcel data (e.g., PARKDY_P = daily paid parking spaces on the parcel). The buffer variables are calculated in a way similar to the urban form network buffers already described, using a GIS process to create buffer areas around each parcel, sum the parking capacity within the buffers, and calculate the weighted average of the parking price at the parking lots in the buffer.

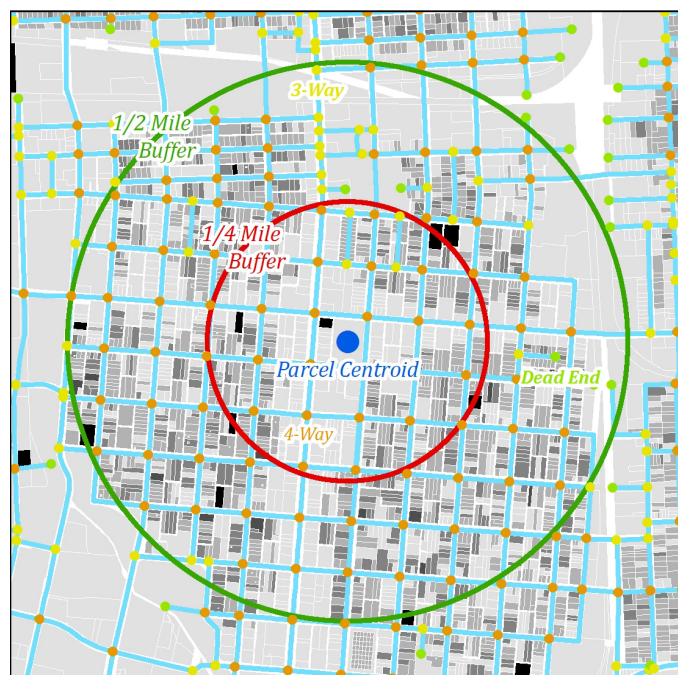


Figure 1.20. Example of quarter-mile and half-mile node buffers.

DaySim TAZ Data

Parcels are the primary spatial units used in DaySim. However, current implementations have used a limited set of TAZ-level data, including PUMA and summary district correspondence codes, and physical attributes such as the land area and coordinate locations. The Jacksonville model uses the TAZ system from the NERPM model, except that the zones are renumbered so that external zones are first (1–23) and internal zones are numbered consecutively (24–1,335). Similarly, the Burlington model uses the TAZ system from the CCMPO model.

Table 1.37 shows the file layout for the Jacksonville implementation of DaySim. The XCORD, YCORD, and SQFT_Z fields were developed in ArcGIS using the TAZ shape file supplied with the NERPM model. PUMAs were assigned to each TAZ by intersecting the TAZ shape file with a PUMA boundary shape file obtained from the Census Bureau.

DaySim Pricing Enhancements

Key goals of the SHRP 2 C10A model system development effort include providing enhanced representation of travelers' sensitivities to price and incorporating findings from other SHRP 2 Capacity projects. This section describes how DaySim and TRANSIMS have been refined and configured to provide more robust capabilities with respect to tolls and other types of road user charges that are modeled in the integrated DaySim–TRANSIMS model framework. The section starts with a more theoretical discussion of an ideal model representation, then

Table 1.37. TAZ Data Input File Format

Label ^a	Definition
TAZ	Zone number
AUTACC	Auto access time (min × 100) ^b
AUTEGR	Auto egress time (min × 100) ^b
PRKCOST	Parking cost in zone (cents per hour) ^b
DAVIS	Davis dummy (0/1)
PEDENV	Pedestrian environment score ^b
PUMA	PUMA code for zone
RAD	RAD code for zone (aggregation of zones) ^b
XCORD	X coordinate of zone centroid (state plane feet)
YCORD	Y coordinate of zone centroid (state plane feet)
PKNRCOST	Park and ride lot cost in zone (cents)
SQFT_Z	Area of zone (square feet)

^a DaySim can read these variables in any order, but the variable names must remain the same as shown. All values from the file are read as integers, with no decimal.

^b Not used in models.

addresses the more practical aspects of the current implementation. In several aspects of this work, the project team has made use of the findings from the SHRP 2 C04 project, Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand. The objective has been to implement the key findings from that study in a manner that retains as much behavioral detail as possible while also remaining practical for model application.

Choice Model Context

DaySim is an activity-based model (ABM) structure that includes several different levels of travel choices, as shown in Figure 1.21. The solid arrows in the figure depict the downward flow of conditionality of the simulated choices—auto ownership is conditioned by the simulated longer-term work and school locations, the day activity pattern (tour generation, plus some aspects of intermediate stop generation) is conditional on all longer-term choices, the tour-level choices are conditional on the longer-term and day-level choices, and so on. The dashed arrows represent the upward flow of accessibility in the models; travel times and costs have the most immediate effects on the trip-level models but ultimately affect all of the DaySim models.

The DaySim structure has been carefully designed to include accessibility effects at all choice levels, as consistently and comprehensively as possible. (In the literature, this is termed *vertical integrity*, with consistent information flows both upward and downward.) This is done through the use of accessibility logsums, a logsum being a statistical construct

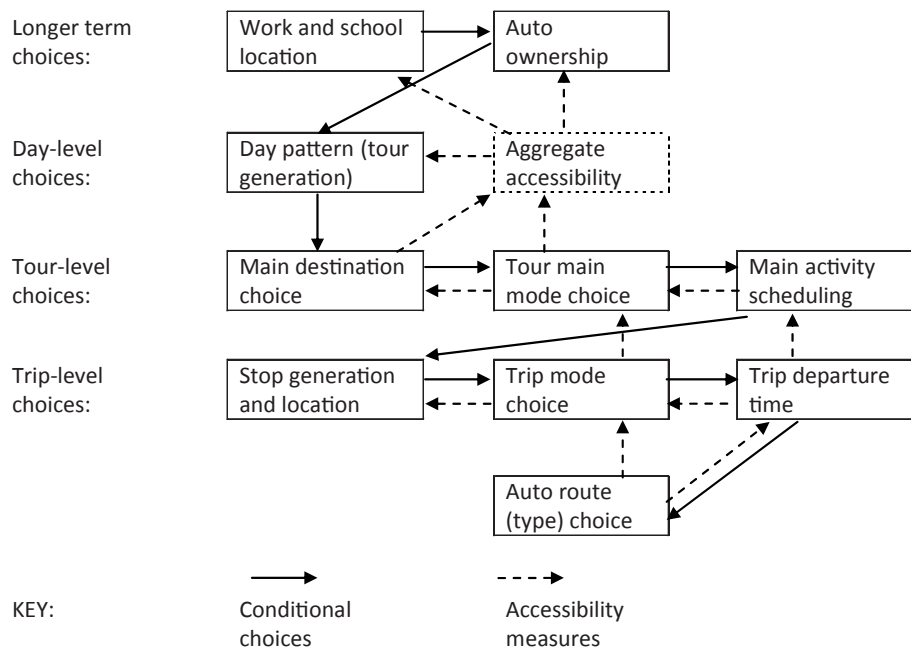


Figure 1.21. DaySim model structure.

used in discrete choice modeling to capture the expected utility across all available choice alternatives. As much as possible, DaySim uses fully disaggregate logsums, which essentially combine two models into a single joint, simultaneous model. An example is the tour-level main destination-choice model, which uses logsums representing the composite attractiveness of traveling to a given destination across all available modes. For the longer-term and day-level choices, however, the use of fully detailed disaggregate logsums is not practical, because too many possible combinations of tour- and trip-level alternatives correspond to each upper-level choice alternative. Instead, these models use aggregate accessibility logsums, which are logsums from a simplified tour-level model across all possible destinations, modes, and time periods, segmented by (a) residence zone, (b) travel purpose, (c) car availability level, and (d) distance from the nearest transit stop.

Incorporating Auto Route Choice into DaySim

For modeling highway pricing and congestion effects, the relationship between auto route choice (at the bottom of Figure 1.21) and other travel choices is critical. As the available auto routes change in terms of their travel time and/or cost at different times of day, the most direct effects are on the travel mode and departure time chosen for a particular trip. (However, the effects on the other DaySim choices are important to represent as well and will be addressed.)

In previous implementations of DaySim, auto route choice has been handled outside of DaySim itself. Instead, for a given auto submode, such as single-occupancy vehicle (SOV), and

a given time period, such as a.m. peak, the best route has been predetermined in a network package such as CUBE, TransCAD or EMME, and DaySim has simply used matrices of travel time, distance, and cost along the best path between each origin–destination (O-D) pair. The team’s previous work on integrating DaySim with TRANSIMS followed this same general approach, but with two key improvements: (a) a more realistic, dynamic representation of traffic congestion than is typically possible using a static equilibrium assignment approach, and (b) incorporation of much more detail regarding how congestion levels vary across the day. While DaySim typically uses highway skims from only four or five different time periods across the day, the current DaySim–TRANSIMS implementation uses skims from 22 time periods, with durations as short as 30 min during the peak periods.

If finding the best path through a network simply involves finding the shortest-time path, then all path building and assignment may satisfactorily be done outside of DaySim in a more aggregate environment. That may not be the case, however, when toll cost and/or operating cost become key considerations in choosing a route. Each traveler may have different trade-offs between travel time and cost—their so-called value of time (VOT) or willingness to pay (WTP) for time savings. The same is true if additional variables such as travel time variability or reliability are added to the route-choice model, in which case different travelers may also have different values of reliability (VOR) relative to travel time and cost.

Ideally, the network path choice would be fully integrated into an ABM such as DaySim. When applying a time-of-day

choice for a given tour or trip, for example, DaySim would evaluate all available paths through the network at each time of day for that given traveler on that given tour or trip. In other words, network path choice would be done “on the fly” in a fully disaggregate manner depending on each traveler’s trade-offs between travel time, toll, distance, and any other important route characteristics that are known in the network.

Although the project team studied possibilities for setting up such an “on the fly” integration of DaySim with TRANSIMS, it is not yet practical from the standpoint of computation and runtimes. Another possible solution is to set up different user classes depending on VOT and to use different network skim files with predetermined best paths for each class. For example, if the two best paths for a given O-D are a travel time of 40 minutes with no toll, or a travel time of 30 minutes with \$2.50 toll (and no difference in distance or operating cost), then any traveler willing to pay \$2.50 for a 10-minute savings (VOT higher than \$15/h) would choose the tolled path and any traveler with VOT lower than \$15/h would choose the free path. In the same example, three user classes could be designed as (1) VOT = \$0 to \$10/h, (2) VOT = \$10 to \$20/h, and (3) VOT > \$20/h. The best path for class (1) would clearly be the free route, and the best path for class (3) would clearly be the tolled route. For class (2) however, which path is best is not clear, because the indifference point of VOT = \$15/h falls in the middle of the class (2) range of \$10 to \$20/h.

To deal with this type of inaccuracy, the project team has adopted an approach which is commonly used in practice:

- Provide network skims of the best paths for two different route types: routes from the full network, including tolled links, and routes from the nontolled network only, excluding tolled links.
- Incorporate a binary route-type-choice (tolled versus nontolled) model into DaySim.
- To further increase the accuracy of the approach, provide different sets of best tolled and nontolled paths for different ranges of VOT. (Even the nontolled links include operating cost, so the best nontolled path may also vary by VOT class.)
- Within each VOT class, use the VOT at the high end of the range to select the best path in TRANSIMS to use as input to DaySim.

Thus, in the example with three VOT classes, six different routes would be selected in TRANSIMS and input to DaySim:

1. VOT = 0–10/nontolled network: the lowest generalized-cost route with VOT set at \$10/h, excluding tolled links;
2. VOT = 10–20/nontolled network: the lowest generalized-cost route with VOT set at \$20/h, excluding tolled links;

3. VOT = 20+ /nontolled network: the lowest generalized-cost route with VOT set at \$50/h (an arbitrary, high value), excluding tolled links;
4. VOT = 0–10/full network: the lowest generalized-cost route with VOT set at \$10/h, including tolled links;
5. VOT = 10–20/full network: the lowest generalized-cost route with VOT set at \$20/h, including tolled links; and
6. VOT = 20+ /full network: the lowest generalized-cost route with VOT set at \$50/h (an arbitrary, high value), including tolled links.

Using the same example, if the best two paths are 40 min with no toll and 30 min with a toll of \$2.50, then the best nontolled route for all VOT classes (options 1–3) would be the 40-min free route, as the tolled route is excluded. The best path from the full network for VOT = 0–10 (option 4) would also be the free route. But the best path from the full network for the other two VOT classes (options 5 and 6) would be the tolled path, because both of those classes use a VOT set higher than \$15/h to pick the best path.

Inside of DaySim, travelers with VOT in the range 0–10 would face a binary choice between two identical nontolled paths, which is essentially no choice. Travelers with VOT higher than 10 would all have a choice between the tolled and nontolled paths. The probability that any traveler will pick the tolled path increases with VOT, so moving the route-type choice inside of DaySim makes it more sensitive to small variations in WTP and ultimately more accurate. The binary route-choice model is a probabilistic model, however, so even for very high VOT there may be a small probability of selecting the free route.

The following sections provide more details about how the binary model is implemented in DaySim. First, however, more perspective on the need to include a route-type choice model within DaySim is useful, as is information on different skims to DaySim for different ranges of VOT. The feature using different VOT user classes is not always used in practice, and may seem unnecessary, because the binary route-type-choice model already accounts for differences in WTP. In cases with simple pricing scenarios, such as those that include one or two isolated high occupancy/toll (HOT) lanes or express lanes, the best tolled route is usually the facility in question, and that is not likely to vary across VOT classes. A more detailed pricing scenario, however, such as mileage-based pricing on a regional freeway network, may include a large set of different tolled paths to choose from; and the best tolled path may vary according to VOT. In such a case, providing different best paths for different ranges of VOT helps compensate for the decision to choose a single best tolled path to input to DaySim rather than providing a larger set of possible tolled paths. The implication is that the more complex the regional pricing scenario, the larger the number of VOT-specific user classes which should be used.

Binary Route-Type-Choice Model

The route-type-choice model implemented in DaySim works as shown in Equation 1.2:

$$\begin{aligned}
 V(n,i) &= s.b(i) * \text{Time}(n,i) + s.c(i) * \text{Distance}(n,i) * \text{opcost} \\
 V(t,i) &= s.a(i) + s.b(i) * \text{Time}(t,i) + s.c(i) \\
 &\quad * [\text{Toll}(t,i) + \text{Distance}(t,i) * \text{opcost}] \\
 P(t,i) &= 1 - P(n,i) = \exp[V(t,i)] / \{ \exp[V(t,i)] + \exp[V(n,i)] \} \\
 &\quad (1.2)
 \end{aligned}$$

where

$V(n,i)$ and $V(t,i)$ are the systematic logit utilities for the nontolled and tolled routes, respectively, for individual traveler i , and $P(t,i)$ and $P(n,i)$ are the corresponding binary logit probabilities;

$\text{Time}(n,i)$, $\text{Time}(t,i)$, $\text{Distance}(n,i)$, $\text{Distance}(t,i)$ are the travel time and distance along the best nontolled and tolled routes, respectively, for traveler i , depending on the traveler/trip's origin, destination, time of day, and VOT class;

$\text{Toll}(n,i)$ is the toll along the best tolled route for traveler i , depending on the traveler/trip's origin, destination, time of day, and VOT class;

$a(i)$ is an alternative-specific constant for the tolled route for traveler i ;

$b(i)$ is the travel time coefficient for traveler i ;

$c(i)$ is the travel cost coefficient for traveler i ;

s is a scale factor applied to all coefficients, denoting the scale of this model relative to mode choice; and

opcost is the auto operating cost per mile.

The strategy for providing best path skim values for time, distance, and toll from TRANSIMS to DaySim was explained in the previous section. The assumptions and methods used for setting coefficients a , b , c , and s are given in the next section.

Note that if two paths are identical in terms of time, distance, and toll ($= 0$), then the nontolled path is selected as the chosen route type without applying the model. Also note that *operating cost per mile* is treated as a constant in DaySim (which can be varied by the user to represent future fuel cost assumptions). If DaySim is enhanced in the future to include a model of vehicle type choice (e.g., economy, sport utility vehicle, hybrid), then operating cost can be treated as traveler-specific. Also, network simulation software such as TRANSIMS could be enhanced to provide an O-D/time-of-day-specific estimate of average fuel usage based on speeds and traffic conditions (e.g., stop and go) along the route. In that case, average fuel usage could be another skim variable used as input to DaySim.

Traveler-Specific Coefficients

In setting traveler-specific coefficients for the model, the project team used the findings from the SHRP 2 C04 study to the

greatest extent possible, both for the functional forms and the magnitudes. Equation 1.3 shows the values are set as follows:

Work tours

$$c(i) = -0.15/\$/\left(\left\{\left[\text{income}(i)/30,000\right]^{0.6}\right\} * \left[\text{occupancy}(i)^{0.8}\right]\right)$$

$b(i) = -0.030/\text{min} * \text{draw from a lognormal distribution,}$

with mean 1.0 and standard deviation 0.8

$$a(i) = -1.00$$

$$s = 1.5$$

Nonwork tours

$$c(i) = -0.15/\$/\left(\left\{\left[\text{income}(i)/30,000\right]^{0.5}\right\} * \left[\text{occupancy}(i)^{0.7}\right]\right)$$

$b(i) = -0.015/\text{min} * \text{draw from a lognormal distribution,}$

with mean 1.0 and standard deviation 1.0

$$a(i) = -1.00$$

$$s = 1.5$$

(1.3)

The cost coefficient c is set at $-0.15/\$$ for both work and nonwork tours. It is adjusted according to the household income of the traveler, using a power function with a somewhat higher exponent for work tours (0.6) than for nonwork tours (0.5). When applied to specific car occupancy levels, the cost coefficient is also adjusted downward for cost-sharing, again using a power function with a somewhat higher coefficient for work tours (0.8) than for nonwork tours (0.7).

The base travel time coefficient is set at $-0.030/\text{min}$ for work tours and $-0.015/\text{min}$ for nonwork tours. For an SOV trip for a traveler with income = \$30,000, this corresponds to a VOT ratio of $60 * -0.030/-0.15$, or \$12/h for work tours, and $60 * -0.015/-0.15$, or \$6/h for nonwork tours.

The C04 study also found significant random taste variation around the base travel time coefficient, with the best results assuming a lognormal shape to the distribution, which is typical for VOT analysis. Although the results are not conclusive with regard to the amount of random variation, the C04 study and past analyses of this type generally support a coefficient of variation (standard deviation/mean) in the range of 0.7 to 1.0. Here the project team assumes a somewhat higher coefficient of variation for nonwork trips because that covers a wider variety of trip types. (Note that the code for performing random draws from approximate normal—Gaussian—and lognormal distributions uses the ratio of uniforms method of A. J. Kinderman and J. F. Monahan augmented with quadratic bounding curves. The original algorithm was published in *Transactions on Mathematical Software*, Vol. 18, No. 4, 1992, pp. 434–435.)

The alternative-specific constant for the tolled route is set at -1.0 for both work and nonwork tours, as evidence shows some aversion to paying tolls, all else being equal. Note that

simulating normal or lognormal taste variation around this coefficient for each individual would also be possible. However, empirical evidence to go by is lacking, and, statistically, estimating taste variation parameters on both the toll constant and the time or cost coefficient at the same time would be difficult.

The final parameter is s , the model scale relative to mode choice. If we think of the binary toll/nontoll model as a nest of mode alternatives under each of the auto alternatives in a mode-choice model, then the unscaled time and cost coefficients b and c are those used in the mode-choice model, while the scaled coefficients $s.b$ and $s.c$ are those used in the lower-level route-type-choice nest when the logsum parameter for the nest is $1/s$. Empirically, the C04 report contains nest logsum parameters on the route-type-choice nest ranging from 0.9 (constrained) for the New York revealed preference (RP) data to 0.5 for various stated preference (SP) data sets. Here, the project team assumed a logsum of roughly 0.67, and the scale s is the inverse of that, at 1.5.

Conceptually, the larger the value of s , the more sensitive and deterministic the route-type-choice model probabilities will be, and the less sensitive the logsum from the model will be to the attributes of the unchosen/inferior alternative. The logsum from the model is important, because it is that value which is fed upward from the auto route-type-choice model to all of the other DaySim models, as described in the following section.

Use of the Route-Type-Choice Model Within DaySim

Conceptually, the route-type choice model can be thought of as a binary nest beneath each of the auto alternatives—single-occupancy vehicle (SOV), high-occupancy vehicle with two people (HOV2), high-occupancy vehicle with three people or more (HOV3+)—in the DaySim mode-choice model. Whenever auto time and cost for one of the auto submodes is referenced in the DaySim models, they need to be replaced by the composite utility from both the tolled and nontolled paths under each of those modes, just as they would be in a fully nested model. In DaySim, this is done by using the route-type-choice model to return a “generalized auto time” logsum whenever it is applied. The generalized time is calculated as shown in Equation 1.4:

$$\begin{aligned}
 V(n,i) &= s.b(i) * \text{Time}(n,i) + s.c(i) * \text{Distance}(n,i) * \text{opcost} \\
 V(t,i) &= s.a(i) + s.b(i) * \text{Time}(t,i) + s.c(i) \\
 &\quad * [\text{Toll}(t,i) + \text{Distance}(t,i) * \text{opcost}] \\
 \text{GT}(i) &= \text{LN} \{ \exp[V(t,i)] + \exp[V(n,i)] \} / [s.b(i)] \quad (1.4)
 \end{aligned}$$

The two utility equations are the same as presented earlier and are used to set the logit probability of choosing either route. The generalized time $\text{GT}(i)$ is simply the logsum across

those two alternatives, divided by the scaled travel time coefficient $[s.b(i)]$ to obtain units of minutes. (Because a , b , and c are always negative and there are only two alternatives, the logsum will virtually always be negative as well; so the generalized time will be positive. However, a check has been placed in the code to avoid cases of negative generalized time.)

When no tolled alternative exists, then the $V(t,i)$ term is not used, so the generalized time simplifies to $V(n,i)/[s.b(i)] = \text{Time}(n,i) + c(i)/b(i) * \text{Distance}(n,i) * \text{opcost}$, which is simply travel time plus operating cost divided by VOT. In upper-level models, this generalized time is typically multiplied once again by a time coefficient, $b(i)$, so it becomes $b(i) * \text{Time}(n,i) + c(i) * \text{Distance}(n,i) * \text{opcost}$, which is the unscaled version of $V(n,i)$. Note that the generalized time now includes the effects of tolls and operating cost as well as travel time, so all explicit utility terms related to time, tolls, and operating cost were replaced in the code for those models by the single generalized time term (times a relevant time coefficient, when appropriate).

Table 1.38 summarizes how the route-type-choice model is used within the various component models within DaySim. Note that only one of the lowest-level models, trip-mode choice, actually simulates a route-type choice (toll or nontoll) as a prediction, but nearly all of the DaySim models use the route-type-choice model in the form of the generalized auto time logsum. This feature ensures that the effects of pricing at various times of day are represented consistently at all levels of the model system. Also, most of the models take into account the effects of pricing and congestion separately for the SOV, HOV2, and HOV3+ modes; that allows the effects of HOT lanes and other occupancy-specific types of pricing and facilities to be accurately represented. The effects of pricing are also treated consistently for each of the 22 different skim periods in the tour and trip time-of-day choice models, so time-of-day variations in prices and congestion can have nuanced effects on demand. The tour-level and upper-level models also react to pricing for both legs of a tour round trip.

As indicated in the table, the upper-level models use disaggregate logsums from the tour-mode-choice model and/or aggregate mode and destination choice accessibility logsums to “carry up” the effects of pricing and congestion in a way that is as consistent as possible with discrete choice theory.

Feedback of DaySim Results to TRANSIMS

The DaySim model system produces a list of person-trips for a single day for the entire regional population. With the incorporation of the route-type-choice model for tolling, three new variables have been added to the DaySim trip level output file:

- The toll paid for the trip;
- The trip-specific (unscaled) time coefficient; and
- The trip-specific (unscaled) cost coefficient.

Table 1.38. How Route-Type-Choice Model Is Used in DaySim

DaySim Model	Predicts route-type choice?	Uses logsum as generalized auto time?	Used for modes . . .	Used for periods . . .	One way or round trip?
Work location	No	Yes	SOV, HOV2, HOV3+ ^a	Assumed ^a	Round trip ^a
School location	No	Yes	SOV, HOV2, HOV3+ ^a	Assumed ^a	Round trip ^a
Auto ownership	No	Yes	SOV, HOV2, HOV3+ ^a	Assumed ^a	Round trip ^a
Day-pattern choice	No	Yes	SOV, HOV2 ^b	Assumed ^b	Round trip ^b
Tour-destination choice	No	Yes	SOV, HOV2, HOV3+ ^c	Simulated ^c	Round trip ^c
Tour-mode choice	No	Yes	SOV, HOV2, HOV3+	Simulated	Round trip
Tour-time-of-day choice	No	Yes	Predicted tour mode	All possible	Round trip
Stop-generation and location choice	No	Yes	Predicted tour mode	Predicted tour periods	One way via stop detour
Trip-mode choice	Yes	Yes	SOV, HOV2, HOV3+	All possible	One way
Trip-time-of-day choice	No	Yes	Predicted trip mode	All possible	One way

^a Via both.

^b Via aggregate accessibility logsums.

^c Via disaggregate tour-mode-choice logsum.

This extra information can be used by TRANSIMS to (a) know whether to exclude tolled links from possible paths when assigning the trip to the network, and (b) use the ratio of time and cost coefficients to determine the best VOT-specific path of each type. Both of these types of information will help ensure that the choice behavior being predicted by DaySim is consistent with the route choices and traffic flows being predicted by TRANSIMS.

Treatment of Travel Time Variability and Reliability

Travel time variability has not yet been included in the route-type-choice model or other choice models within DaySim. Although the C04 report provides a good deal of useful evidence regarding trade-offs between cost, usual travel time, and travel time variability and reliability, the project team has not yet determined a feasible way to simulate spatial, O-D-specific levels of travel time variability in TRANSIMS as input to the DaySim demand models.

As discussed in the C04 report, most proxy-type variables that can be generated from a single run of the network model (e.g., congested time minus free-flow time) tend to be so highly correlated with the main travel time variable that they provide very little new information. Also, given the long TRANSIMS runtimes, any procedures that would require multiple network simulation runs to produce day-to-day distributions of O-D travel times are not practical at this point. The project team reviewed the latest available versions of the SHRP 2 C04 and L04 (Incorporating Reliability Performance

Measures in Operations and Planning Modeling Tools) reports and considered methods they suggested which might be both useful (in terms of adding real network spatial and temporal information) and feasible (in terms of computation and runtimes).

TRANSIMS Network

The supply side models developed for the Jacksonville and Burlington model implementations are based on the TRANSIMS network and travel assignment process. This process assigns for each individual household person a sequence of trips or tours between specific activity locations and to roadways, walkways, and transit modes on a second-by-second basis for a full travel day. The network includes detailed information regarding the operational characteristics of the transportation facilities that may vary by time of day and by vehicle or traveler type. This information includes the number of lanes, lane-use restrictions, traffic controls and signal timing and phasing plans, turning restrictions, tolls, and parking fees.

Most of the detailed network coding can be synthetically generated from traditional transportation modeling networks or GIS files. Traffic engineering warrants and coding rules can be customized for local conditions. The resulting data for a regional network can be edited to more accurately reflect actual conditions in the field. However, because TRANSIMS and the SHRP 2 C10 project are designed to address transportation planning needs and future operational and policy scenarios, the network models should be

designed and developed to dynamically adjust to future conditions rather than be fixed or limited to existing traffic controls.

Network Conversion Process

The TRANSIMS suite includes a number of tools to synthesize a TRANSIMS network from traditional MPO networks. These tools provide a quick method of developing a detailed TRANSIMS network without a lot of extra data collection and arduous network coding. This gets the model up and running quickly and uses the trip assignment process to identify locations where the synthetic process requires refinement. The generic process for converting a TP+ network is depicted in Figure 1.22.

The TPPlusNet program reads the one-way link records and the speed-capacity lookup table used in the regional model network (in Jacksonville this is a TP+ network while in Burlington this is a TransCAD network). The program reformats, regroups and reconfigures the data into standard TRANSIMS input link and node data files. TransimsNet then reads the modified link and node files to synthesize the additional information needed for a network simulation. This information includes pocket lanes, lane connectivity, parking lots, activity locations, and signal and sign warrants. The signal and sign warrants are typically

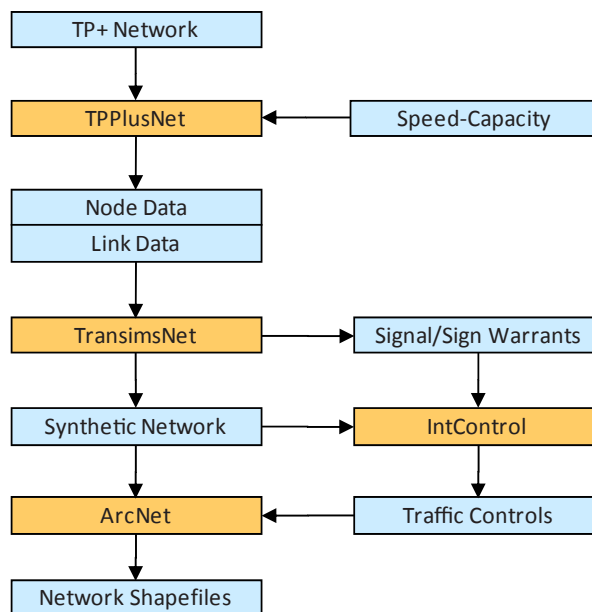


Figure 1.22. Network conversion process.

reviewed and edited before the execution of IntControl. IntControl synthesizes traffic signal timing and phasing plans, detectors, and signs. The ArcNet program then creates ArcGIS shape files to display and edit the network. Figure 1.23 shows a typical TRANSIMS network following this conversion.

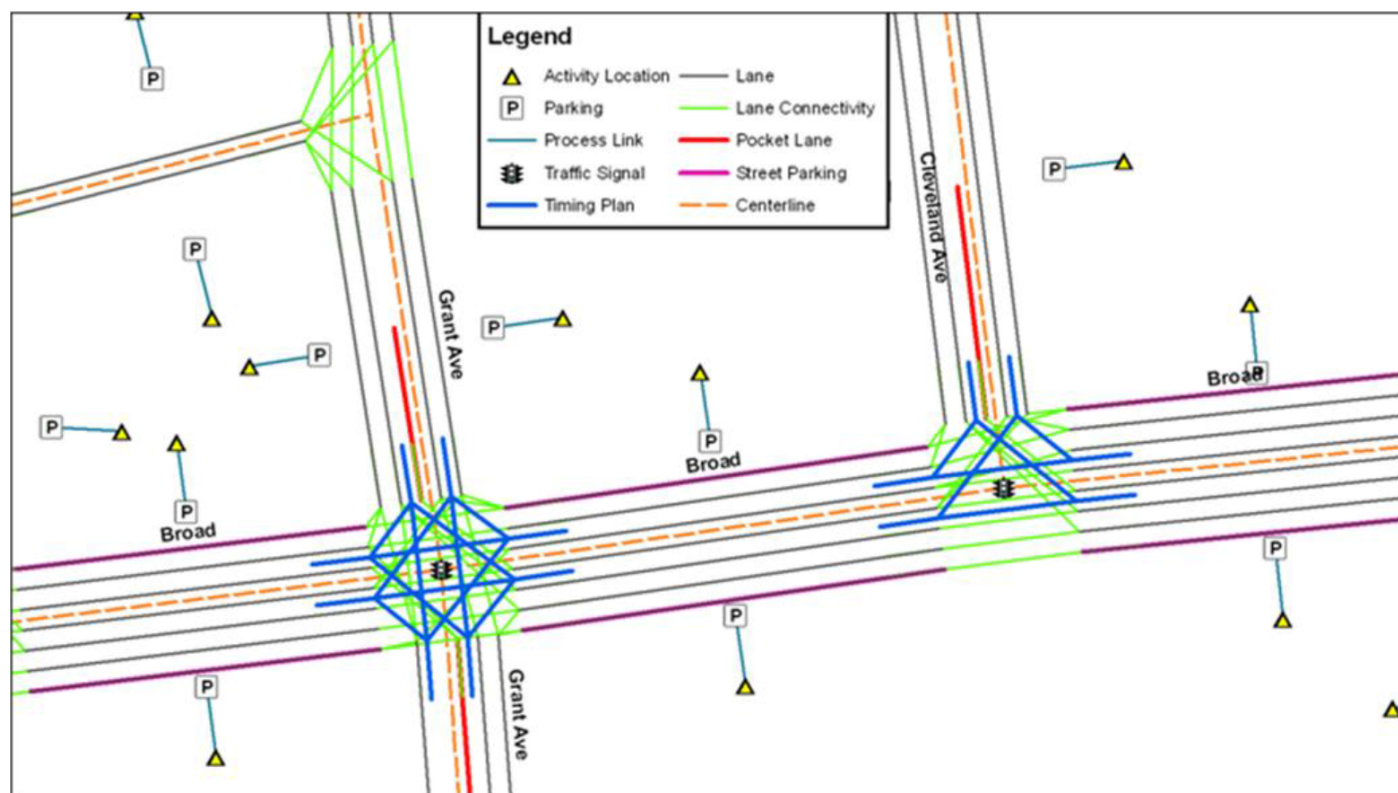


Figure 1.23. Typical TRANSIMS network.

Jacksonville Network Development

In consideration of the flexibility requirement and the project goal to develop a fine-grained network, the team started the model development by creating three network resolutions from the NERPM regional modeling data sets:

1. **PLANNING Network.** This network is equivalent to the NERPM regional modeling network.
2. **ALLSTREETS Network.** This network is equivalent to the NERPM regional modeling network plus all other existing minor streets such as neighborhood streets and alleys.
3. **FINEGRAINED Network.** This network adds local through streets to the PLANNING network to provide greater distribution of travel to, from, and within traffic analysis zones.

In addition to the information included in the NERPM network files, the TRANSIMS conversion process synthesizes the operational details required for network simulation. These include traffic controls, pocket lanes, lane connectivity, and lane-use or vehicle-use restrictions. The following sections describe the generic as well as network-specific conversion and enhancement processes, including network data inputs and their treatment and application. These networks were prepared using TRANSIMS Version 4 tools and later converted to TRANSIMS Version 5 in order to support the implementation of the C10A model system in TRANSIMS v5.

NERPM Network

Florida Department of Transportation (FDOT) District 2's Northeast Regional Planning Model (NERPM) maintains multiple networks in a single master network file. The master files are those files that are universally applicable to all scenarios in NERPM. These files are not altered from scenario to scenario. Instead, the files contain source data from which scenario-specific information is extracted.

1. **MERGED-GIS.** This is a set of files that collectively form an ESRI shapefile corresponding to the master network.
2. **MERGED.NET.** This is the master network file from which all scenarios and alternatives are derived.
3. **TCARDS.PEN.** This is the turn penalty file that contains all turning movement penalties and prohibitions for all scenarios. Penalty sets are used to distinguish scenarios.

Thus, various modeling year networks are coded as scenarios with specific attributes. As such, their values change from scenario to scenario. Scenario-specific attributes are identified by the presence of catalog keys designating the year and alternative of the scenario. For example, the attribute for facility

type for the 2005 base year scenario is called FTYPE_05A, whereas the facility type attribute for the 2030 network is called FTYPE_30A. A breakdown of the default scenario-specific networks is as follows:

- 00A—2000 base year;
- 05A—2005 interim year;
- 10A—2010 existing-plus-committed (no socioeconomic data);
- 15A—2015 interim year;
- 25A—2025 interim year;
- 30A—2030 cost feasible plan horizon year; and
- 30N—2030 needs plan (no socioeconomic data).

The C10A study focuses on using the 2005 scenario for the base year network and the financially constrained 2030 scenario for the forecast year network. The MERGED.NET master network is conflated with the MERGED-GIS ESRI shapefile and allows viewing the true shapes of the links in CUBE. The shape information is also exported to the output shapefiles for input to the TransimsNet program. (See Figure 1.24.)

The NERPM model network topology is accomplished by having distinct nodes that are superimposed. The distinction is not visible at normal zoom levels. However, grade-separate roadways have unique Anode-Bnode pairs relative to the underpass/overpass roadways. Figure 1.25 highlights nodes where links are seemingly intersecting with their cross streets but in reality need to be represented as grade separations.

The 2005 regional planning network has approximately 9,800 directional links, 6,500 nodes, and 1,642 zones. Shape points or curvature information is available for approximately 6,000 directional links. The project team converted the 2005 TP+ network with time-of-day variations to a time-dependent TRANSIMS network. The TRANSIMS network was subsequently used to route and simulate the TP+ trip tables. (See Figure 1.26.)

The NERPM master network attributes are described in Table 1.39.

NERPM Speed Capacity

The Jacksonville regional model stores speed and capacity information for links in TP+ formats. An example file for the base year 2005 is shown in Figure 1.27. For a given area-type range, facility-type range, and lane range combination, this file provides a corresponding speed and capacity value. The speed is considered to be free-flow speed and is translated as such during conversion to TRANSIMS formats.

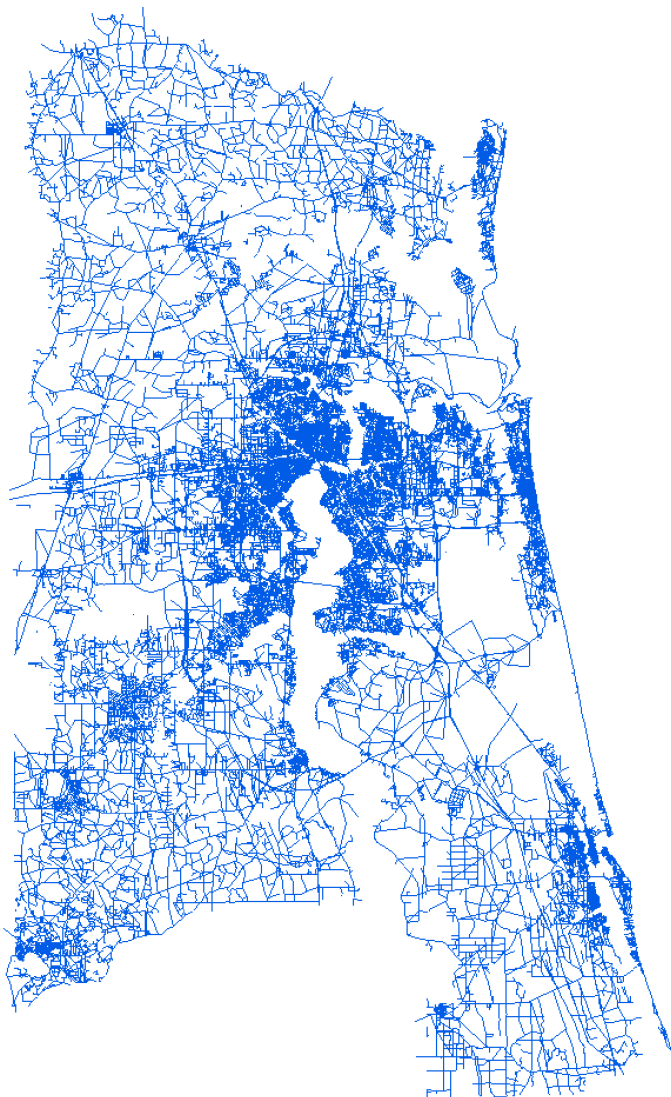


Figure 1.24. NERPM master network.

TAZ-Area-Type Definition

Area-type information is typically stored as an attribute of the TAZs in most regional models. TransimsNet was therefore designed to read this TAZ-area-type equivalence to allow users to control the generation of synthetic TRANSIMS network elements such as pocket lanes by area type in addition to facility type. Figure 1.28 shows an example of the TransimsNet control parameters.

However, the NERPM area types are only available on links and not on zones. The area types are also subdivided to range from 11 to 99. Figure 1.29 shows the distribution of area types by link.

Because the area types were link-based, a representative area type for a given TAZ could not be easily established given the presence of multiple area types within a TAZ. This problem was overcome by weighting link-based area types with their lane-feet to create a TAZ-area-type equivalence.

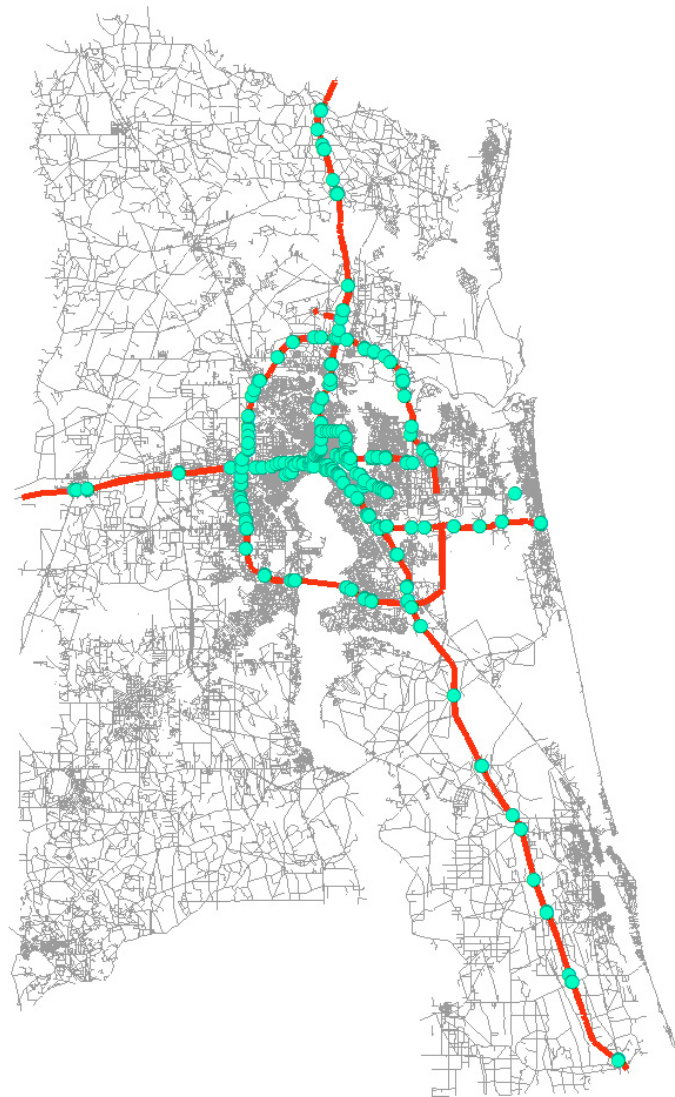


Figure 1.25. Locations of NERPM superimposed nodes.

Network Corrections

As mentioned earlier in this chapter, the superimposed nodes in the NERPM network were collapsed during the TransimsNet application to synthesize TRANSIMS network elements. Only the nodes that connect what would otherwise be a single continuous link are considered during the collapsing process. Attention is paid to link attributes such as the facility type, number of lanes, and speeds. The nodes are not collapsed if any of these attributes differ; in other words, only homogeneous links are merged.

During the network conversion and simulation processes a number of issues with the network were revealed which required the project team to implement a series of network refinements. These issues can be divided into two basic types. The first type is refinements pertaining to large abrupt changes in roadway attributes such as facility type, through lanes, and speeds. These refinements were included in the TPPlusNet

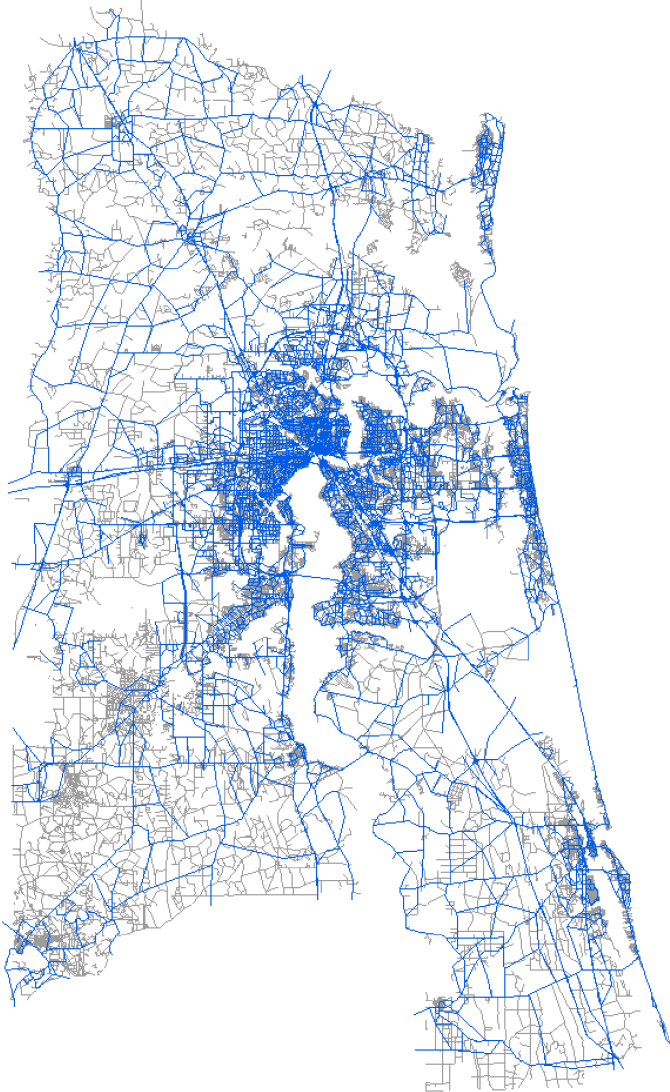


Figure 1.26. NERPM year 2005 network (shown in light blue).

SPDCAP.05A					
1	10101010	1	2	1810	45.0
2	10101010	3	3	1863	45.0
3	10101010	4	9	1891	45.0
4	10101111	1	2	1778	40.0
5	10101111	3	3	1863	40.0
6	10101111	4	9	1905	40.0
7	10101212	1	2	1810	45.0
8	10101212	3	3	1863	45.0
9	10101212	4	9	1891	45.0
10	10101515	1	2	1810	37.5

Figure 1.27. NERPM speed capacity file.

conversion scripts to maintain automated procedures to retain their applicability to future-year networks and network alternatives. The abrupt changes can be classified as follows:

1. Discontinuities in facility types;
2. Discontinuities in through lanes; and
3. Discontinuities in speeds.

Figure 1.30 shows the locations where such discontinuities were observed.

Figure 1.31 illustrates an example location where the functional class changed to local (FTYPE_05 = 46) for a short distance in between a continuous facility type of major arterial (FTYPE_05 = 23) as the link approached an intersection. This resulted in an extremely short link that complicated intersection operations.

The next type of discontinuity was the unrealistic change of two or more through lanes as seen in Figure 1.32. Because

Table 1.39. NERPM Network Attributes

FTYPE_{year}{alt}	This is the facility type attribute. It distinguishes such facility types as freeway, arterials, and collectors. Values range from 11 to 99 and generally follow Florida Standard Urban Transportation Modeling Structure (FSUTMS) highway network coding practices. A facility type value of zero is used to indicate that a particular link is not present in a given scenario. For any given scenario, the facility type for many of the links in the master network is zero. This is one of three attributes used to calculate link speeds and capacities, the other two being area type and number of lanes.
ATYPE_{year}{alt}	This is the area type attribute. It distinguishes such land uses as CBD, Residential, and Rural. Values range from 11 to 55 and generally follow standard FSUTMS highway network coding practices. This is one of three attributes used to calculate link speeds and capacities, the other two being facility type and number of lanes.
LANES_{year}{alt}	This is the attribute that designates the number of directional lanes on any given link. Values range from 1 to 9 and follow standard FSUTMS highway network coding practices. This is one of three attributes used to calculate link speeds and capacities, the other two being facility type and area type.
IMPROV_{year}{alt}	This attribute indicates whether a particular link is a roadway improvement project that first becomes active in this scenario. Values are Y(es)/N(o).
AGENCY_{year}{alt}	This attribute identifies the agency responsible for making the roadway improvement (indicated in the improvement attribute) if that agency is known. Values are the names of the funding agencies.
DESC_{year}{alt}	This attribute describes in plain text the nature of the roadway improvement indicated in the improvement attribute.

FACILITY_TYPE_ACCESS_FLAGS	0,0,1	#-- freeway, expresswa
ACTIVITY_LOCATION_SIDE_OFFSET	25	#-- meters
POCKET_LENGTHS_FOR_FACILITY_1	100, 200, 350, 400, 500	#-- freeway=1
POCKET_LENGTHS_FOR_FACILITY_2	60, 150, 200, 250, 300	#-- expressway=2
POCKET_LENGTHS_FOR_FACILITY_3	40, 80, 100, 125, 150	#-- principal=3
POCKET_LENGTHS_FOR_FACILITY_4	30, 70, 80, 90, 100	#-- major=4
POCKET_LENGTHS_FOR_FACILITY_5	30, 70, 80, 90, 100	#-- minor=5
POCKET_LENGTHS_FOR_FACILITY_6	30, 70, 80, 90, 100	#-- collector=6
POCKET_LENGTHS_FOR_FACILITY_7	30, 70, 80, 90, 100	#-- local=7,
POCKET_LENGTHS_FOR_FACILITY_9	60, 150, 200, 250, 300	#-- ramp=9
POCKET_TO_FACILITY_BY_AREA_TYPE	7, 7, 7, 7, 7	#-- allow pocket turn

Figure 1.28. TransimsNet controls, by area type.

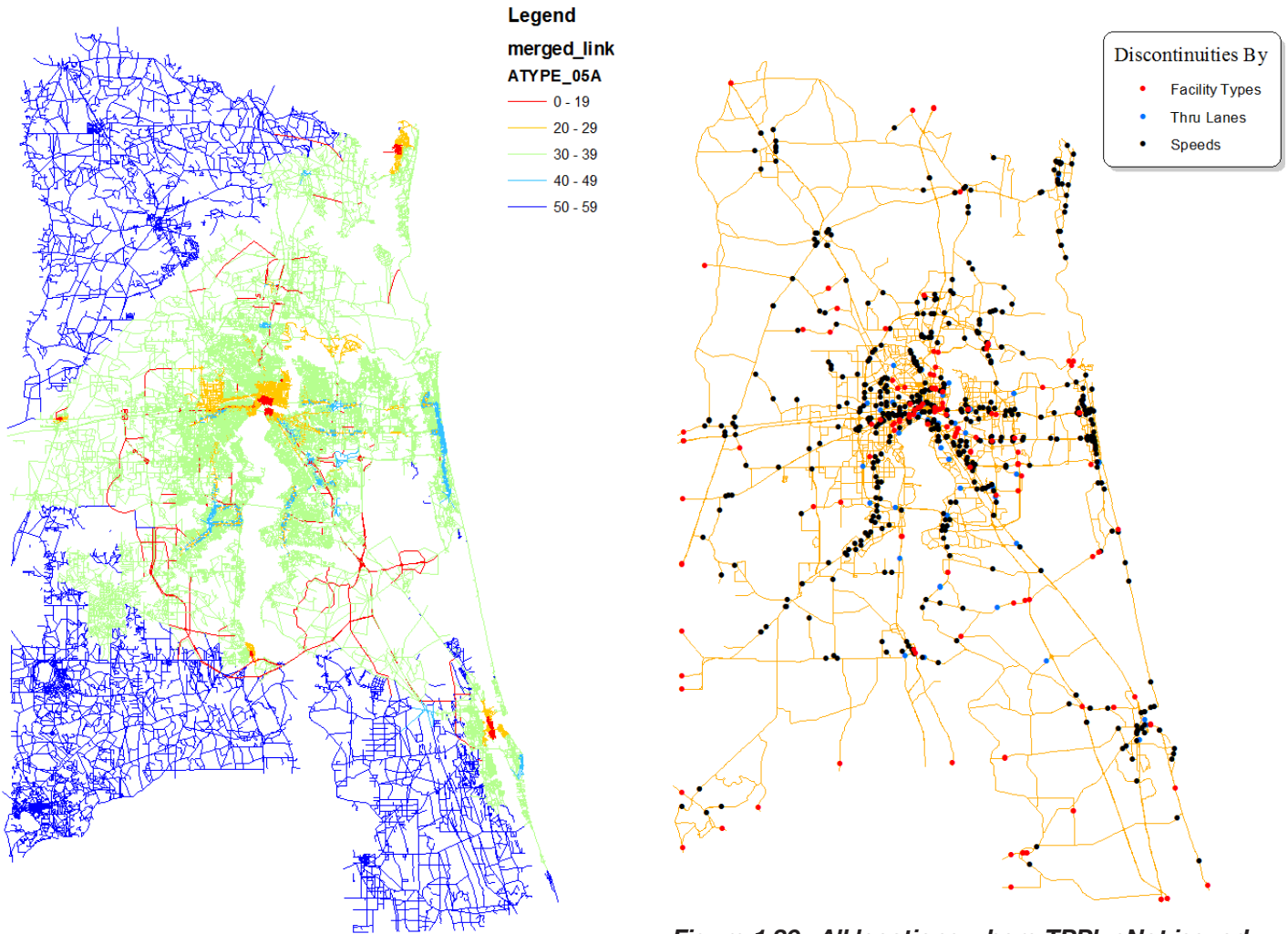


Figure 1.29. NERPM link-based area types.

Figure 1.30. All locations where TPPlusNet issued warnings.

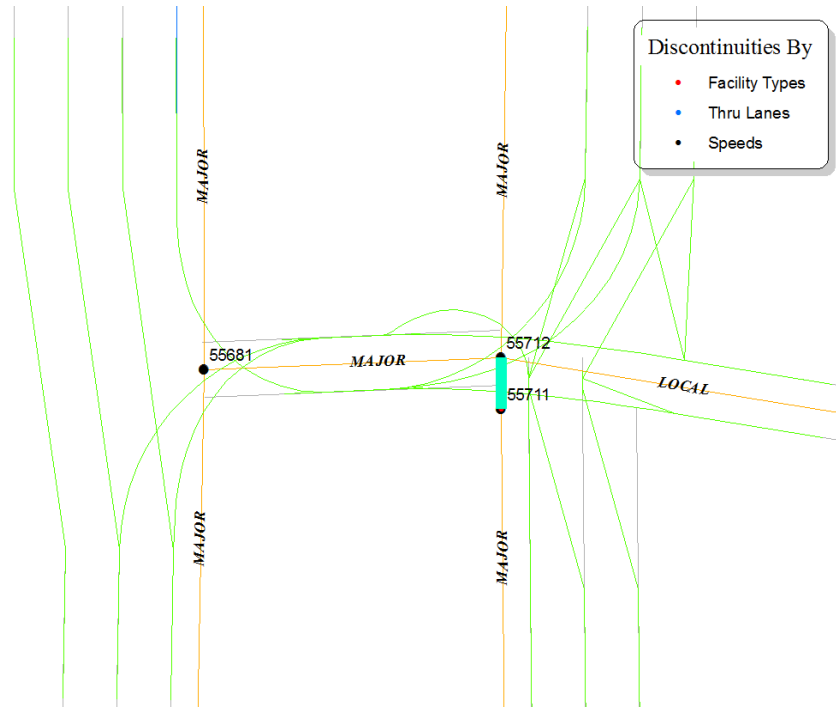


Figure 1.31. Example location showing short link resulting from facility-type change.

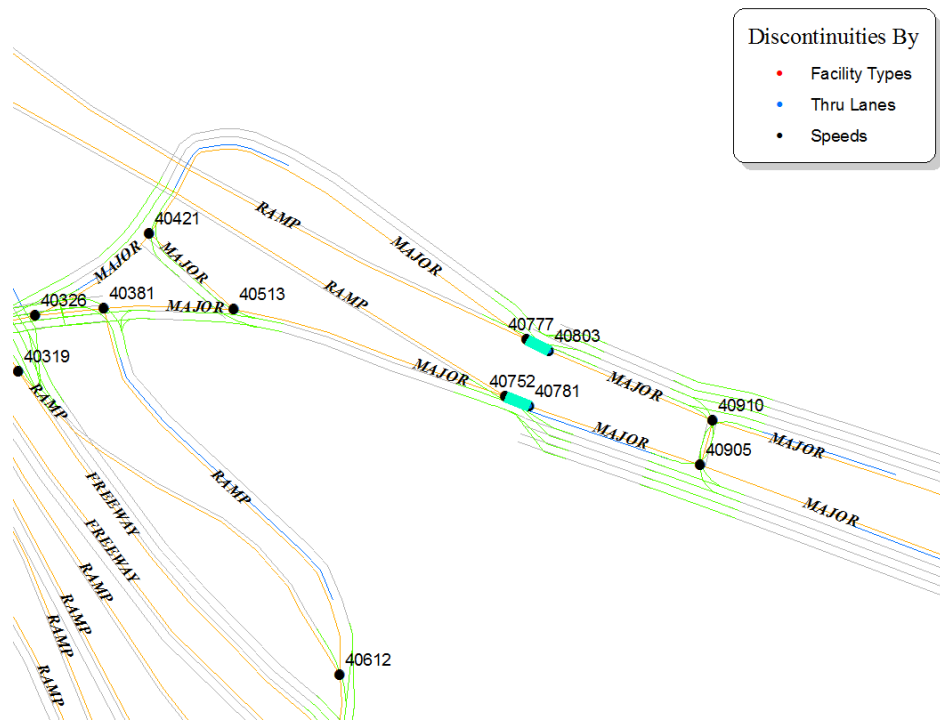


Figure 1.32. Example location where roadway cross section changed abruptly.

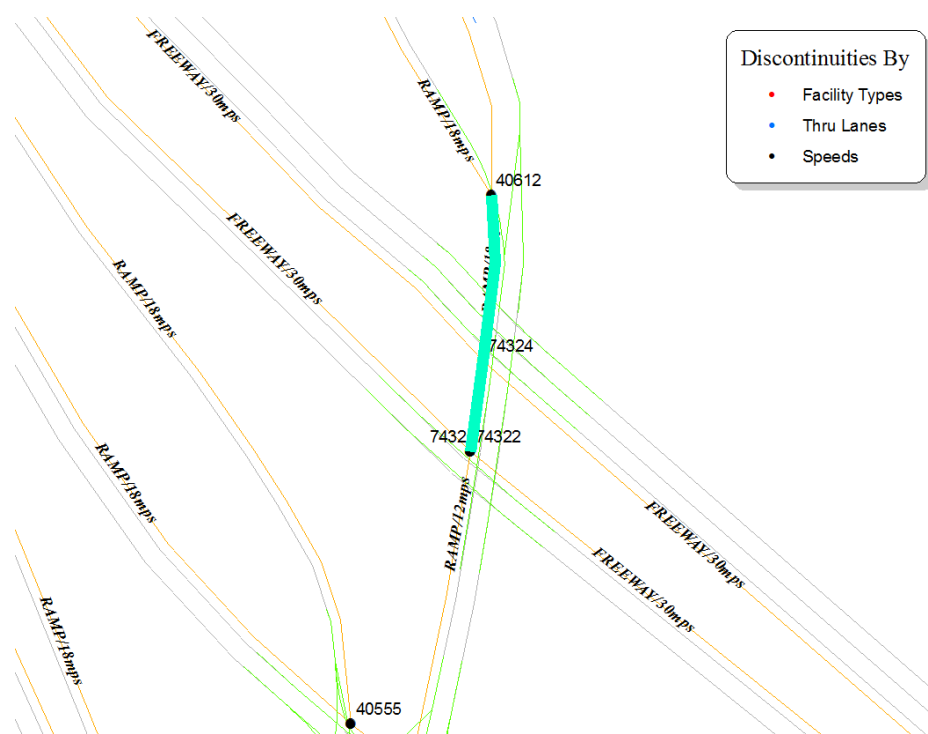


Figure 1.33. Example location with sudden drop in speeds.

lanes are the primary source of capacity within the simulation and lane changing is one of the primary reasons for congestion and lost vehicles, these types of errors are extremely problematic.

The last type of discontinuity was a large change in speeds as seen in Figure 1.33. The speed discontinuity was the result of a change in the coded area type for the link.

These three coding errors result in a significant number of unnecessary nodes and short links which cause congestion problems in the simulation. Most of the issues were addressed by modifying the TPPlusNet conversion script and collapsing the nodes. Figure 1.34 shows the distribution of locations where these nodes were dropped. Since the edits were performed at the input level, they can easily be applied to all network resolutions and analysis years.

The second group of issues relates to more systematic problems raised by the assignment visualization. The visualization results showed significant backups on freeways at several locations far away from their real access points. Investigation showed several locations where freeways intersect with arterial roadways because of network coding errors in the input NERPM master network. These were locations where links should have been coded using grade-separated nodes, but the link was assigned the wrong node number. An example is shown in Figure 1.35. Again, to address this issue, network edits were performed to the NERPM TP+ network to keep the conversion procedure intact.

Intersection Controls

TRAFFIC SIGNALS

TRANSIMS includes a number of ways to change the configuration of the network by time of day. In addition to the roadway configurations, traffic controls can also vary by time of day. The signal timing and phasing plans can be adjusted to optimize time-of-day flow conditions. Signal progression tools are also available to coordinate fixed time signals along specified corridors or throughout a grid system. Demand-actuated signals can include multiple detectors and simulate ramp metering behavior. The signal formats also allow changing signal types by time of day.

A rich data set containing the location of all signals in ESRI shapefile format was available from FDOT for the entire state of Florida. As discussed in earlier sections, this signal location information was used to replace rule-based signal warrants from TransimsNet. However, some processing was required by the project team to interface these data with TRANSIMS programs. There was no equivalence between these signals and the NERPM node numbers. The signals had to be spatially or manually tagged to the 2005 scenario of the NERPM master network nodes. As an outcome of this process, one or more nodes were identified as part of a single signal in the Jacksonville region. This occurred because, in a number of cases, a single real-world intersection is represented by two or more nodes in the NERPM network.

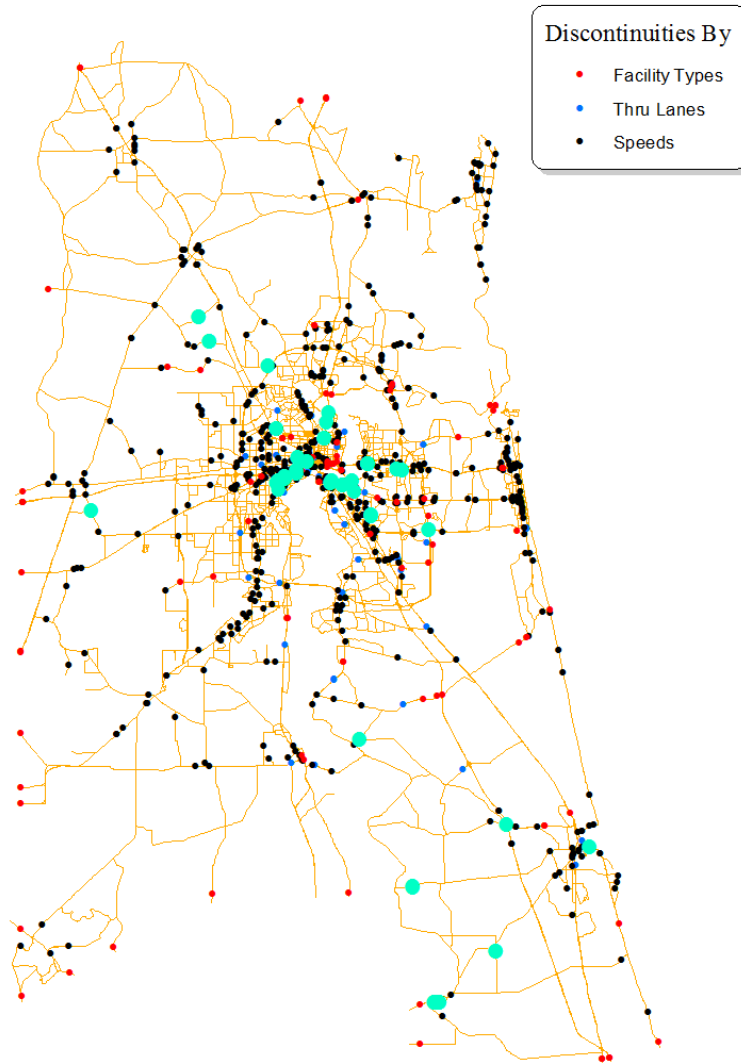


Figure 1.34. Nodes collapsed as result of removing discontinuity in link attributes.

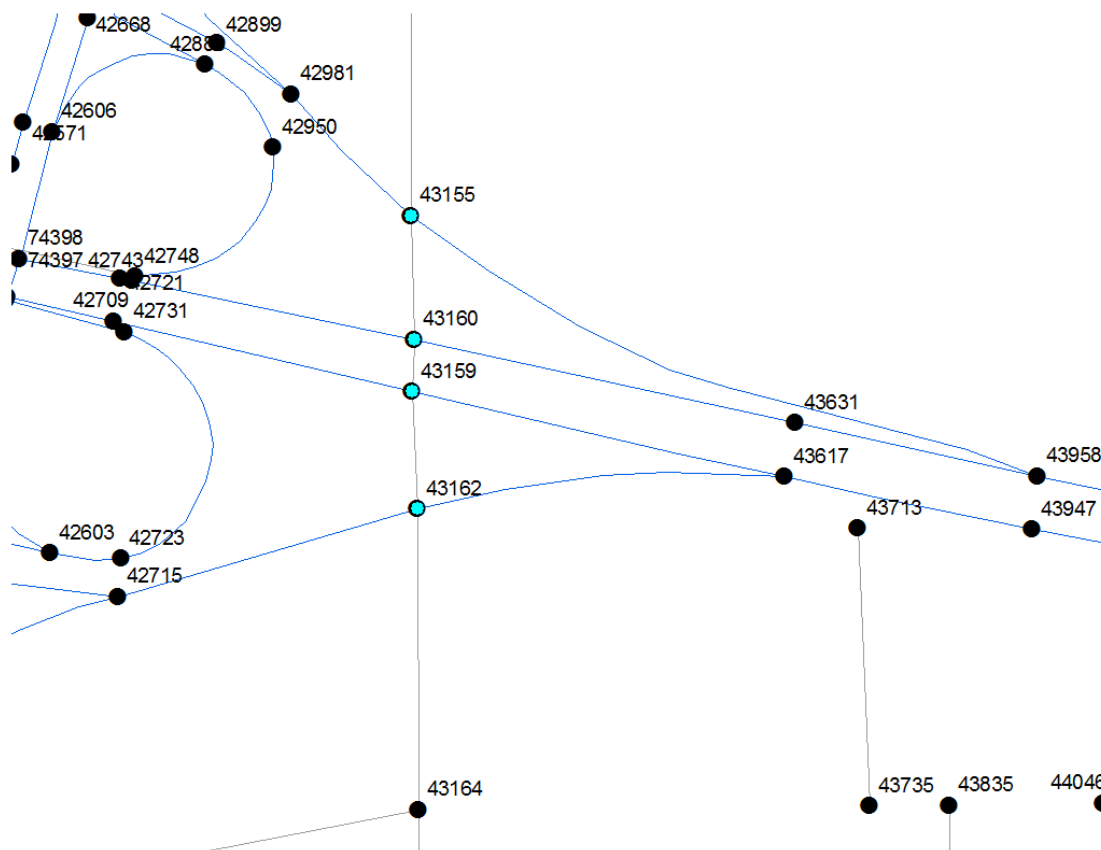


Figure 1.35. NERPM freeways intersecting with arterials because of coding errors.

For example, when a divided arterial is represented as a pair of two one-way links, the intersections are represented by two nodes.

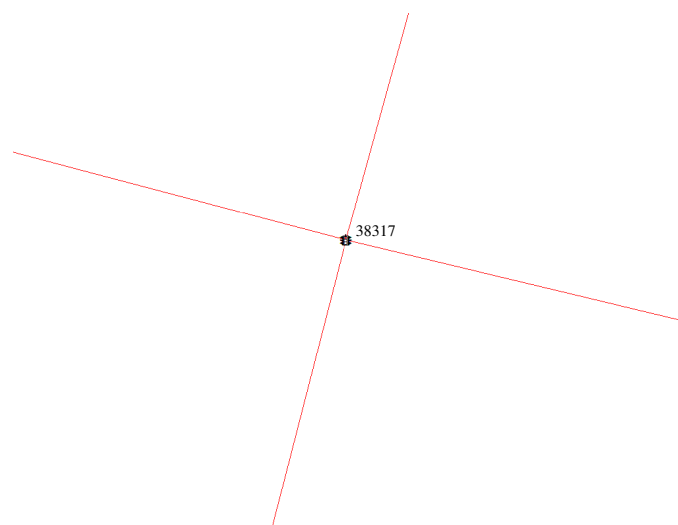
The tagging process was useful in two respects. First, it served as a direct resource for the replacement of rule-based synthetic signal warrants in TRANSIMS Version 4 network conversion across all the three network resolutions. Also, it provided for leveraging the group control feature of TRANSIMS Version 5 signal format, in which a single signal could be defined over more than one node.

The following steps describe how this process of matching FDOT signal locations with the NERPM master network (MERGED.NET) was carried out:

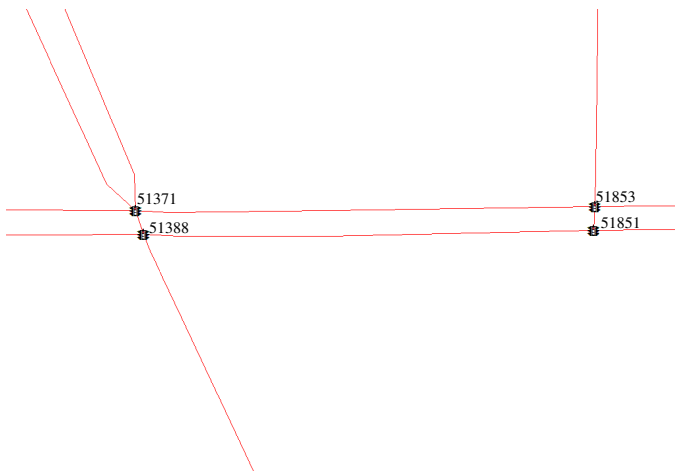
1. The merged_node and merged_link shapefiles were projected onto the coordinate system of the traffic_signal_locations shapefile, NAD_1983_UTM_Zone_17N.
2. Using a spatial join, the project team joined all of the nodes to the nearest traffic signal. A filter was used so that only nodes whose joining distance was less than or equal to 50 ft were considered.
3. When deciding which nodes should be attached to a specific traffic signal, the team used a few general cases that

came up regularly to make this decision. These cases are explained in the following examples. The red nodes indicate the nodes that were attached to the traffic signal.

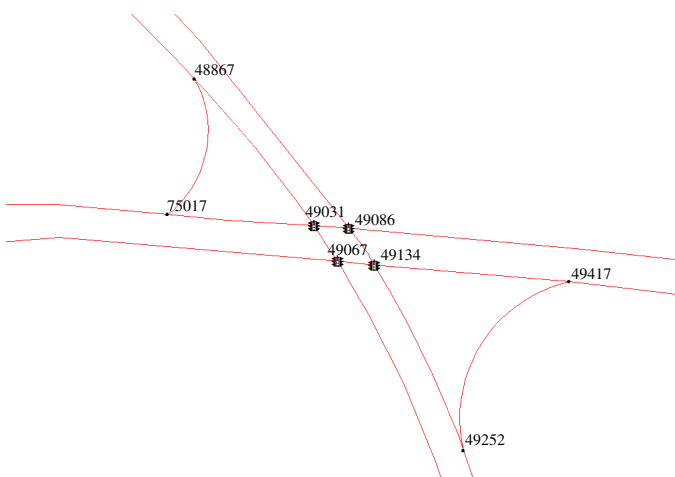
- a. If two single-link roadways intersected at a single node intersection, then only that node was attached to that traffic signal.



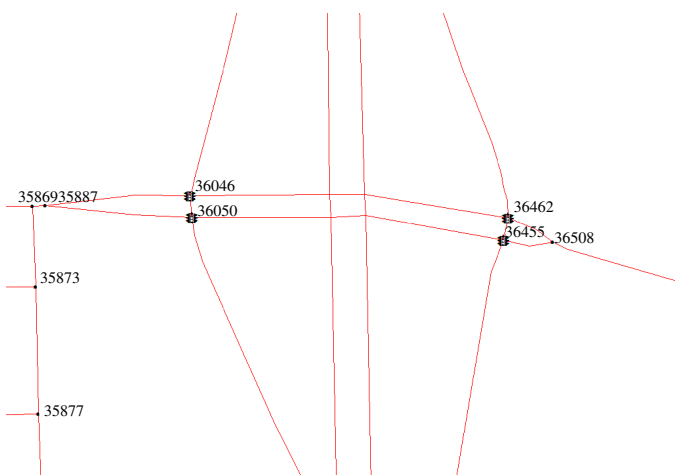
- b. If a single-link roadway intersected a double-link roadway, then the nodes at the two intersection points were attached to the traffic signal.



- c. If two double-link roadways intersected, then all four nodes of the intersection were attached to the traffic signal.



- d. Freeway on and off ramps usually had two traffic signals: one on either side of the freeway. Usually two nodes were attached to each traffic signal as shown.



Traffic signal intersections that varied from these examples were evaluated on a case-by-case basis. The intersections were examined using Google Earth, and a determination was made as to which nodes belonged to each signal. Only traffic signals with a VALUE_field of 02 were used in this mapping. Others, such as flashing beacons and school signals, were omitted. The output shapefile with mappings was formatted for use with TransimsNet.

UN SIGNALIZED INTERSECTIONS

The sign warrant creation logic in TransimsNet was used to synthesize traffic controls for the unsignalized intersections. This logic considers the facility class levels and their differences in addition to the area-type information to determine whether and what type of sign control is required for each of the approaching roadways at an intersection. The TransimsNet program allows the user to define rules for generating signal warrants and places sign warrants for the remaining intersections. Because signal location information from the FDOT data set was used, no rules were specified in TransimsNet, resulting in the creation of sign warrants for all intersections in the region. The IntControl program was later provided with the FDOT signal location-based signal warrants, and TransimsNet generated signal timing and phasing plans and sign controls for the intersections. Naturally, many conflicting sign and signal warrants resulted; signal warrants were preserved and sign warrants were discarded.

Network Conversion Process

The network conversion process starts with applying TPPlusNet to convert TP+ network formats to generic TRANSIMS link and node format. During this application, the coordinate system is also converted from Florida StatePlane 0901 in feet to UTM 17N in meters. The resulting TRANSIMS network is maintained in metric units. This process is depicted in Figure 1.36.

The TPPlusNet conversion script is critical to the conversion process. It maps the NERPM functional codes to TRANSIMS facility-type strings and populates the hourly capacity, number of lanes, maximum speed, and free-flow speed fields.

Table 1.40 shows how the TP+ functional class codes were mapped to TRANSIMS facility types.

The number of lanes coded in the NERPM network represents all-day travel lanes and excludes parking and turn lanes. In TRANSIMS, all lanes are coded along with link names and distances, which are converted from feet into meters. The generic TRANSIMS link, node, and shape files are then provided to TransimsNet along with TAZ area-type equivalence files to generate synthetic TRANSIMS network elements as shown in Figure 1.36.

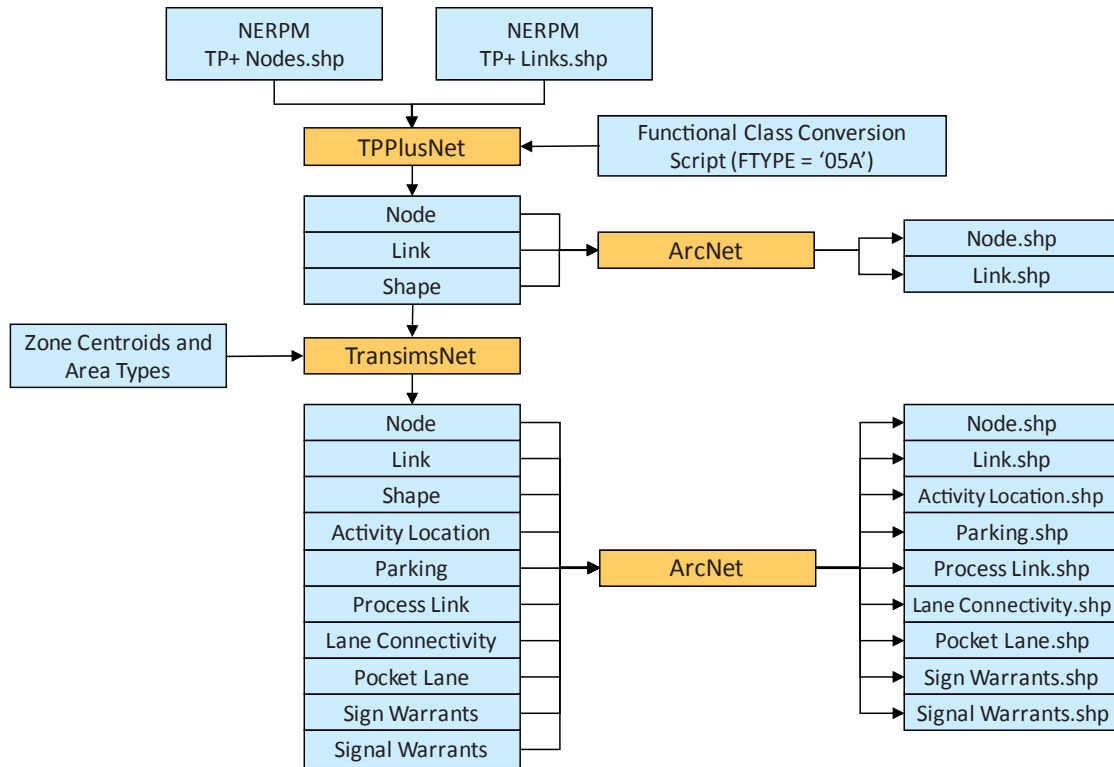


Figure 1.36. Network conversion process.

To overcome the problem of visualizing network topology at grade-separated crossings, the collapse-nodes feature in TransimsNet was used to merge homogenous links and reduce the number of input nodes that are kept in the output network. Following this step, synthetic intersection controls are created using the process shown in Figure 1.37 and the activity location fields are updated and expanded to include zonal attributes.

PLANNING Network

The PLANNING network is a network resolution including only the NERPM regional modeling links. The corresponding scenario in NERPM model is year 2005, or 05A. Only the records defined in the 05A scenario, that is, records containing nonzero values for field FTYPE_05A, were included. The resulting network, which includes 6,525 nodes and 9,864 links, is shown in Figure 1.38.

Table 1.40. TRANSIMS Functional Class Mapping

FUNCLASS Codes	TRANSIMS Facility Type
11-12, 79-84, 90-91	FREEWAY
16-17, 61, 85, 93	EXPRESSWAY
70-78, 86-89, 97-98	RAMP
20-22, 60, 94-95	PRINCIPAL
23-25, 62-63	MAJOR
30-38, 64	MINOR
15, 40-43	COLLECTOR
65-68	FRONTAGE
44-49	LOCAL
29	FERRY
50	ZONE CONNECTOR
52	EXTERNAL
92	OTHER

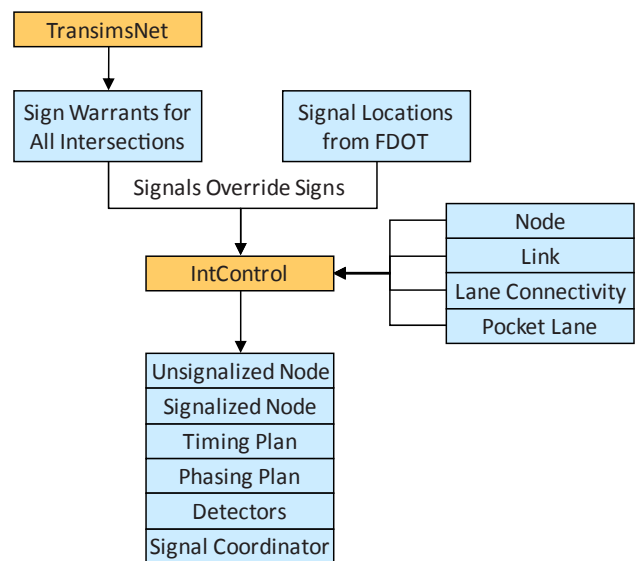


Figure 1.37. Process to create synthetic intersection controls.

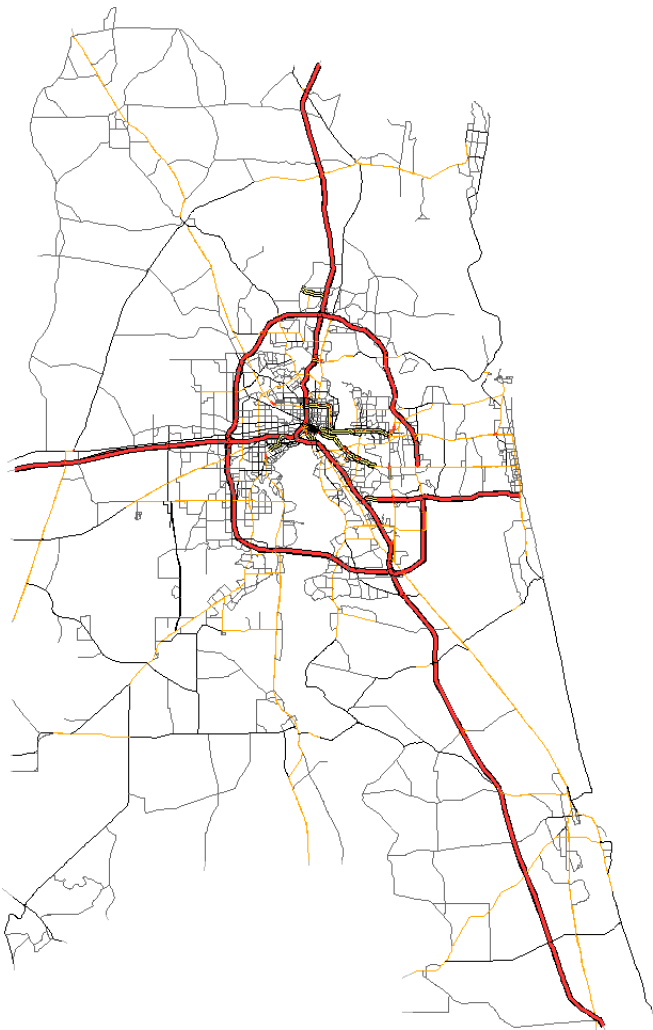


Figure 1.38. PLANNING network.

ALLSTREETS Network

The PLANNING network and the ALLSTREETS network were envisioned as the two ends of network resolution for this project. While the PLANNING network was limited to the NERPM modeling links for the 2005 scenario, the ALLSTREETS network used links that were not defined in any of the NERPM scenarios. Such links in the NERPM master network are assumed to be existing streets of very low facility class—for instance, neighborhood streets—which do not carry any significant level of traffic. These additional links were categorized as locals in TRANSIMS, equivalent to NERPM facility number 42 and marked with a common name for identification purposes (ADDON_DETAIL).

Modification of the TPPlusNet conversion script to include these additional streets was the only difference in the ALLSTREETS network conversion process compared with that of the PLANNING network. The resulting TRANSIMS network, which contains 51,420 nodes and 69,361 links, is shown in Figure 1.39.

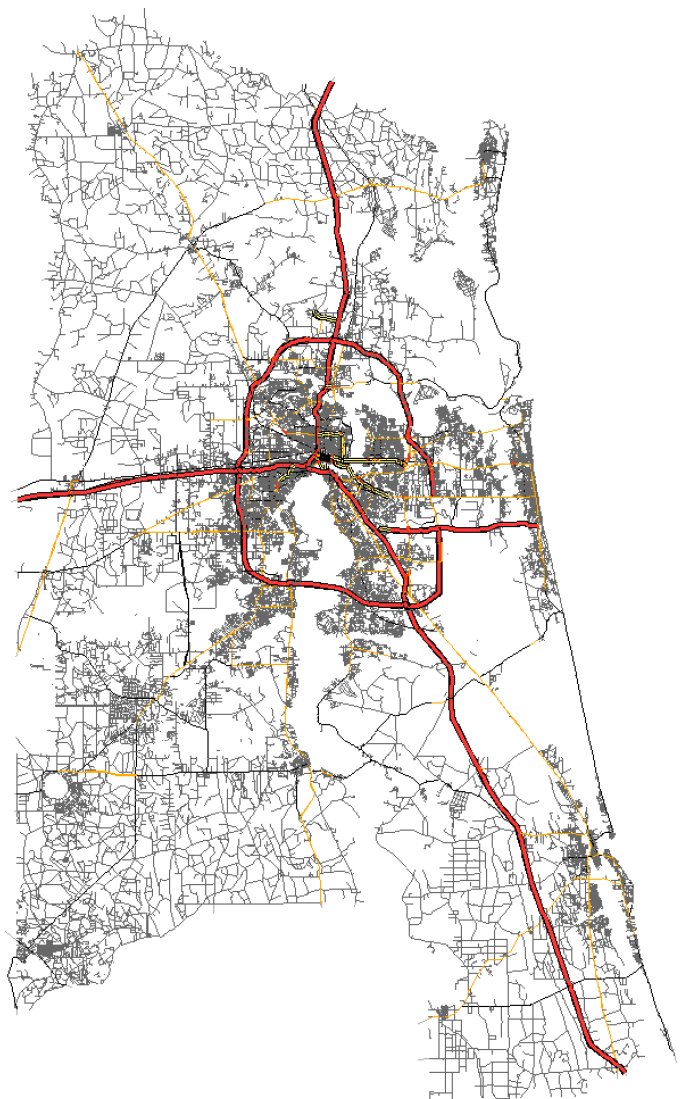


Figure 1.39. ALLSTREETS network.

FINEGRAINED Network

In accordance with one of the primary goals of this project, a fine-grained network was developed as an intermediate resolution network for greater policy sensitivity and increased fidelity without the huge computational overhead associated with the ALLSTREETS network. Since additional local through streets are the fundamental difference between the ALLSTREETS and PLANNING networks, different filtering methodologies can produce several different intermediate resolution networks.

The selection process, however, needs to address the following considerations to have any reasonable or meaningful impact on the TRANSIMS simulation process:

1. While all streets bring more realism to the modeling process, they come with heavy computational costs, potentially resulting in very large and unreasonable processing times.

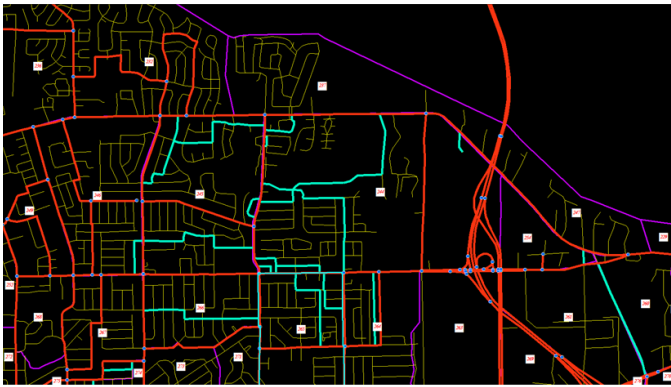


Figure 1.40. Example of qualified links.

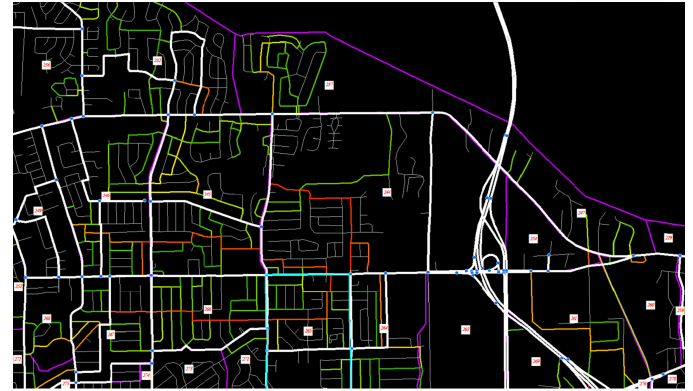


Figure 1.41. Filtering qualified links by volume levels.

2. Additionally, not all streets bring value to the TRANSIMS simulation modeling. For example, long dead-end links may provide better estimates for disaggregate travel times, but they do not affect nearby links or path alternatives; thus the simulation results would be more or less unchanged.
3. The chosen network resolution needs to strike a balance between reasonable representation of roadway accessibility and the additional burden on model processing times.

Given these considerations, the project team developed an approach that balances the mobility and accessibility factors within the project scope. The presence of additional network detail provides opportunities to consider a wider range of path options or diversions to, from, and within traffic analysis zones. Links were selected for inclusion in the FINEGRAINED network based on the frequency with which they were used on paths between zone origins and destinations.

Figure 1.40 demonstrates this conceptual approach, showing planning links in red, zone boundaries in purple, additional links in brown, and potential links for selected zones in blue based on distance-based paths built from a single zone.

Since the analysis of mobility options was the primary motivation for this approach, the PLANNING network is used as a benchmark for keeping a subset of the additional ALLSTREETS links that provided new path-diversions. Multiple levels of network resolutions can thus be created from this subset by filtering based on an accessibility score. This score could alternatively be considered a parameter for choosing the intermediate network resolution. The score would compute the percentage of the regional employment, population, and households within a given distance from roadways. Figure 1.41 shows an approach for further filtering the additional streets by examining volume levels.

This process of selecting local through streets requires building numerous paths between targeted activity locations. The TRANSIMS Version 5 program, PathSkin, with enhanced capabilities was used for this purpose.

Additionally, the project team found that deleting undesirable streets from the ALLSTREETS network was an easier way to create the FINEGRAINED network than adding selected streets to the PLANNING network. Figure 1.42 shows the process of creating a FINEGRAINED network

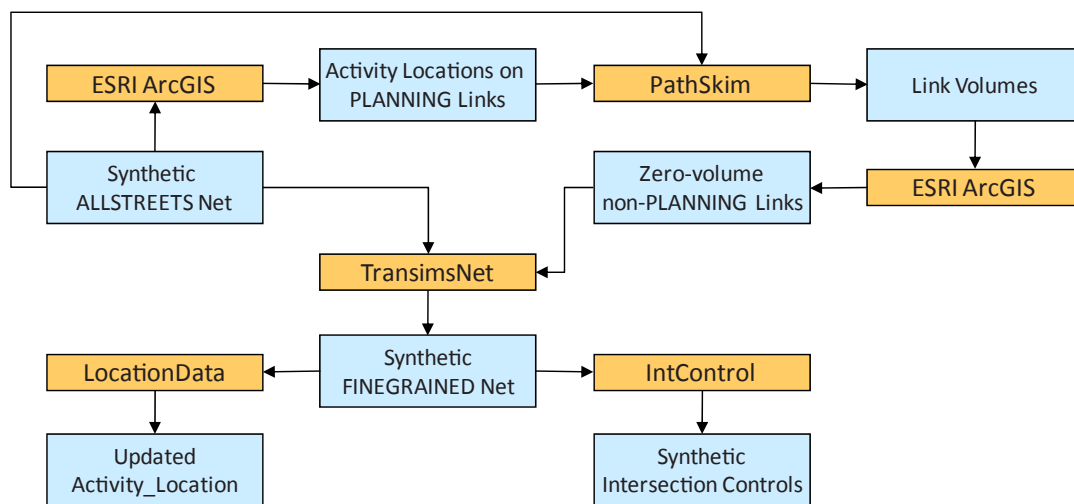


Figure 1.42. FINEGRAINED network conversion overview.

given the PLANNING and ALLSTREETS networks using PathSkim.

The accessibility scores for the resulting FINEGRAINED network were computed by measuring the Euclidean distance of each parcel in the region from its spatially nearest roadway. The distribution of employment, population, and households in the region is summarized by this distance in Table 1.41.

The FINEGRAINED network chosen for this project had the following accessibility score:

- 80% of the regional employment is within 1/10th of a mile of a modeled roadway.
- 50% of the regional population is within 1/10th of a mile of a modeled roadway.
- 50% of the regional households are within 1/10th of a mile of a modeled roadway.

Figures 1.43 through 1.45 show the employment, population, and household distributions for the PLANNING and FINEGRAINED networks.

The resulting FINEGRAINED network, which includes 10,577 nodes and 16,910 links, is shown in Figure 1.46. Figure 1.47 shows the distribution of the additional network detail in the FINEGRAINED network in contrast to the PLANNING network. A comparison of the network attributes included in the three network resolutions is provided in Table 1.42.

Network Conversion Summary

The overall network conversion process is summarized in the following steps:

1. Enable True Shape Display in CUBE using MERGED-GIS ESRI shape file and TP+ network files.
2. Export the TP+ network data files to link and node ESRI shape-file format. Note that the user is not required to perform any attribute-based filtering to create specific scenarios in this step. The entire master network is exported. The filtering process is performed in subsequent steps.
3. Run TPPlusNet to convert the TP+ link and node files to generic TRANSIMS input files. During this process a conversion script is used to translate NERPM facility-type codes, number of lanes, speeds, and capacities to TRANSIMS coding rules. Zone centroids and connectors are excluded. For the PLANNING network, records containing nonzero values for field FTYPE_05A are selected. For the ALLSTREETS network, links that are not defined in any other scenarios are included as locals and marked with a separate name. Warnings are raised if area type or lanes are not defined for such links, since those are required to obtain speed and capacity information from the speed-capacity lookup table. These warnings are

examined, and appropriate values for missing attributes are coded on the basis of neighboring links. This step is repeated until all the warnings are addressed.

4. Run ArcNet to review basic link information and network continuity related to facility types, speeds, capacities, and number of lanes.
5. Run TransimsNet with the shapes file to create the synthetic TRANSIMS network files such as pocket lanes, lane use, lane connectivity, parking lots, activity locations, process links, and signal and sign warrants. Note that rules for creating signal warrants are not provided in TransimsNet; thus the resulting signal warrants file is empty. In the absence of these signal rules, all of the intersections in the region are “filled” with sign warrants, as it were. The FDOT signal location information takes the place of signal warrants and replaces the prefilled sign warrants wherever applicable.
6. Run ArcNet to visualize and review the resulting network. The focus of this review is pocket lanes and intersection connectivity. The locations of signals and signs are typically reviewed and edited as well.
7. Run IntControl using the signal and sign warrants to generate the signal timing and phasing plans, demand actuated detectors, and sign-controlled intersections.
8. Run ArcNet again to review the traffic control data.
9. Run LocationData to post the zonal attributes to activity locations and update their TAZ numbers on the basis of the supplied TAZ boundary layer. This method uses a point-in-polygon approach to update the initial TAZ number assignment to activity locations in TransimsNet on the basis of Euclidean distances from zone-centroids.
10. Run ArcNet to visualize the resulting network.

The process used to create the FINEGRAINED network requires the output of steps 1 through 5 for both the PLANNING and ALLSTREETS networks. The process then implements the following additional steps:

1. In ArcGIS: From the ALLSTREETS network, flag all links (street name equal to ADDON_DETAIL) not part of the PLANNING network.
2. In ArcGIS: Select all activity locations in the ALLSTREETS network that are located on links included in the PLANNING network and save this list to an output file. This file will be supplied to PathSkim to create paths between activity locations.
3. Run PathSkim to build paths between the selected activity locations. This process may be time consuming ($\sim 55,000 \times \sim 55,000 = \sim 2.8$ billion paths), taking over 46 hours on an eight-core workstation. Save the output Link Delay file from PathSkim in text format without any turning movement data. Note that it is not necessary to build paths for

Table 1.41. Accessibility Computation

S. No.	Distance (m)	Distance (miles)	PLANNING							FINEGRAINED						
			Parcels	Emp	Pop	HH	% Emp	% Pop	% HH	Parcels	Emp	Pop	HH	% Emp	% Pop	% HH
1	16.1	0.01	10,385	12,333	15,294	6,264	2%	1%	1%	19,495	17,370	31,512	12,822	3%	3%	3%
2	32.2	0.02	47,365	61,108	70,707	28,651	11%	6%	6%	81,706	82,396	138,684	56,141	14%	12%	12%
3	48.3	0.03	80,569	151,652	124,839	50,505	26%	11%	11%	125,866	176,814	216,632	87,690	31%	18%	18%
4	64.4	0.04	111,272	223,312	175,343	71,028	39%	15%	15%	161,358	248,365	279,140	113,074	43%	24%	24%
5	80.5	0.05	138,861	275,838	232,602	94,367	48%	20%	20%	190,431	299,207	341,108	138,304	52%	29%	29%
6	96.6	0.06	163,117	327,106	286,118	115,977	56%	24%	24%	214,491	350,131	394,641	159,915	60%	33%	33%
7	112.7	0.07	187,394	362,727	344,530	139,612	63%	29%	29%	237,538	385,291	450,734	182,627	66%	38%	38%
8	128.7	0.08	210,519	400,430	399,719	161,872	69%	34%	34%	258,688	419,907	501,369	203,119	72%	42%	42%
9	144.8	0.09	231,568	426,750	452,307	183,124	74%	38%	38%	277,403	443,605	550,639	222,992	77%	47%	47%
10	160.9	0.10	249,946	445,855	499,480	202,156	77%	42%	42%	293,863	461,575	594,959	240,874	80%	50%	50%
11	241.4	0.15	327,751	506,998	686,590	278,188	87%	58%	58%	361,953	515,980	758,228	307,196	89%	64%	64%
12	321.9	0.20	385,118	530,225	818,972	332,153	91%	69%	69%	412,523	537,705	870,301	352,815	93%	74%	74%
13	402.3	0.25	426,539	545,337	902,178	365,841	94%	76%	77%	450,015	550,012	943,052	382,199	95%	80%	80%
14	482.8	0.30	458,811	555,324	957,838	388,304	96%	81%	81%	479,454	559,577	992,539	402,117	97%	84%	84%
15	563.3	0.35	484,129	562,376	1,005,355	407,632	97%	85%	85%	502,681	565,587	1,035,266	419,450	98%	88%	88%
16	8046.7	5.00	618,981	579,535	1,182,431	478,072	100%	100%	100%	618,981	579,535	1,182,431	478,072	100%	100%	100%

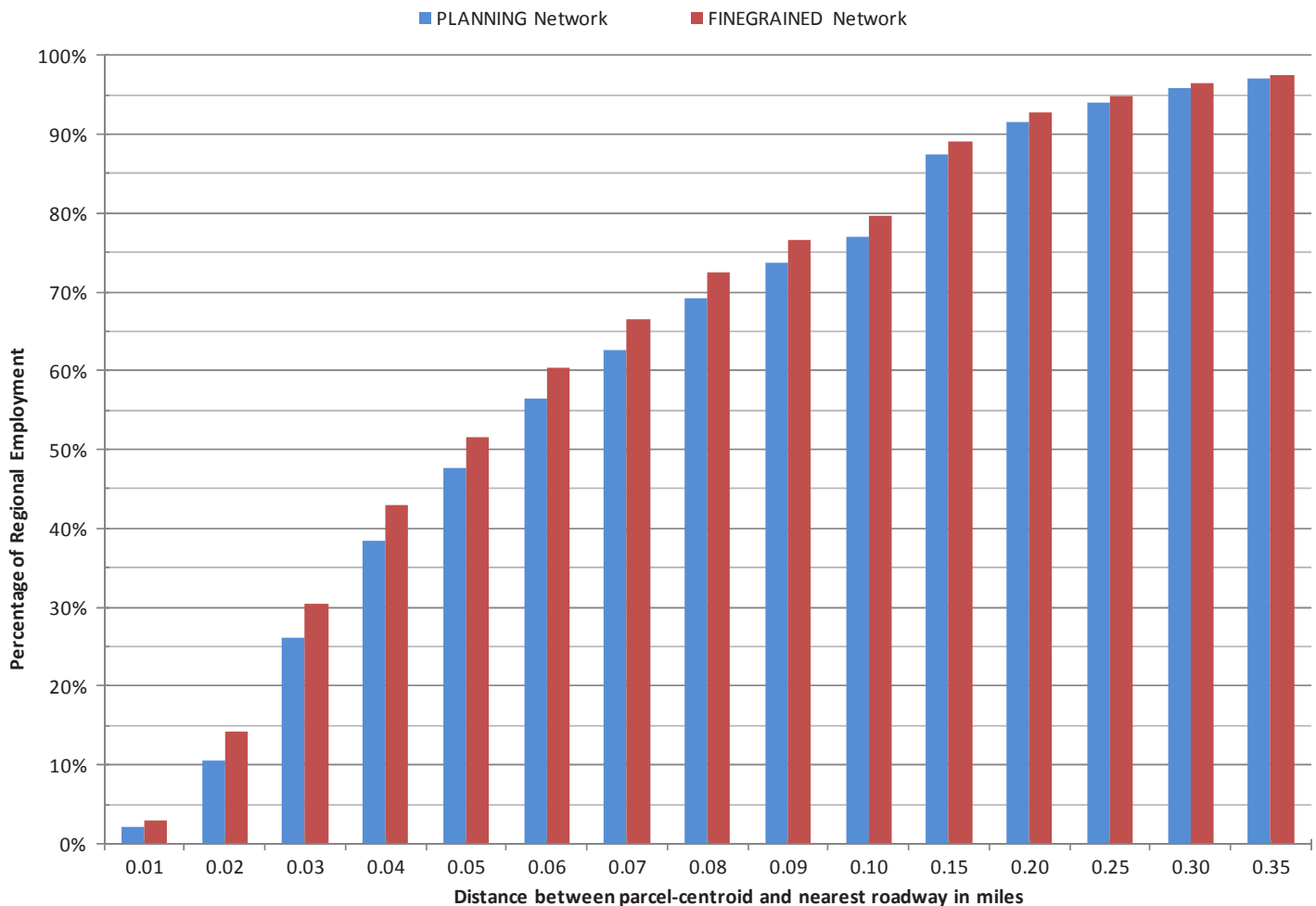


Figure 1.43. Employment accessibility.

all activity location combinations. A sufficient number of samples, approximately 10 per zone, requires much less processing time and is quite representative.

4. In ArcGIS: Join the PathSkim output Link Delay file to the ALLSTREETS link shapefile to flag all links that have non-zero volumes. Be sure to include all PLANNING network equivalent links. Flip this selection, and save the list of non-PLANNING zero-volume links to a file.
5. Run TransimsNet in Update mode with the ALLSTREETS network and a list of deleted links as input. This process deletes the requested links and their corresponding parking lots, process links, and activity locations. In addition, all nodes, links, and lane connections are also refreshed including the evaluation of sign and signal warrants.
6. Continue with steps 6 through 10 of the conversion process.

Burlington Network Development

The Burlington TRANSIMS network was developed following a process similar to that described for Jacksonville, although only

a single network was built. The TransCAD base year highway network maintained by the Chittenden County Metropolitan Planning Organization (CCMPO) for use in its daily regional travel demand model was the starting point for developing a detailed microsimulation TRANSIMS network for the region.

The 2005 base year model highway network has approximately 1,700 links and 1,300 nodes which represent the major roadway facilities in the county. Interstate I-89 is the only interstate highway in the county; it serves the 18 cities and towns in Chittenden County, most notably Burlington, the largest city in Vermont. The TransCAD base year highway network is a typical planning-level network—though the links reflect true shapes while zonal access to the street grid is modeled with centroid connectors. Table 1.43 presents the extent of roadway network coverage by facility type. Figure 1.48 presents the 2005 base year CCMPO TransCAD four-step planning model network.

Table 1.44 provides the number of records in each of the TRANSIMS network files generated by the network preparation process. The Burlington TRANSIMS network for the 2005 analysis year has 524 nodes, 779 links, and 2,608 activity

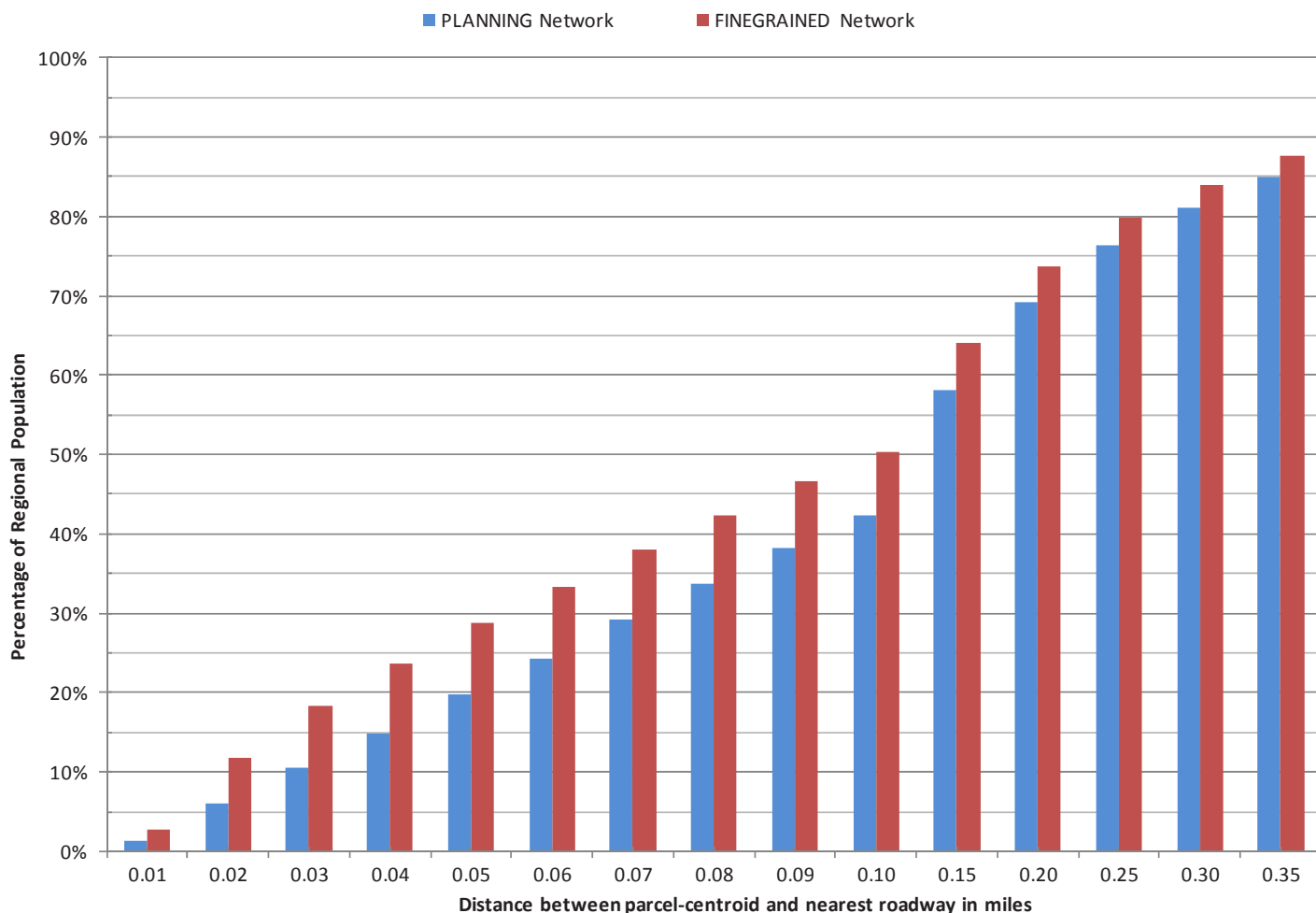


Figure 1.44. Population accessibility.

locations. To synthesize TRANSIMS simulation network data, the number of links into and out of a given node was used along with intersection logic to construct turn pockets, lane connectivity, and traffic controls—both signs and signals. Unique logic was applied depending on the facility type of the link. For instance, arterial intersections examine the relative orientation of 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 was added to accommodate the movement. Signal warrants are determined based on the number of legs and the user-specified functional class, by area type signal warrant parameters.

Activity locations were automatically synthesized using the TransimsNet utility. The program creates activity locations (loading points for TRANSIMS) along every block face separated by a user-specified location spacing variable (e.g., 100 m). Two additional criteria that dictate the placement of activity locations in the simulation network are (1) a minimum block length of 30 m and (2) no more than three activity locations per block face.

Enhancing the Synthesized Network Integrity

The automated procedure works well, but two problems typically needed to be corrected subsequent to running TransimsNet. First, in the more rural areas of Chittenden County, some traffic analysis zones in the four-step model were not associated with at least a single activity location. This typically occurred in places where the traffic analysis zone represents open land with very little road frontage and/or where the roadway network is sparse. An ArcMap overlay of the traffic analysis zones on top of the activity locations was used to manually associate TAZs with activity locations on the nearest appropriate roadway for the cases not automatically allocated correctly by TransimsNet.

The automatic synthesis of activity locations using TransimsNet can also produce loading points where, in reality, no loading should occur—for example, in the middle of highway interchanges. Rather than manually remove such activity locations, a polygon layer representing those areas was built. Geographic rules were then applied to systematically remove all locations within the undesired polygon

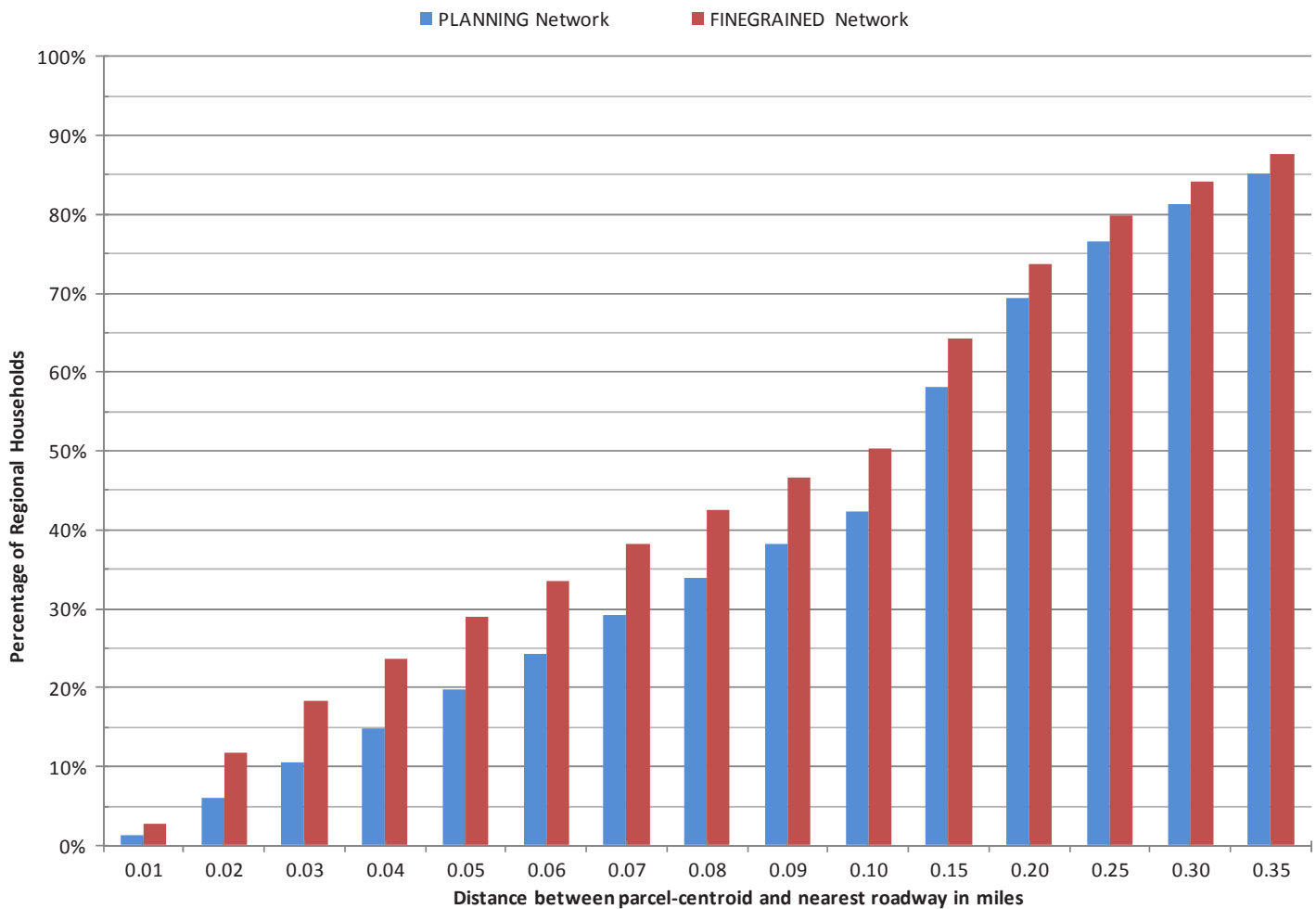


Figure 1.45. Household accessibility.

locations. This provided an automated means of importing new and future-year four-step planning networks and automatically correcting and updating the activity locations synthesized by TransimsNet.

Regional Signal Retiming

The original Burlington TRANSIMS network was developed as part of an earlier Federal Highway Administration (FHWA) TRANSIMS demonstration project. During this C10A project effort, the project team elected to review and update the fixed traffic signal timing and phasing plans developed as part of the original network development. A regional signal retiming and rephasing of the traffic signals in the simulation network was performed using the TRANSIMS utility IntControl. An automated and iterative retiming and rephasing of the traffic signal data was conducted using 90-s cycle lengths and link volumes resulting from the simulation of the increased regional demand. The signal timings and phasing were iteratively updated until link flows reached an acceptable level of calibration against observed ground counts.

Auxiliary Demand

Jacksonville

DaySim provides detailed estimates of the long-term and short-term travel choices of Jacksonville residents when they travel within the region. But this travel demand does not fully represent all trips on the regional transportation networks. Commercial and truck traffic comprise a significant share of all roadway volumes, typically up to 20% or more. In addition, nonresidents enter the region through key external gateways to access jobs, shopping, or other opportunities or they may simply pass through the region. Similarly, residents may leave the region to satisfy other needs. Special generators may also create demand not explicitly represented by person-travel-demand models.

Auxiliary demand refers to the regional demand that is not forecast by the DaySim model system but that must be represented in the Jacksonville DaySim-TRANSIMS-MOVES integrated model system to reasonably assess network performance and the impacts of different policies or improvements. Auxiliary demand is derived from the existing

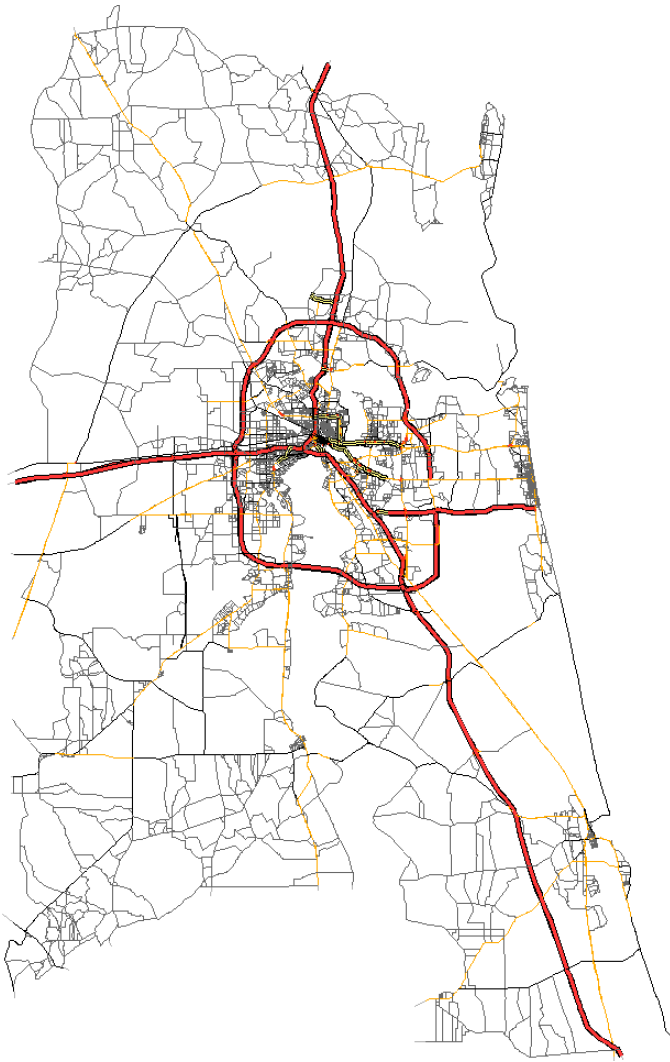


Figure 1.46. Resulting FINEGRAINED network.

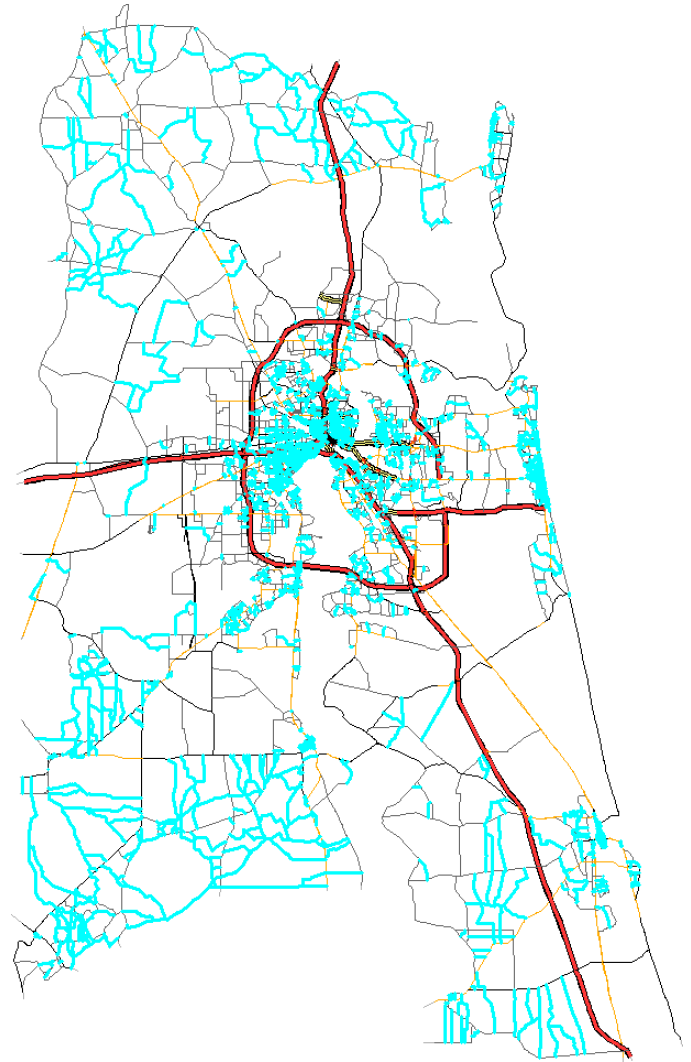


Figure 1.47. Distribution of network detail in FINEGRAINED network compared with PLANNING network.

Table 1.42. Network Attributes Comparison

Attribute	PLANNING	ALLSTREETS	FINEGRAINED
Nodes	6,519	51,305	10,577
Links	9,850	69,106	16,910
Links w/Shape Points	5,960	25,250	9,345
Activity Locations	29,272	216,246	58,846
Parking Lots	29,272	216,246	58,846
Process Links	58,544	432,492	109,692
Pocket Lanes	6,461	76,152	16,574
Lane Connections	37,758	303,106	74,302
Unsignalized Nodes	3,820	36,215	8,458
Signalized Nodes	934	1,140	1,058

Table 1.43. CCMPO TransCAD Base Year Network Lane Miles, by Facility

Facility	Links	Lane Miles	% Share
Interstate	66	166	11%
Limited Access Hwy	18	18	1%
Principal Arterial	285	159	10%
Minor Arterial	178	163	11%
Major Collector	163	174	11%
Urban Local	54	165	11%
Rural Major Collector	313	305	20%
Ramps	80	18	1%
Internal Centroid	530	325	21%
External Centroid	17	32	2%
Total	1,704	1,523	100%

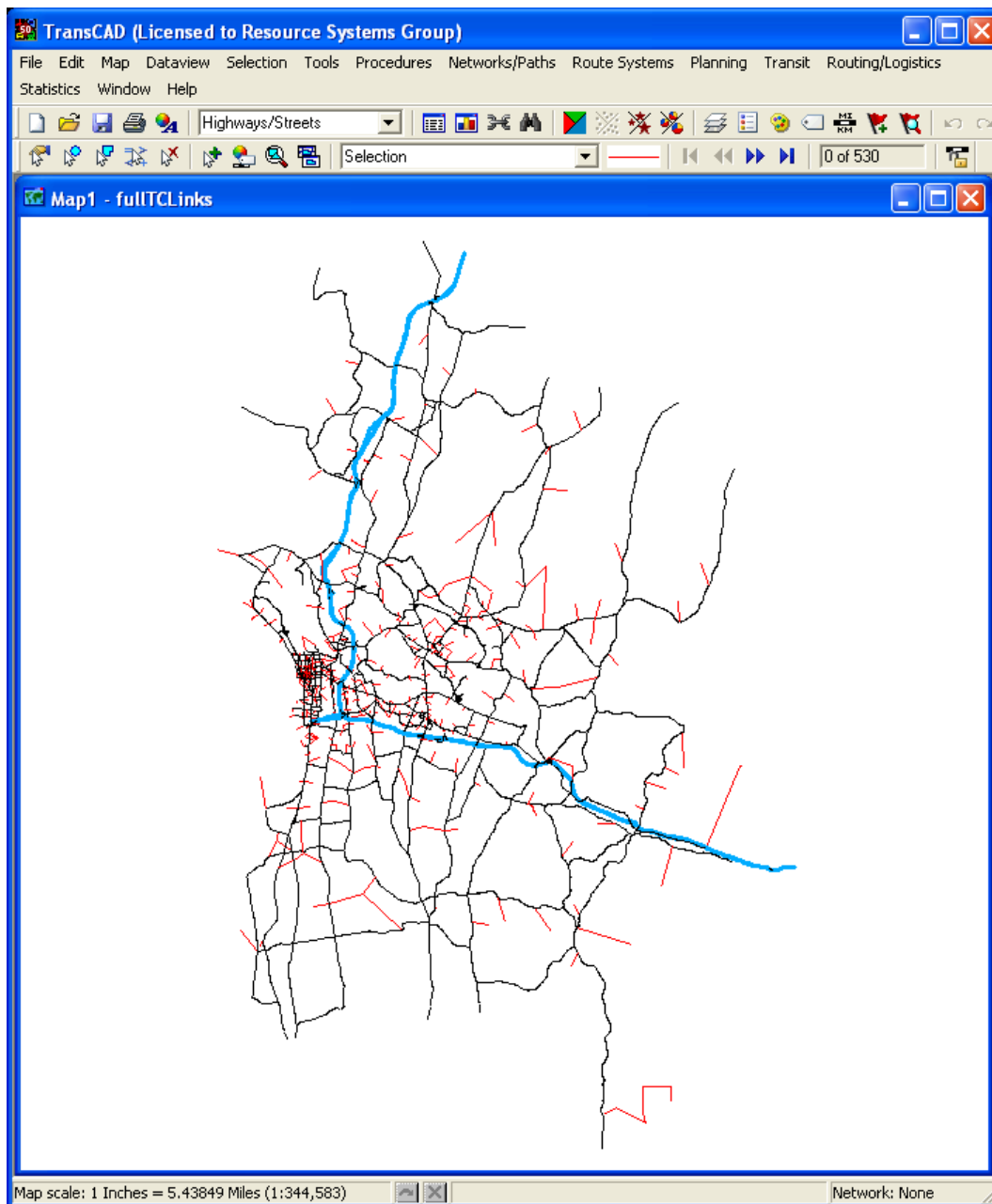


Figure 1.48. CCMPO TransCAD base year network.

NERPM model system currently used in Jacksonville, with spatial and temporal detail added to support integration with the detailed demand and supply simulation models. Because this demand is exogenous to the DaySim-TRANSIMS model system, the total demand—and the spatial distribution, mode, and timing of those trips—is fixed within a given forecast or horizon year, though of course it will vary across model run years. Network times and costs influence the routes used, however, so the network assignment of auxiliary demand is not fixed.

The auxiliary demand in Jacksonville can be generally grouped into four main classes: internal-internal commercial

vehicle trips, internal-external personal and commercial vehicle trips, external-external personal and commercial vehicle trips, and internal-internal special generators. Table 1.45 lists the demand components of each of these four main classes, the total trips associated with each component, and the relative share of total regional demand that this component represents. The table shows that auxiliary demand accounts for approximately 19% of the total regional demand in the DaySim-TRANSIMS model system, which seems generally consistent with reported practice. However, a closer inspection reveals that commercial vehicles make up about 12% of total regional demand.

Table 1.44. Burlington TRANSIMS Network Size

Network File	Records
Nodes	524
Links	779
Activity Locations	2,608
Parking Lots	2,608
Process Links	5,216
Pocket Lanes	310
Lane Connectivity	31,000
Unsignalized Nodes	328
Signalized Nodes	114

Note that, regarding special generators, the original NERPM model contains more special generators than were ultimately included in the DaySim-TRANSIMS model system (e.g., state parks, military bases, and malls). In the end, only the airport special generator was maintained in the integrated model system. In some cases, the NERPM locations were not treated as special generators because the employment and population assumptions used in DaySim generate sufficient demand. The primary examples of this type are military bases and university group quarters. In other cases, the data were not used because they contained counterintuitive patterns.

Table 1.45. Jacksonville Auxiliary Demand Summary

Auxiliary Demand Segment	Total Trips	Regional Share (%)
II four-wheeled truck	269,695	8
II single-unit truck	75,957	2
II combo truck-trailer	30,190	1
IE SOV	94,640	3
IE HOV	48,158	1
IE light duty	3,318	0
IE heavy duty	14,188	0
EE SOV	22,709	1
EE HOV	17,864	1
EE light duty	1,686	0
EE heavy duty	8,867	0
Airport	41,080	1
Total auxiliary vehicle demand	628,352	19
Total DaySim vehicle demand	2,708,077	81
Total vehicle demand	3,336,429	100

Note: II = internal-internal; IE = internal-external; EE = external-external.

The auxiliary demand was temporally disaggregated from daily numbers using the same household survey information that was used in the original NERPM trip matrix conversion process. Figure 1.49 shows the diurnal distribution of trip start times. Future refinements to this temporal disaggregation process may include using vehicle class-specific or external station-specific diurnal distributions derived from traffic counts, or using scheduled airport takeoffs and landings to impute the temporal distribution of travelers coming from or going to the airport. The auxiliary demand should also be disaggregated spatially from TAZs down to TRANSIMS activity locations, which are the fundamental spatial units used in the TRANSIMS network assignment process. The subzone distribution of the trips is based on simple activity-location weights, though additional refinements—such as the use of size variables reflecting employment and population—can be easily implemented.

Component Integration

A key goal of the SHRP 2 C10A project is implementing the integrated demand-supply model in a dynamic modeling framework in a way that is easily transferable to local jurisdictions for policy analysis. In support of this goal of transferability, the model system incorporates a system manager that controls the execution of the three primary model system components: DaySim, TRANSIMS, and MOVES.

The model system manager, TRANSIMS Studio, is a Python programming language–based integrated development environment (IDE) built specifically to run TRANSIMS Version 4 applications. It has two basic components: (1) a Python-based library called Run Time Environment (RTE) and (2) a full-featured Python GUI. The RTE is at the core of TRANSIMS Studio and is responsible for executing a series of TRANSIMS programs and external programs such as DaySim and MOVES in an iterative modeling framework. The GUI is fully featured, allowing users to manage and view input and output files, develop program controls and processing scripts, and track model execution status.

The TRANSIMS Studio model manager is configured to do the following:

- Run on Windows or Linux.
- Run on stand-alone or clustered computers (e.g., TRACC).
- Run Jacksonville or Burlington models.
- Run tour-based (DaySim) or trip-based models (converted static demand).
- Start the assignment process from free-flow speeds (cold start) or from the loaded speeds of a previous assignment (warm start).

Figure 1.50 illustrates the configuration of the integrated model system components.

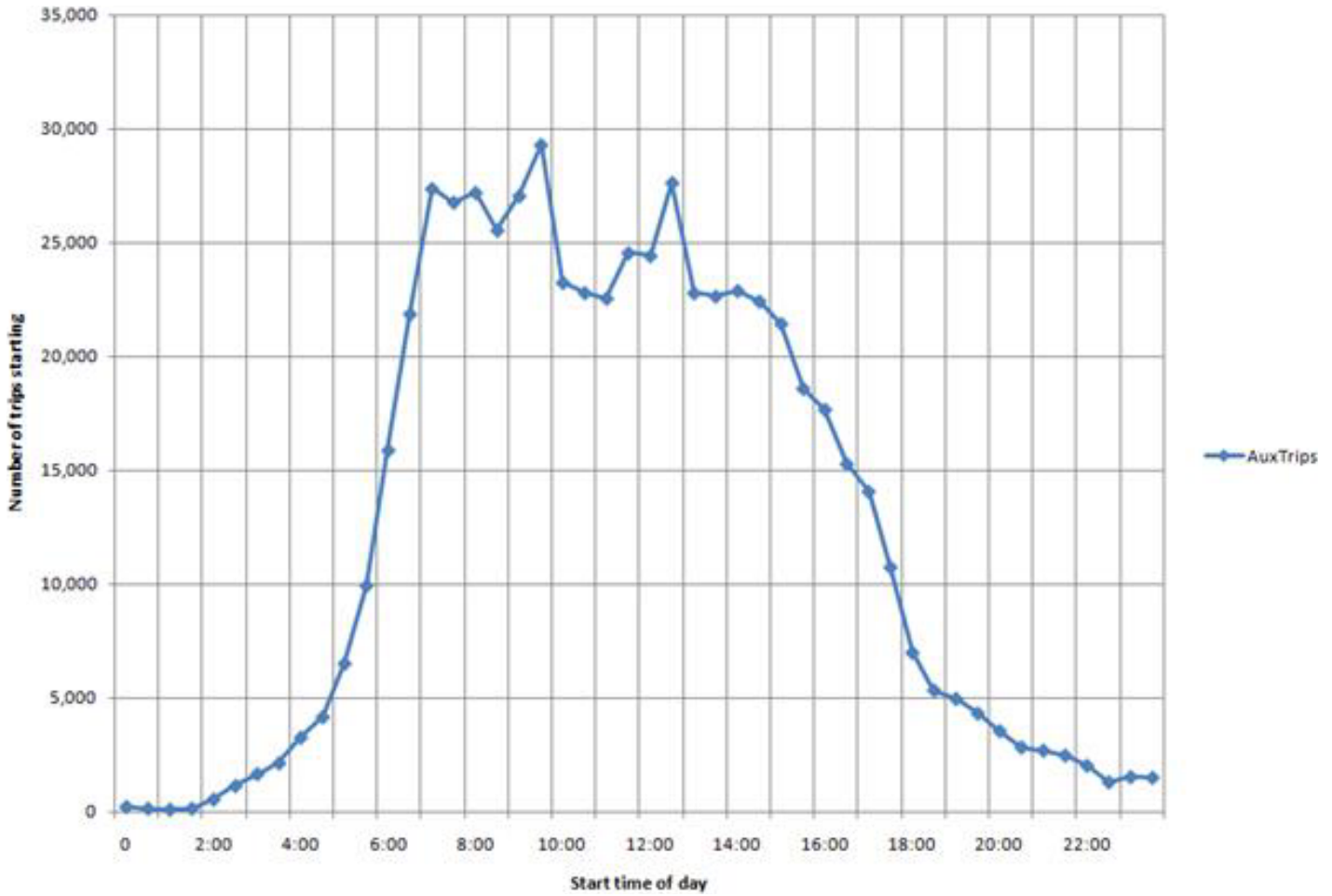


Figure 1.49. Jacksonville auxiliary demand time-of-day distribution.

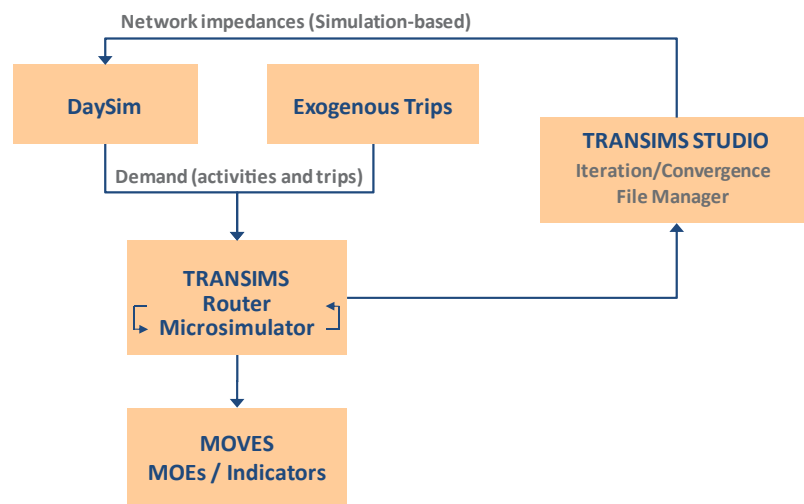


Figure 1.50. Integrated model system components.

Studio Components

The integrated model implemented in TRANSIMS Studio comprises four software components:

1. TRANSIMS Studio user interface and application management software;
2. TRANSIMS and DaySim modeling software;
3. Python scripts that define the modeling process; and
4. A folder structure housing network and other input data.

The modeling scripts and input data sets for Jacksonville, Florida, and Burlington, Vermont, are a deliverable of this project distributed through SHRP 2. All of the software components are available free of charge from the following open-source websites:

- The TRANSIMS Studio software can be obtained from <http://sourceforge.net/projects/transimsstudio/>.
- The latest TRANSIMS modeling software can be obtained from <http://sourceforge.net/projects/transims/>.

The modeling package consists of two primary folders: (1) a folder containing the TRANSIMS and DaySim software and (2) a folder containing all the model data. Figure 1.51 shows the folder names created for this project. The model uses the concept of relative-paths which makes it easy to move the modeling package folders without having to set the full system paths in every control file. File paths also use the Linux directory convention to enable the programs to run on both Windows and Linux operating systems without modification. Thus the user can easily set up the model and also easily repackage or move the model folders.

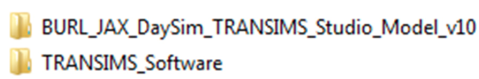


Figure 1.51. Model package folders.

The model data folder is further subdivided into a folder named “RTE” and a folder containing the actual model data. Figure 1.52 and Figure 1.53 show the condensed and expanded subfolders inside the model folder.

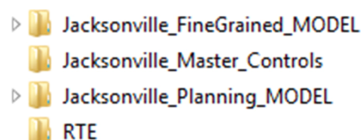


Figure 1.52. Model folder structure.

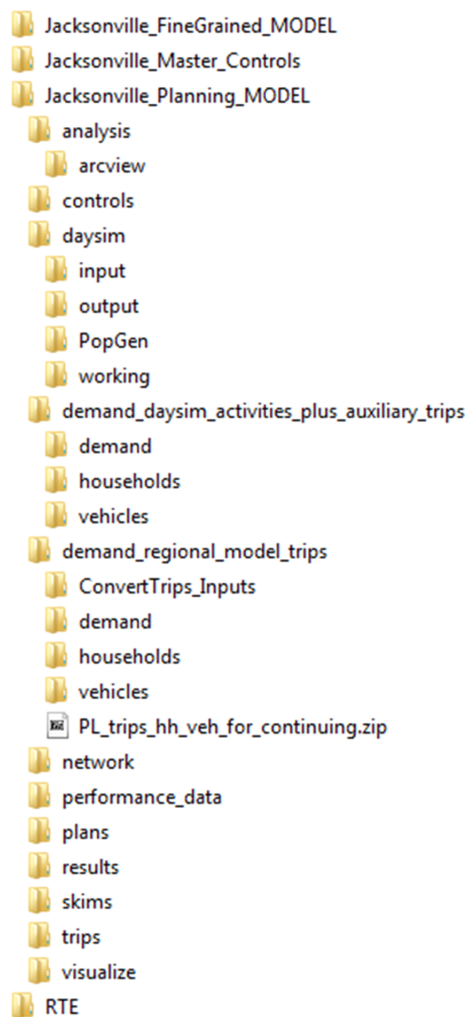


Figure 1.53. Expanded model folder structure.

All of the Python scripts used in the model are placed under the RTE folder. The following is a brief description of the purpose and functionality of each script:

1. *SysDef.py*. This script is the central location at which configuration keys that affect the entire model are defined. Changes to this script are usually performed only at the beginning of a model run. This script inherits relevant standard Python libraries and is inherited by each of the other scripts.
2. *Main.py*. This script defines the various procedures and software steps used to perform global and assignment iterations. This is the only script that is actually executed as part of a model run. It inherits all model definitions and global variables from *SysDef.py* and functions from other scripts.
3. *AssembleSkims.py*. This script defines the process for creating free-flow or loaded speed zone-to-zone skims for 22 time periods as input to DaySim.

4. *DaySim.py*. This script runs DaySim and prepares the DaySim outputs for input to TRANSIMS.
5. *MsimIterations.py*. This script defines the steps involved in a TRANSIMS assignment iteration.
6. *MiscUtilities.py*. As the name indicates, this script contains several miscellaneous procedures. These include the startup procedures and various data processing functions.
7. *VisualizerPrep.py*. This script prepares the microsimulator outputs for visualization using TRANSIMS-VIS.

In addition to the Python scripts, which are identified by the “.py” extension, a number of other file types are created during the course of model execution. These include the following:

1. “.pyc” or compiled Python script;
2. “.gui” for display in the navigator pane of TRANSIMS Studio;
3. “.log” for display in the execution log window of TRANSIMS Studio;
4. “.pfm” for TRANSIMS Studio management;
5. “.pid” for recording the process ID;
6. “.job” for model execution commands; and
7. “.res” for files that contain the information for resuming a model run.

A batch file is provided in the same folder to help remove temporary files created during model execution. However, the batch file is intended to be run only when a model needs to be started afresh because it clears all model logs and tracking information.

The TRANSIMS Studio settings are saved in a file with a “.prj” extension, which is also saved in the RTE folder. This file is also called the TRANSIMS Studio project file.

Application Options

The model scripts were designed to store key model parameters and application options in a central location—SysDef.py—and to reference those parameters across all other scripts, using the high-level processing steps defined within a single application script—Main.py—which controls the model execution and data flow. In addition, the procedures included in all Python scripts except Main.py are encapsulated within one or more functions to facilitate the “resume” feature of TRANSIMS Studio. Functions that perform small limited tasks help break down the complex model flow into simpler substeps, thus simplifying the process of tracking and resuming from a substep after an abnormal execution termination.

A typical application of the modeling process involves decompressing the model package at a certain location on the local or network drive, opening the TRANSIMS Studio software, and loading the TRANSIMS Studio project file by

navigating to the RTE folder inside the model package. Then the user opens SysDef.py in the navigator pane to confirm or edit the folder paths and model variables. Next, the user opens Main.py from the navigator pane to check the number of global and assignment iterations. After everything is set, the user presses the *play* button for the Main.py script to launch a model run.

Information is shared between the scripts by means of variables that are declared within the scope of RTE. The variables are prefixed with the term “var.” and are globally accessible across all scripts that import the script where these variables are defined. For instance, *the link delay resolution* is defined inside SysDef.py script as “var.LINK_DELAY_RESOLUTION” and is used within MsimIterations.py for generating controls for TRANSIMS programs. This variable is coded inside a master control file by replacing the prefix, “var.,” with the symbol, “@,” and adding the same symbol as a suffix to the variable name. Thus, “var.LINK_DELAY_RESOLUTION” is referenced in a master control file as “@LINK_DELAY_RESOLUTION@.” This functionality helps dynamically adjust control key values, if required, during TRANSIMS applications.

For the assignment iterations, the user can choose between the default simulation-based iterations or skip simulation and perform only Router-based iterations by relying on volume-delay functions (VDF) in lieu of simulation-based delays. The following two model parameters are used to switch between Router-based iterations or Microsimulator iterations.

1. Router-based iterations (planning mode):
 - a. var.MODEL_ASSIGNMENT_OPTION = 'No_Simulation'; and
 - b. var.SKIMS_LINK_DELAY_SOURCE = 'Router_Based.'
2. Microsimulator-based iterations (planning + operations mode):
 - a. var.MODEL_ASSIGNMENT_OPTION = 'Default'; and
 - b. var.SKIMS_LINK_DELAY_SOURCE = 'Msim_Based.'

Other model parameters defined in SysDef.py that affect the TRANSIMS supply-side model are shown below along with their default values and a description of their impact on the modeling process:

- var.NUM_PARTITIONS = 8
This variable defines the number of partitions (.t*) to be used in the model. Partitioning helps use multiple cores across one or more machines, depending on the resources dedicated for the job. Partitioning primarily helps in the application of the Router and PlanPrep programs by enabling tasks to be performed in parallel. When running the model on a single machine, this value is set equal to the number of cores available on a machine. A default value of 8 is provided, corresponding to a modern workstation with eight cores.

- `var.NUM_PATHSKIM_THREADS = 8`
This variable applies only to the TRANSIMS Version 5 software PathSkim, which is used to create skims. It specifies the number of threads to use in its application. A default value of 8 is provided, corresponding to a modern workstation with eight cores.
- `var.MAXIMUM_PERCENT_SELECTED = 10`
This parameter applies to the PlanCompare program and defines the maximum percentage of regional trips to be changed per iteration. Large changes during iterations tend to have a destabilizing effect on the model convergence; thus an upper limit of 10% is provided as a default.
- `var.WEIGHTING_FACTOR = 1`
This parameter applies to the LinkDelay program and defines the value for the `PREVIOUS_WEIGHTING_FACTOR` key in that program. It defines the weight for the previous link delay during the link delay averaging process. A value of 1 implies equal weights or simple averaging; a value of 2 implies a weight of 2/3 for the previous link delay and 1/3 for the current link delay.
- `var.NUM_DELETE_PREVIOUS_RUN = 3`
TRANSIMS assignments produce several gigabytes of data per iteration. A simulation-based Jacksonville model produces in excess of 7 to 8 gigabytes per iteration. Because the intermediate iterations are not normally saved, this variable allows users to retain only the last few iterations at any time to conserve hard disk space. When set to “3,” the three most recent iterations are preserved and the model deletes the fourth most recent iteration at the end of each assignment iteration. This deletion feature can be turned off so that all intermediate iterations can be preserved by setting the variable to a number greater than or equal to the number of expected assignment iterations.

DaySim Demand Component

All the inputs, controls, intermediate files, and outputs of DaySim reside under the “daysim” folder of the model as shown in Figure 1.54. The input skims and output activities are processed and copied into and out of this folder for interfacing with TRANSIMS.

As discussed earlier, the calls to the DaySim process are placed from within the `Main.py` script, while the actual procedures for running DaySim are defined inside the `DaySim.py` script. Initial skims for the first DaySim run are prepared using a call to the `AssembleSkims.py` script. The user can choose to create these initial skims on the basis of free-flow speeds or a link delay file. The details of the skim generation process are discussed in the Time Period Skims section.

The DaySim demand creation process starts by running the DaySim executable using the initial skims in an iterative loop to prepare shadow-prices and subsequently executes the entire DaySim model system.

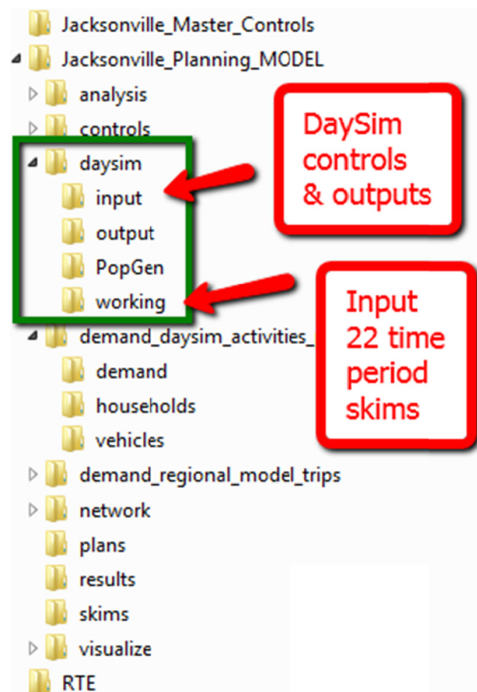


Figure 1.54. DaySim folders.

DaySim produces an activity file and a vehicle file in TRANSIMS Version 4 format. For the Jacksonville region, the process takes approximately an hour of computer processing time. The resulting activity file includes the internal travel demand generated by regional households. This demand is combined with the auxiliary trips to represent the complete travel demand for the region. To this end, the script combines the internal and auxiliary vehicle files and places the output in the “vehicles” subfolder of the “demand_daysim_activities_plus_auxiliary_trips” folder. The activity file is copied to its “demand” subfolder. The DaySim activity file does not need to be merged with the auxiliary trip file because TRANSIMS programs, especially the Router, are able to read both the activity and trip files and process them in the same application.

Copies of DaySim activity and vehicle files are preserved from each global iteration for convergence analysis purposes.

TRANSIMS Supply Component

The TRANSIMS supply-side model assigns the DaySim internal demand and auxiliary trips on the TRANSIMS network through assignment iterations designed to achieve dynamic user equilibrium convergence of the individual travel paths. The resulting network performance by time of day is used to generate zone-to-zone travel time, distance, and cost skims for 22 time periods for input into the next global iteration.

TRANSIMS models demand as trips between an origin and a destination activity location (i.e., link offsets) at a specific time of day (i.e., seconds). The Router builds a minimum

impedance path between the origin and destination based on time-dependent link travel times and turning movement delays. The paths or travel plans for all of the trips over a 24-hour period are loaded onto the network and simulated by the Microsimulator. The Microsimulator considers traffic signal timing, lane changes, and vehicle interactions in estimating the volume and travel time on the network at any point in time. These data are aggregated by link and time period for feedback to the Router for path adjustments. The process continues until most travelers cannot improve their travel time by changing paths.

The temporal resolution of the link delays has traditionally been 15 min, but this model typically uses 5-min link delays and has been tested using 2-min link delays and interpolated link delays. The appropriate time increment for link delay summaries depends significantly on the simulation methodology. The TRANSIMS Microsimulator uses a cellular automata method that moves vehicles between link-lane cells on a second-by-second basis. A 6-m cell size was used for this model. This has the effect of limiting the instantaneous speed of a vehicle at any second within the simulation to one of seven values (i.e., 0, 6, 12, 18, 24, 30, and 36 m/s). This means that a relatively large number of vehicle-second observations are required for a given link to generate a reasonable average speed. Average speeds generated using 5 min of data appear to generate the best results.

Startup

To get the assignment process started, a startup script is used to separate the steps that either are applied only once during the model execution or require special considerations because of the lack of a previous iteration. The startup procedures are implemented as functions within the MiscUtilities.py script. This step or function is executed at the beginning of every global iteration before commencing assignment iterations and is run only once.

The primary steps executed at this stage are as follows:

1. Partitioning the regional households;
2. Building all-or-nothing (AON) paths for each trip on the basis of free-flow speeds or loaded speeds from a previous model application;
3. Creating link delays by time of day on the basis of volume-delay functions; and
4. If appropriate, averaging the link delays with the results of the previous model run.

This process is depicted in Figure 1.55.

One of the most significant steps at this stage is the partitioning of households because it affects the rest of the model execution and the overall processing time. A higher number of partitions typically implies lower processing times for partitioned programs such as Router and PlanPrep. However, the

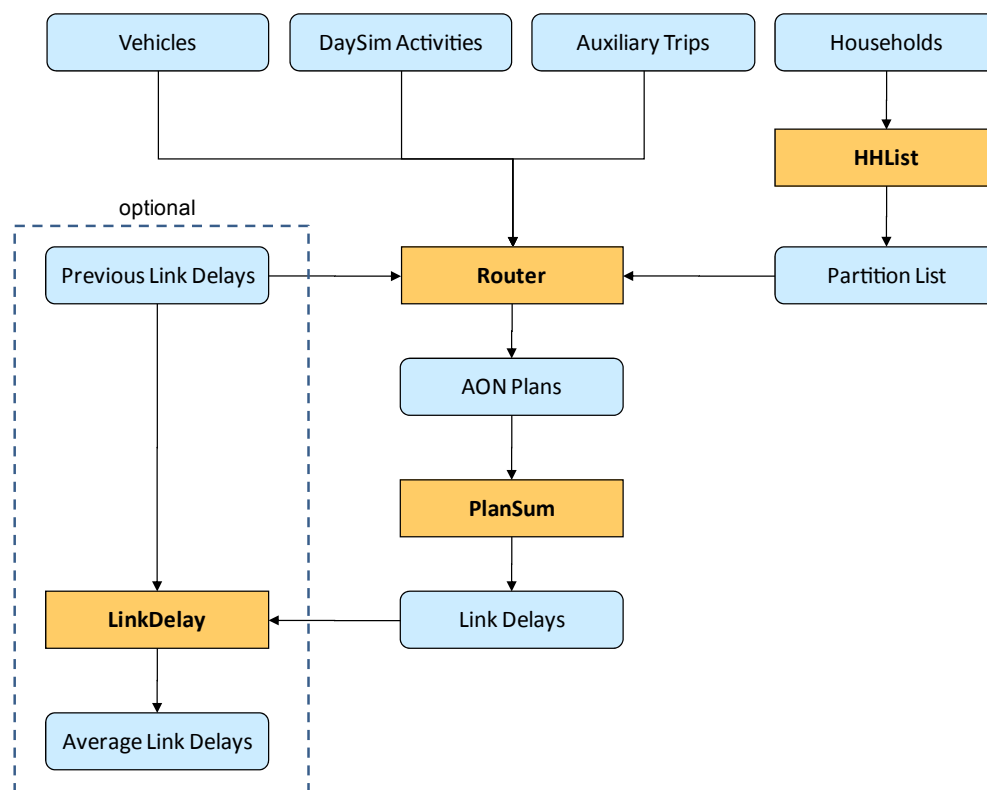


Figure 1.55. TRANSIMS assignment startup.

number of partitions can be specified independent of the number of machines/threads or nodes at the user's disposal. When the number of partitions is specified higher than the number of machines/threads, TRANSIMS Studio processes the partitions as sequential sets of applications according to the number of machines/threads available. For example, if 18 partitions (“tAA” through “tAR”) are processed on a machine with eight cores, the first set of eight partitions (“tAA” through “tAH”) is processed first, followed by the second set of eight partitions (“tAI” through “tAP”); finally, the remaining two partitions (“tAQ” through “tAR”) are processed using only two threads while the other six threads remain idle. Therefore, for maximum efficiency, the number of partitions should be set equal to or an integer multiple of the number of machines/threads available.

In the tour-based model, the HHLIST program reads the household or traveler lists generated by DaySim and the auxiliary trip model to compile a master list of all travelers in the region; it then randomly distributes each traveler into a specific partition file. All trips made by a household are processed within the same partition. In the trip-based model, all regional trips are stored in a single file, and each trip is assigned a unique household number. The trips are partitioned according to the household trip number.

Equilibrium Convergence

Convergence is necessary 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 is essential to support planning and engineering analyses, and changes to demand or supply should lead to reasonable changes in model outputs.

In the context of an integrated demand and network simulation model system, an essential precondition for pursuing the overall model system is establishing network assignment convergence. Network convergence is analogous to model system convergence—the inputs to the network assignment process (the current traveler paths that give rise to the current network costs) must be approximately equal to a set of new best paths that are based on these current network costs.

A key focus of the C10A effort has been identifying and testing different strategies for achieving both network assignment convergence and overall model system convergence within the context of the DaySim-TRANSIMS integrated model. This section describes the user equilibrium convergence, or gap, calculation procedures employed in the TRANSIMS supply-side model. These procedures are run at the end of every iteration and do not influence the model assignment procedures.

Two gap measures have been defined and employed in this model: *relative-gap* or link-based-gap and *trip-gap* or traveler-based-gap measures. The relative-gap measure is equivalent to the widely used network link-based-gap measure in conventional deterministic travel demand models. The trip gap is a newer measure enabled by the detailed information about individual travelers available within a disaggregate model like TRANSIMS. The trip-gap concept is further divided into three estimation methods identified as reskipped, event-based, and hybrid. The event-based and hybrid trip-gap methods require the Event file from the Microsimulator and therefore are not applicable in the Router-only assignment methods. For Router-only iterations, the model automatically switches the trip-gap measure to the reskipped method.

Microsimulation-Based Equilibrium (Planning + Operations Mode)

The project team has extensively investigated and tested methods for achieving dynamic user equilibrium in the context of the TRANSIMS Router and Microsimulator. This work has been done in coordination with a parallel FHWA-funded TRANSIMS deployment effort researching convergence and other issues associated with advanced integrated travel demand model systems. As part of this parallel effort, a peer review panel organized by the FHWA reviewed the C10A integrated model process and identified refinements that ensured the methods implemented were consistent with current practice. A key strategy related to convergence that the peer exchange panel deemed acceptable was to average Microsimulator link delays to dampen oscillation effects but simulate the full set of AON paths during each iteration. This application approach is depicted in Figure 1.56.

This method involves generating a new set of plans for each traveler at each iteration based on average simulated delays and simulating those plans. A key concern is the ability of the Microsimulator to realistically simulate AON paths. However, empirical tests of this method in both Jacksonville and Burlington confirmed that the Microsimulator can simulate AON paths without creating significant congestion problems. Because each traveler has a unique AON path between activity locations, starting at a specific time of day sufficiently distributes the paths to avoid the types of AON assignment problems typically experienced by traditional modeling frameworks. These results appear to hold even with large increases in demand.

Router-Based Equilibrium (Planning Mode)

Microsimulator-based iterations are the preferred method of performing a user equilibrium assignment using TRANSIMS, but they are not the only way. The Router-only iterative process used in the model system planning mode is similar to the Microsimulator-based iterative process, but it uses traditional

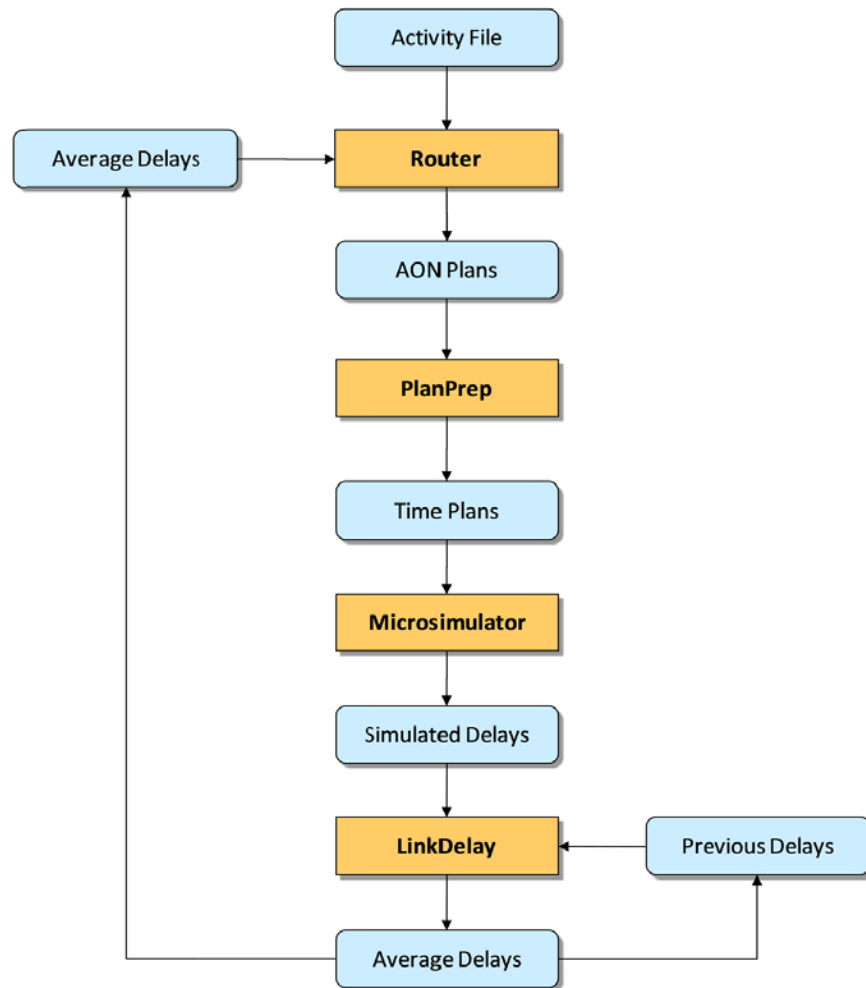


Figure 1.56. Microsimulator-based equilibrium process.

VDFs for computing link delays rather than the second-by-second simulation of individual vehicles. Thus, the Router-only process does not consider traffic signal operations, lane changing, or vehicle interactions. It simply takes user-provided link capacity and estimated volumes to calculate the link travel time for each time increment. In this case, volume is estimated by tracing the location of each vehicle at any given time using the trip path and start time stored in the travel plan file.

The primary reason for using Router-only iterations for all or some of the assignment process is the time saved. The Microsimulator is computationally complex and therefore the most time consuming step in each iteration. The Microsimulator performance is further complicated because it is a single-threaded program in TRANSIMS Version 4 and cannot be partitioned. As a result, the Router-only approach can perform an assignment iteration in approximately one-tenth of the time required for a Microsimulator-based iteration. This makes the Router-only process attractive for initializing estimates of link travel time before performing

Microsimulator-based convergence or as a substitute for simulation for applications that can tolerate less rigorous analysis or are not focused on traffic operations.

As with the Microsimulator-based process, the Router-only iterations can be implemented within TRANSIMS in two fundamental ways. The primary method used in this project is shown in Figure 1.57 and is conceptually consistent with a traditional assignment process. An AON path is built in accordance with the previous link delays, and the resulting volumes are converted to travel times using a VDF. The link delays are averaged using a weighted average or method of successive averaging (MSA) technique for input to the next set of AON paths. In this case the averaging technique is critical to managing the stability of the assignment and the convergence process.

Alternative approaches to seeking convergence are also feasible. One is an incremental assignment approach that compares an AON routing of each traveler with a reskinned version of the previous path and selects a subset of trips with large travel time and impedance differences for inclusion in

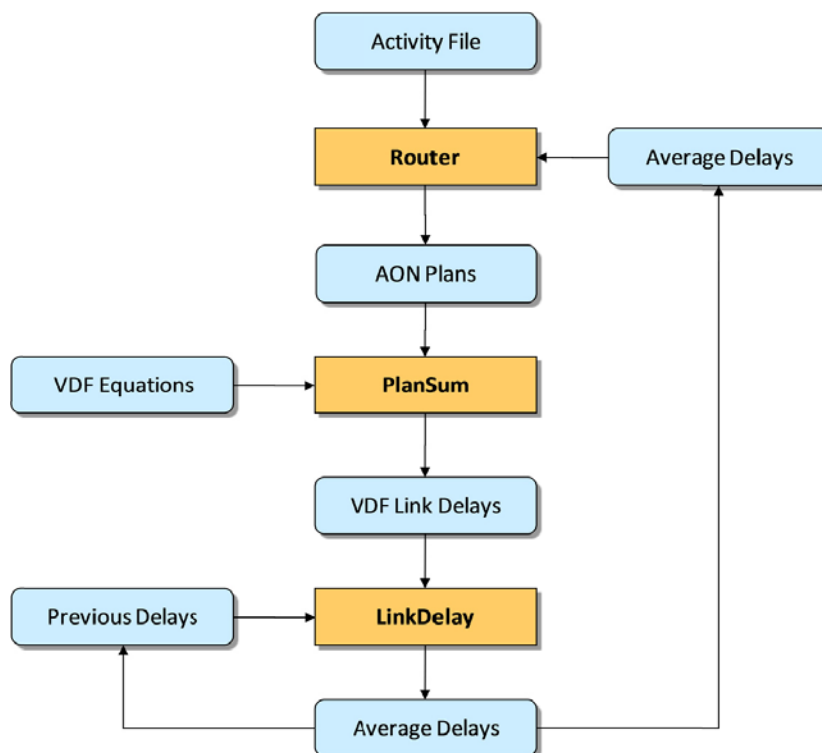


Figure 1.57. Router-only user equilibrium.

the composite plan file. This plan file is then aggregated into link volumes by time of day; delays are calculated using a facility-type-based VDF to the 5-min or 15-min link volumes to estimate the travel time for each time increment; and a weighted average or MSA procedure is used to combine the travel time estimates with previous travel time estimates for feedback to the next Router iteration.

Note that, in either approach, volume-to-capacity ratios can exceed 1.0 just as they do in traditional models. In fact this problem can be even more significant in TRANSIMS when fine-grained time periods are used. Volume-to-capacity ratios for 5-min or 15-min time periods are significantly more likely to exceed 1.0 than volume-to-capacity ratios calculated using peak period or daily volumes. Thus, extra care needs to be taken in designing the parameters used in the VDFs. If the travel times become excessive, the Router will have difficulty completing trips, which will create scheduling problems for subsequent trips within tours and move link volumes into much later time periods of the day.

Equilibrium Convergence Measures

Relative-Gap Measure

Link-based relative gap is a convergence statistic that quantifies the difference between the simulated performance of the traffic on each link by time of day and the vehicle hours of

travel that would result from each traveler taking the minimum impedance path based on the simulated travel times. The mathematical formulation for link-based relative gap is shown in Equation 1.5.

$$\text{Relative Gap} = \frac{|\sum VE_t \times CE_t - \sum VA_t \times CE_t|}{\sum VA_t \times CE_t} \quad (1.5)$$

where

\sum = summation over all network links;

VE_t = the simulated volume on a given link and time increment;

CE_t = the travel cost (time) associated with volume VE_t ; and

VA_t = the link volume from an AON assignment based on CE_t .

The data processing steps required to calculate the relative-gap convergence measure are outlined in Figure 1.58. The primary inputs to the process are travel plans from the current iteration and the Microsimulator performance or link delay file. These are shown in grey in Figure 1.58. The relative-gap process then builds AON paths using the performance file. The paths are then reskinned using the same performance file. The reskinning process updates the travel time and generalized-cost values for all travel plans in a consistent way. The AON plans are processed by PlanSum to create an

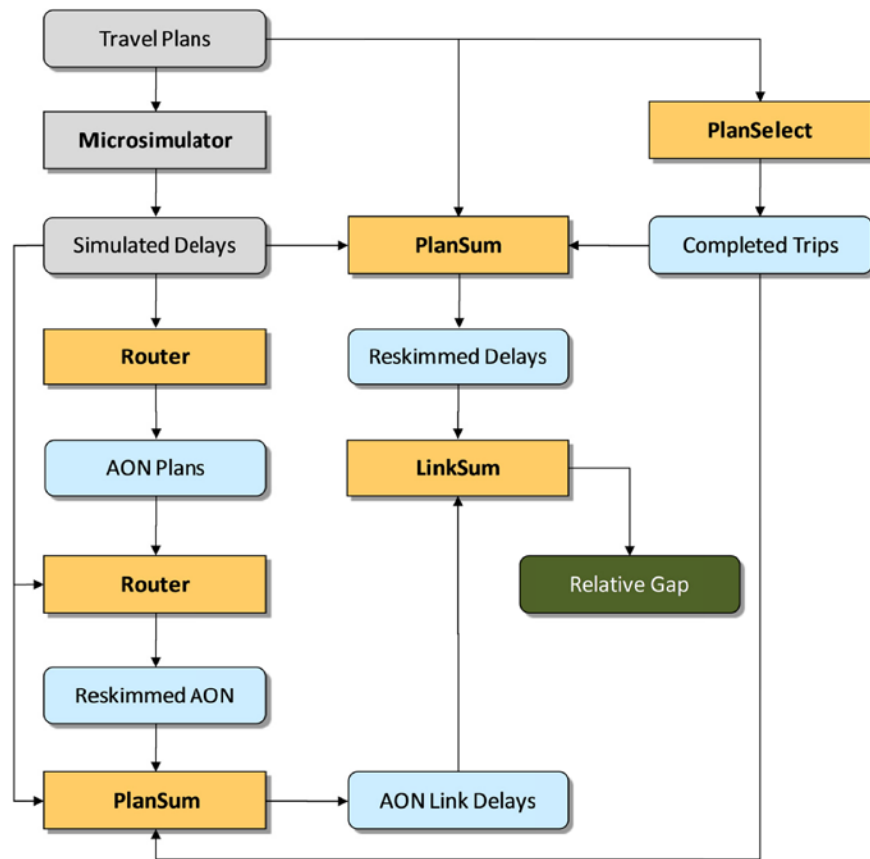


Figure 1.58. Link-based relative-gap calculation process.

AON link delay file. Similarly, PlanSum is used to create a link delay file using the travel plans and the Microsimulator performance file. This step, although seemingly unnecessary, is needed to create a link delay that has a complete and consistent set of volumes for all times of day. Furthermore, a common list of travelers is supplied to both PlanSum applications to limit the statistical comparison to trips that were successfully completed in both path building applications. The final two link delay files are compared using LinkSum to compute relative gaps for every hour of the day.

Trip-Gap Measure

TRANSIMS builds a unique path or travel plan for each trip on the basis of the origin and destination activity locations, trip start time, and other travel mode attributes (e.g., HOV or truck restrictions). In its simplest form, a trip gap is computed by comparing the generalized costs for every traveler’s path in the travel plan file with that traveler’s path in the AON plan file. However, a number of variations and complexities arise when calculating this measure, depending on whether only the Router is used in assignment or whether the Microsimulator is used. The nature of traffic microsimulation also contributes to those complexities. Ultimately, three

variations of the trip gap were developed and tested. Two use *experienced time* for each traveler, derived directly from the Microsimulator outputs. The formula for these gaps is shown in Equation 1.6. The third gap measure is based on reskinned time and is shown in Equation 1.7.

$$\text{Trip Gap} = \frac{|\sum (CE_x - CA_x \{C_{mt}\})|}{\sum CA_x \{C_{mt}\}} \tag{1.6}$$

where

- $\{C_{mt}\}$ = simulated time varying link costs;
- CA_x = AON cost of trip x based on link costs $\{C_{mt}\}$; and
- CE_x = simulated cost of trip x that resulted in link costs $\{C_{mt}\}$.

$$\text{Trip Gap} = \frac{|\sum (CR_x \{C_{mt}\} - CA_x \{C_{mt}\})|}{\sum CA_x \{C_{mt}\}} \tag{1.7}$$

where

- $\{C_{mt}\}$ = simulated time varying link costs;
- CA_x = AON cost of trip x based on link costs $\{C_{mt}\}$; and
- CR_x = reskinned costs for trip x along the path used to generate $\{C_{mt}\}$.

The data processing steps required to calculate the three trip-gap convergence measures are outlined in Figure 1.59. The inputs to this process are the same as the relative-gap process. They include the travel plans and the Microsimulator performance or link delay file from the current iteration. These are shown in gray in Figure 1.59. All three measures are calculated in every iteration; however, only one of them is used in the model for measuring convergence. The event-based and hybrid trip-gap methods attempt to consider the actual simulation travel time for every traveler. The hybrid trip-gap method additionally attempts to correct for the influence of simulation and routing problems.

The reskinned trip gap is obtained by comparing the reskinned travel plans with the reskinned AON plans. The event-based trip gap is computed by comparing reskinned AON plans and the updated travel plans incorporating the actual start and end times of every traveler in the simulation.

In this comparison, problem travelers in the Microsimulator are excluded. The hybrid trip gap goes one step further and includes the reskinned paths for travelers with simulation problems for comparison against the reskinned AON plans.

DaySim-TRANSIMS Integration

As shown in earlier figures, DaySim provides trip and vehicle information to the TRANSIMS Router to perform network assignment. In its original implementation, DaySim produced person-trip records with trip-end locations defined as parcels and trip start and end times defined as specific minutes of the day. To integrate DaySim with TRANSIMS, a number of modifications were made to translate DaySim tour and trip records into vehicle-trip records, associate the parcel locations with the activity locations used by TRANSIMS, and output the records in the format required by the Router. DaySim does not

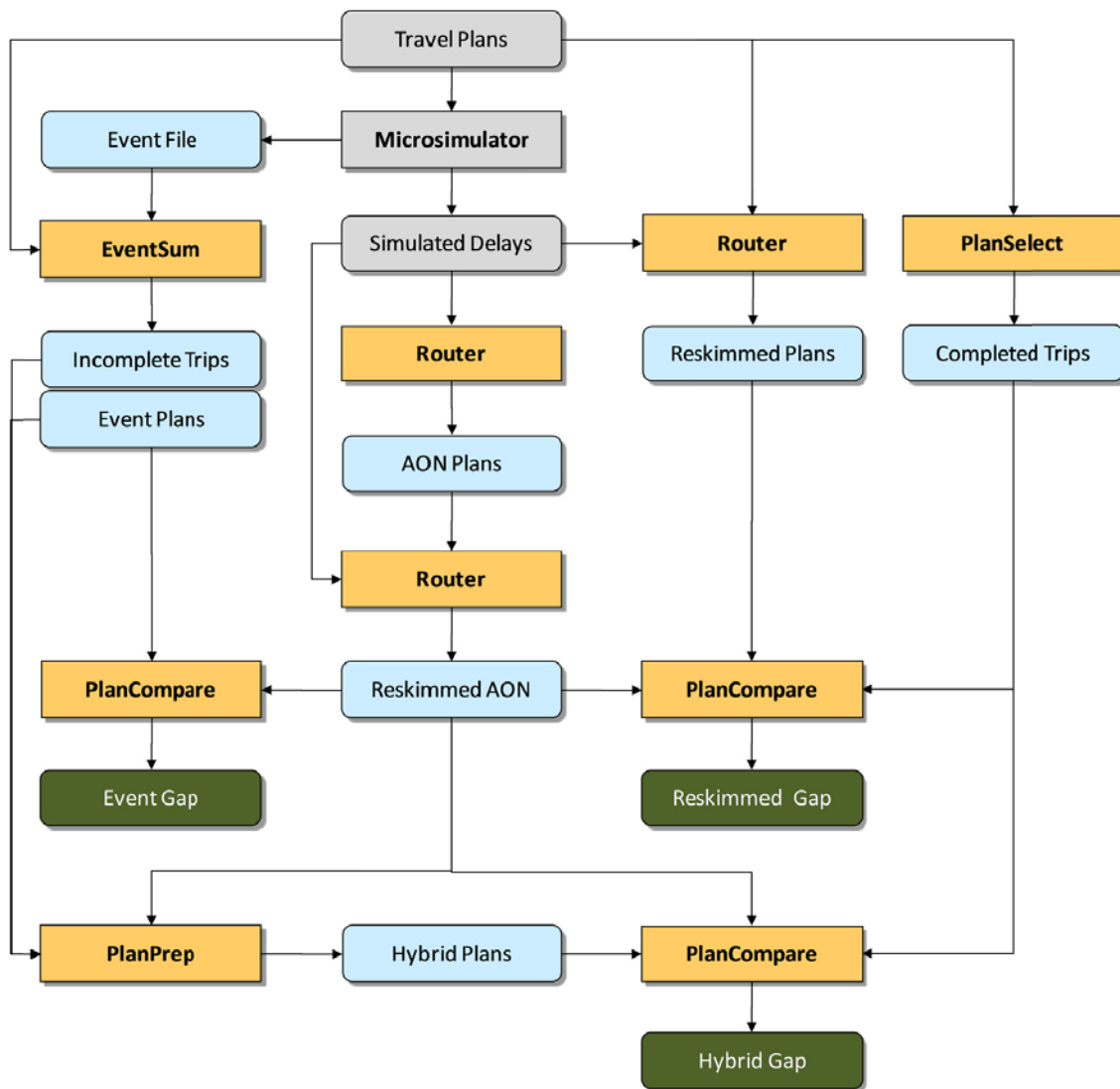


Figure 1.59. Traveler-based trip-gap(s) calculation process.

simulate vehicle-type choice or allocate specific vehicles to person trips. Therefore, a simple procedure is used to treat every vehicle trip as an independent vehicle. These modifications are described in the following subsections.

Activity File

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

Activity Files Versus Trip Files

Version 4 of TRANSIMS can accept two types of list-based inputs: activity files and trip files. A trip file is straightforward: a list of trips to be assigned to the network, including information on the origin activity location, destination activity location, departure time of the trip, and 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 the SACSIM trip matrices developed for Sacramento 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 the 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 all the movements as interconnected—the tour structure is preserved within each person. As currently

configured, the activity durations are fixed; if a traveler takes longer to reach one activity location, the remainder of that traveler's 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 Chapter 2. This approach was necessary in the initial model development to ensure that all trips were assigned and conserved. Future integrated model development efforts will consider how rescheduling and time pressures can be flexibly accommodated in DaySim, TRANSIMS, or both.

Using a simple tour comprising two trips, with a single trip on each tour leg, Table 1.46 and Table 1.47 illustrate the differences between the original DaySim trip output file and the TRANSIMS activity input file. Both files indicate the household and person traveling. For each of the two given trips in Table 1.46, 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.

While 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, the starting point for the day. TRANSIMS derives one trip to take the person from home to the first activity location (shown in the second activity file record) and then derives a second trip to take the person to the 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.

Temporal Units

Table 1.47 also shows that the first at-home activity ends at time 44520. Another key change made to the DaySim output involved

Table 1.46. 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

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

Table 1.47. TRANSIMS Activity File Example

HHOLD	PERSON	ACTIVITY	PURPOSE	PRIORITY	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

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; when translated from seconds to hours and minutes, this time is again 12:22. Thus, 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 the 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.

Spatial Resolution

Table 1.46 and Table 1.47 also illustrate the differences in the geographic resolution between the DaySim trip list output and the TRANSIMS activity file. As previously described, DaySim uses detailed parcels as the fundamental spatial unit; but in the original DaySim implementation, this parcel-level detail was aggregated to a TAZ-level before network assignment, using traditional static equilibrium assignment methods. The DaySim trip list output contains both the origin and destination parcel and the TAZ information. When integrated with TRANSIMS for network assignment, DaySim uses activity locations. Activity locations are more fine-grained spatially than TAZs (the Jacksonville region has approximately 25,000 activity locations) but not as detailed as individual parcels (the Jacksonville region has approximately 620,000 parcels). A correspondence file between parcels and activity locations was developed to translate parcel information to activity locations before assignment in TRANSIMS. This spatial disaggregation in assignment is one of the distinguishing aspects of the integrated model.

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 the travel modes used in DaySim into the preestablished TRANSIMS mode codes. For example, Table 1.46, the DaySim trip list output example, shows the first trip using mode 7, which is “drive

alone” in DaySim. Table 1.47, the new TRANSIMS activity file example, shows the second record contains mode 2, which is “drive alone” in TRANSIMS; mode 2 indicates the traveler’s first trip to the first out-of-home activity location.

The mode logic is significantly more involved for shared-ride trips. In existing activity-based model implementations that used static network assignment procedures, shared-ride trips are simply aggregated to the zonal level and divided by an assumed occupancy rate to calculate vehicle trips. That approach does not work in a disaggregate assignment simulation such as TRANSIMS because the goal is to preserve the details about each individual trip. Dividing discrete shared-ride trips by an occupancy rate to estimate vehicle trips is neither appropriate nor logical. Instead, the driver and passenger status must be assigned to travelers whose mode is identified as shared ride.

In TRANSIMS, only auto driver tours are of interest. 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 driver or the passenger, and it does not coordinate the driver and passengers within a household. In addition, different trip modes (vehicle occupancies) may apply to different trips within an auto tour. The project team used a detailed analysis to derive the most realistic and unbiased method for assigning a driver or passenger designation to each auto tour and trip—and thus determine which tours to send to the Router.

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 noncar trips. Car trips that are part of school bus or transit tours are typically car passenger trips in which the person gets a ride in one tour direction and takes a bus in the other direction. For simplicity, the project team assumed that all such trips are passenger trips and need not be routed in TRANSIMS. In addition, some mixed mode auto tours include one or more walk or bike trips. Because those modes are difficult to handle in TRANSIMS, and their number is quite small, the team assumed that the auto trips in those tours are passenger trips. The expected number of car driver trips was calculated 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 team also established a method for determining which tours

at each occupancy level to assign as driver tours; the method depends on the 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, for tours including only shared-ride trips, a certain proportion of the tours are randomly designated as car driver tours and the rest are designated as car passenger tours according to proportions derived from survey and modeled data.

One final note on mode coding pertains to the TRANSIMS activity file. In TRANSIMS, 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. If `PASSENGER>0`, the trip is treated as a shared-ride driver trip and assigned to the HOV network.

Vehicle File

TRANSIMS has the ability to allocate or assign vehicles to individual travelers and to track those vehicles throughout the day. 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 among household members for the household vehicles. The project team anticipates enhancing DaySim so that it can assign household vehicles to each auto driver tour as part of other research efforts. Such a change 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.

TRANSIMS-DaySim Integration

Network skims, or location-to-location measures of network impedances and costs, are an essential element of any travel demand forecast system. The skims are used directly or indirectly in virtually every component of the DaySim model system, from calculating accessibility measures that influence long-term choices (e.g., auto ownership and overall daily tour and trip generation) to providing direct input into short-term choices (e.g., destination, mode, and time-of-day).

The skims are generated using network assignment or simulation software that is based on network performance by time of day, are defined along a number of key dimensions (e.g., spatial, temporal, and modal resolution), and may be

provided in a number of different file formats. In the initial implementation of the Jacksonville DaySim-TRANSIMS model system, the primary spatial unit used for skimming is the travel analysis zone (TAZ), and the temporal unit used is the detailed time period. In the current implementation, 22 time-period skims are generated and used in the model system; these time periods vary in length from a half-hour during the 3-hour a.m. and p.m. peak periods to 1 hour during the midday, early morning, and early evening, to a single broad overnight time period (Figure 1.60). The DaySim-TRANSIMS model system can be configured to other levels of temporal resolution as well.

One of the significant enhancements to TRANSIMS's capabilities is the new PathSkim program, which is used to build paths and gather travel attributes between selected locations at specific times of day. In addition to significantly improving performance through multithreading and one-to-many path building techniques, PathSkim makes selecting origins and destinations for zone-to-zone skims by time of day significantly more convenient. It automatically selects one or more activity locations near zone centroids as path origins and destinations. The locations can also be randomly or geographically distributed within the zone or provided by the modeler through a zone-location file. The zone-to-zone or district-to-district skim information is aggregated in memory and written directly as a single skim matrix or a series of matrix files for different time periods.

In PathSkim the output time periods can also vary in length or combine travel from different times of day. This is particularly important for the SHRP 2 C10 model because DaySim requires 30-min skims during peak periods, hourly skims for off-peak periods, and a nighttime skim that combines late evening hours with early morning hours. DaySim also uses skims to set the trip departure time on the basis of a scheduled arrival time at the activity location. The TRANSIMS Version 4 Router only builds paths from an origin at a specific time of day to a destination. What DaySim would prefer and what PathSkim provides is the ability to generate paths and aggregate skims on the basis of specified arrival times at the destination. In other words, paths are built backward in time. For the Jacksonville network, the Version 4 skimming process took more than 24 h to run and generated a temporary plan file close to 100 gigabytes in size. Performing the same task with a multithreaded version of PathSkim takes approximately 15 min and produces no temporary files.

The initial C10A system architecture envisioned that the TRANSIMS tools would be used to generate and return to DaySim activity location-level measures of network impedances for a specified set of origin-destination pairs (O-Ds) and a given time period. At present, however, the model system is still employing TAZ-level network impedances.

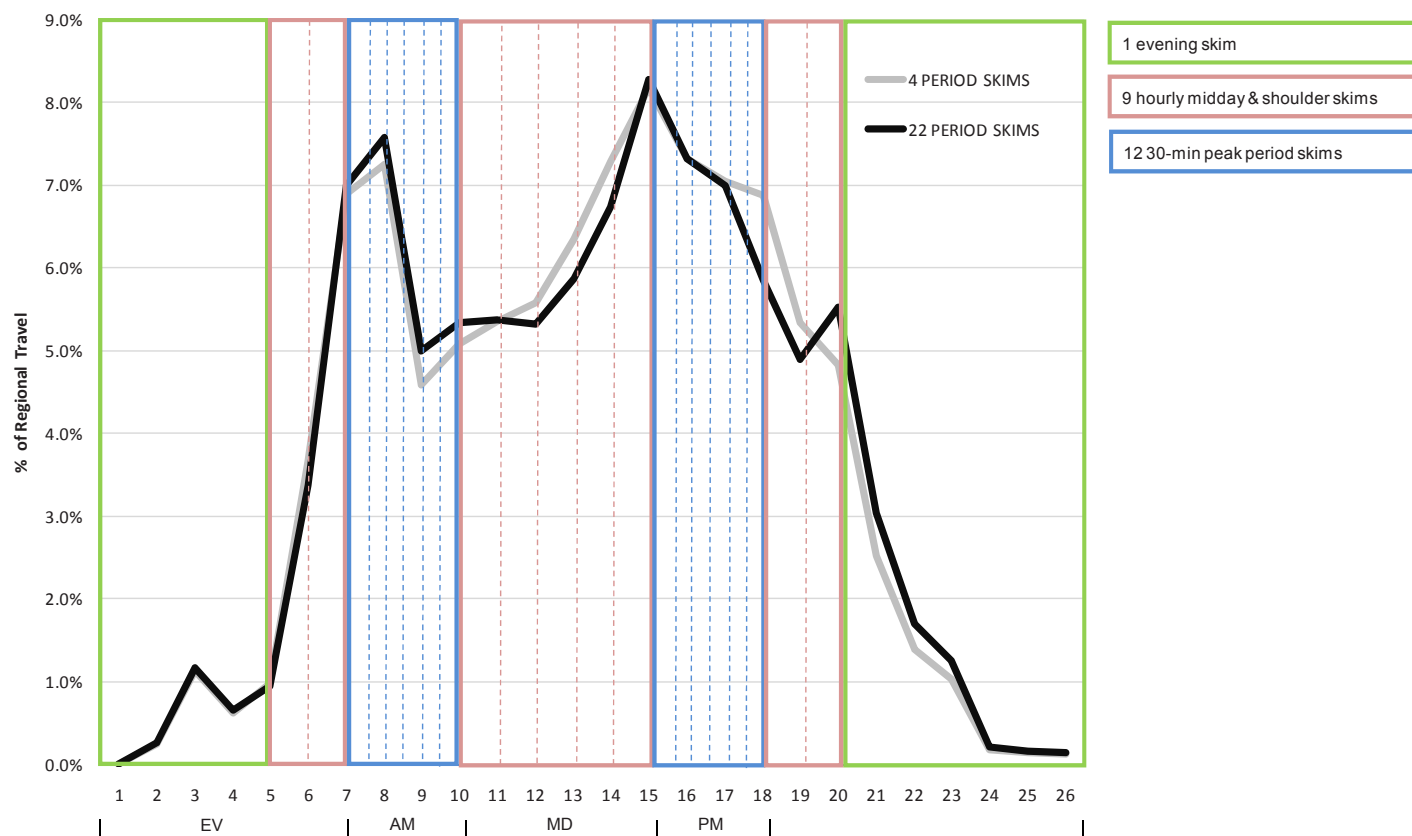


Figure 1.60. 22 time-period skim definition.

Ultimately, time and cost measures may be based on more spatially detailed TRANSIMS activity locations and for specific times that a trip or activity may be routed.

As described earlier, the fundamental spatial unit used in DaySim is the individual parcel, which is significantly more fine-grained than the TAZs used for network skimming. This is primarily driven by the computational burden of creating, storing, and accessing more spatially detailed skim data. For example, a region such as Jacksonville—with approximately 1,500 TAZs—necessitates the development of separate skims that, for each modal attribute and time period, contain 2,250,000 individual values. If those skims were developed at the TRANSIMS activity location level used in network assignment, more than 400,000,000 individual values for each modal attribute and time period would have to be stored. To refine the TAZ-level skims, DaySim does incorporate some parcel-level information, such as the distance from each parcel to the nearest transit stop by transit submode. In the Jacksonville DaySim-TRANSIMS model, TRANSIMS creates fixed format ASCII skim files. However, DaySim can be enhanced to read and write other data file formats, such as native CUBE matrix format and binary files.

TRANSIMS-MOVES Integration

One of the objectives of this study is to estimate the air-quality impacts of each of the application alternatives using the Environmental Protection Agency's (EPA) new motor vehicle emission simulator (MOVES). MOVES replaces MOBILE6 and NONROAD as the mobile source emission tool required for air-quality conformity analysis and emission impact analysis. It is designed to produce county-level emission inventories for the entire nation, zone- and link-level emissions for state implementation plans and regional conformity analyses, and microscale emission rates for hot-spot and project-level analyses. The goal is to move away from average operating characteristics over broad geographic areas to finer analysis scales based on detailed operating characteristics of a wide variety of vehicle types at specific locations and times of day.

MOVES Architecture

At its lowest level, the MOVES software applies emission rates to activity data by source and operating mode bins. For transportation applications, source use types are basically

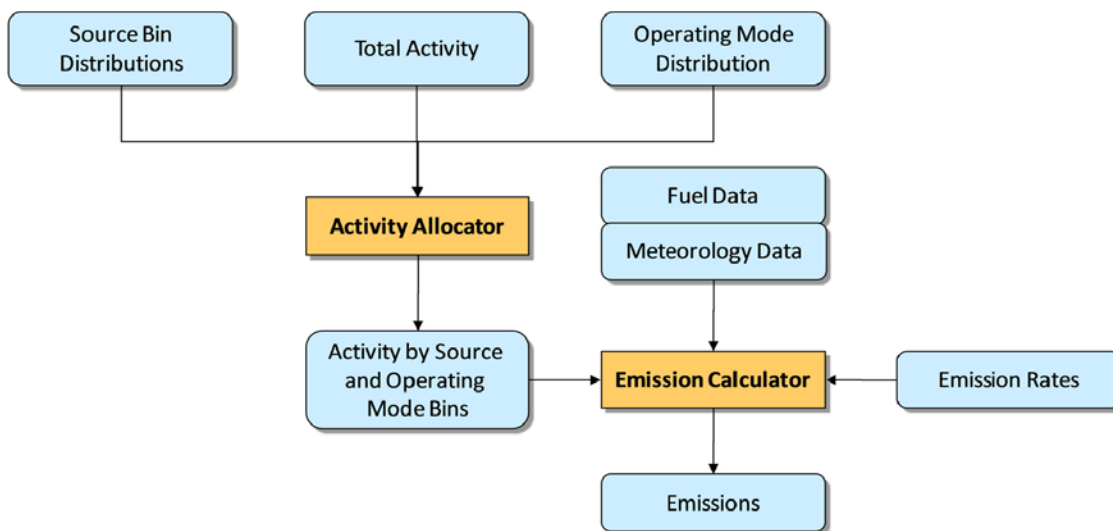


Figure 1.61. MOVES core model.

equivalent to vehicle types. Figure 1.61 provides an overview of the core model processing. The activity data are allocated to source and operating mode bins by the total activity allocator (TAA). This module processes data from three primary data sources: source bin distributions, total activity, and operating mode distributions. The activity data are passed into the emission calculator along with emissions rates, which are adjusted using local and seasonal fuel and meteorology data.

From the MOVES core model perspective,

- Fuel data are the supply of fuel by time, location, and type.
- Meteorology data are the temperature and humidity by time and location.
- Total activity is the quantity of emission-generating activity by time, location, and source use type.
- Operating mode distributions distribute average operating characteristics, such as average speed, to vehicle-specific power (VSP) bins by time, location, and roadway type.
- Source bin distributions convert vehicle data to emission-specific classifications. Distributions can vary by source use type, but not by time or location.

Total Activity Data Generator

To support the core model and facilitate a wide variety of user inputs, the MOVES architecture includes a number of data generators to manipulate and format the required information. The total activity generator (TAG) is designed to produce the activity for the source use types by time and location. This includes the vehicles and the operation of the vehicles. The MOVES process prepares the total activity through a

series of steps that perform calculations at increasing levels of detail and specificity. The steps are controlled through the data input interface. Table 1.48 provides a high-level overview of the calculations performed by the TAG.

The first few steps in the TAG are designed to define the array of vehicle types that are included in the analysis domain or region. MOVES defines vehicles as a source use type and tends to define vehicle types at a much higher level of specificity than a transportation planner. From a MOVES perspective, every combination of vehicle weight, fuel, technology, emission standard, and engine size represents a different source bin for a given vehicle age.

Table 1.48. Total Activity Generator Steps

Step	Calculation
TAG-0	Determine the base year
TAG-1	Calculate base year vehicle population
TAG-2	Grow vehicle population to analysis year
TAG-3	Calculate analysis year travel fractions
TAG-4	Calculate analysis year VMT
TAG-5	Allocate analysis year VMT by roadway type, use type, and age
TAG-6	Allocate annual VMT to hour by roadway type, use type, and age
TAG-7	Convert to total activity basis by process
TAG-8	Allocate total activity basis by zone location
TAG-9	Calculate distance traveled

Operating Mode Distribution Data Generator

The operating mode distribution generator (OMDG) provides a mechanism for defining the distribution of operating modes used to calculate emissions. For exhaust running emissions and energy consumption, this is a distribution of VSP bins by time, location, and roadway type. This generator would typically be used to create the default or user-specific profiles by roadway type to account for link or roadway-specific characteristics. These characteristics might provide specific information for additional roadway types (e.g., ramps), the grade of the link, or the distribution of the drive schedules around a specific average speed value. Adjustments to parameters other than average speed are probably limited to applications involving detailed operational simulations. Table 1.49 lists the calculations performed by the operating mode distribution generator.

Application Modes

MOVES supports three primary levels of analysis: macroscopic, mesoscopic, and microscopic. EPA uses the macroscopic analysis to perform national-level estimates of energy consumption and policy-related studies. The mesoscopic analysis focuses on generating state implementation plans and emissions inventories for the state and regional agencies responsible for air-quality conformity analysis. The microscopic analysis or project-level analysis is designed for hot-spot analysis of local projects that have air-quality implications. This level of analysis is intended to support environmental impact statements.

Table 1.49. Operating Mode Distribution Generator Steps

Step	Calculation
OMDG-1	Define drive schedules
OMDG-2	Define the distribution of drive schedules by average speed
OMDG-3	Calculate the distribution of drive schedules for a given link
OMDG-4	Calculate the second-by-second vehicle specific power
OMDG-5	Determine operating mode bin for each second
OMDG-6	Calculate operating mode fractions for each drive schedule
OMDG-7	Calculate operating mode fractions for each link
OMDG-8	Adjust operating mode fractions based on the grade of the link

Given the primary purposes of the C10A model development effort, the mesoscopic or county-level analysis option is most appropriate. This level of analysis focuses on one or more counties within a region or state. Counties can be modeled independently or grouped into custom domains. If modeled independently, the input tables containing total activity (VMT), fleet mix and age distributions, vehicle inspection programs, fuel types, and meteorology can be different for each county. If a custom domain is used, a single set of inputs is provided for the domain.

The decision to use individual counties or custom domains depends on available data and significant variations within the region. If vehicle populations, fleet, and fuel data are only available at the regional level, a custom domain may be the only option. If the region includes different states or counties with different vehicle inspection programs, the analysis may have to be subdivided. In that case, defining multiple custom domains may be desirable. Custom domains can simplify input data preparation, but they also reduce or avoid the need for output processing. For a region that includes a large number of counties, merging the output databases into a single answer can be time-consuming.

Within the mesoscopic or county-level analysis, MOVES supports two primary application methods. In the “lookup method,” MOVES generates a table of emissions rates by vehicle type, facility type, speed bin, and various other classifications. Customized software can then be used to read the table and to calculate and aggregate emissions from individual links. In the “inventory method,” the transportation data are processed to generate a series of tables and distribution factors that MOVES importers can read for a MOVES emissions inventory application.

The primary advantage of the inventory method is that the emissions estimates can be more accurate by minimizing rounding and interpolation errors within the internal calculations. The application process can also include greater policy sensitivity by permitting the user to adjust the emissions assumptions and input data for each run. The primary disadvantages of this approach are the need to customize inputs and outputs for each application; the time required to run the MOVES software for one or more custom domains or counties; and the skills and training in MOVES applications that transportation modelers require.

The lookup method has the advantage that the MOVES software is run once and the rates are applied to multiple scenarios or alternatives. Transportation modelers can focus on applying the rates and leave the details of setting up and applying the MOVES software to air-quality experts. The process also has the advantage that the rates can be applied to individual links and aggregated in standard ways. It is also

very similar to the way most MPOs applied the MOBILE6 software in the past.

The primary disadvantage of the lookup method is that the resulting rate tables may be too big and bulky for practical use. The attribute details created by MOVES are often not helpful and need to be restructured for efficient application. This restructuring can be challenging because individual rates need to be properly weighted to create aggregate rates that match the available transportation data.

Using the lookup emission rates with operational simulation models can also be problematic. Rates are available in 5-mph increments, but they should not be applied to instantaneous speeds. The rates are based on VMT distributions of average speeds. Since stopped vehicles do not generate VMT, the lowest emission rate cannot be applied to a vehicle that is stopped for 1 s or more. The rate needs to be applied to the average speed of the vehicle over the length of the link or some other measure of distance.

TRANSIMS Interface

The TRANSIMS Emissions program is designed to support both county-level and project-level applications of the MOVES software. For county-level analysis, the program supports both lookup table and inventory application methods.

Figure 1.62 shows the TRANSIMS interface using MOVES lookup tables. In this approach, MOVES is applied once with appropriate county-specific data to generate one or more lookup tables. The TRANSIMS Microsimulator is executed to generate speed bin files for each vehicle type. The files contain

the number of seconds over each 15-min period that each 30-m segment of roadway has vehicles of the specified type traveling in each of six speed bins. The TRANSIMS Emissions program is then executed with various parameters to aggregate some values and disaggregate other values in the MOVES lookup table and output the resulting composite rates. These rates can then replace the MOVES lookup table for subsequent applications. In addition, the Emissions program applies the composite rates to each record and aggregates the resulting emissions by facility type, vehicle type, and/or summary district.

For MOVES inventory applications, the process shown in Figure 1.63 is used. In this case the TRANSIMS Microsimulator generates the speed bin files and a link delay file. The link delay file contains the volume and speed on each link in 15-min increments. The LinkSum program aggregates this information to generate the VMT by Highway Performance Monitoring System (HPMS) vehicle types and the distribution of VMT by MOVES facility types. The Emissions program in this case is configured to output VMT distributions and average speed bin distributions by hour of the day. The tables are generated in the format required by MOVES importers that insert the data into the MOVES MySQL database for emissions inventory processing.

MICROSIMULATOR OUTPUTS

One of the key inputs to the emissions estimate is a set of speed bin files output from the TRANSIMS Microsimulator. Speed bin files are generated for each vehicle type included in the network demand (i.e., travel plans). The control keys are listed in Table 1.50. At a minimum, speed bin files are

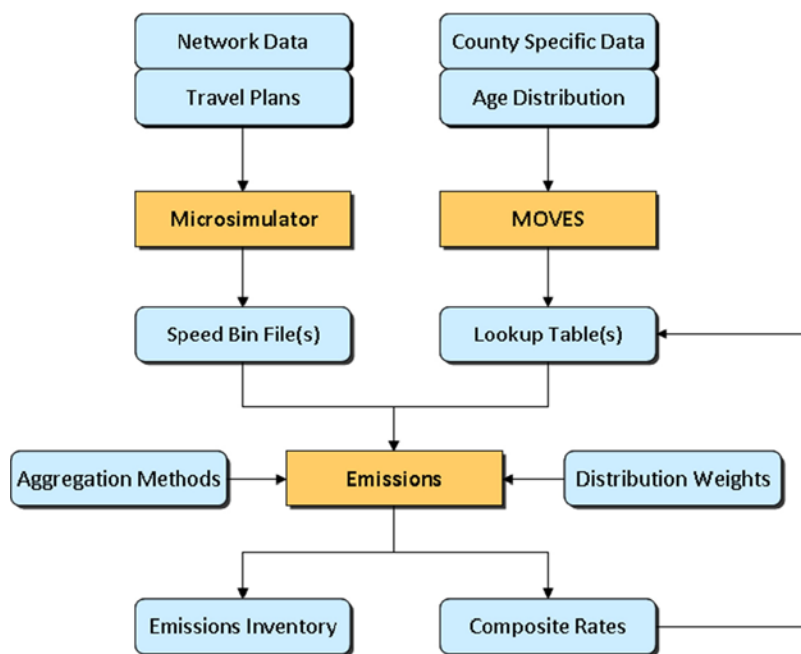


Figure 1.62. Emissions rate lookup table method.

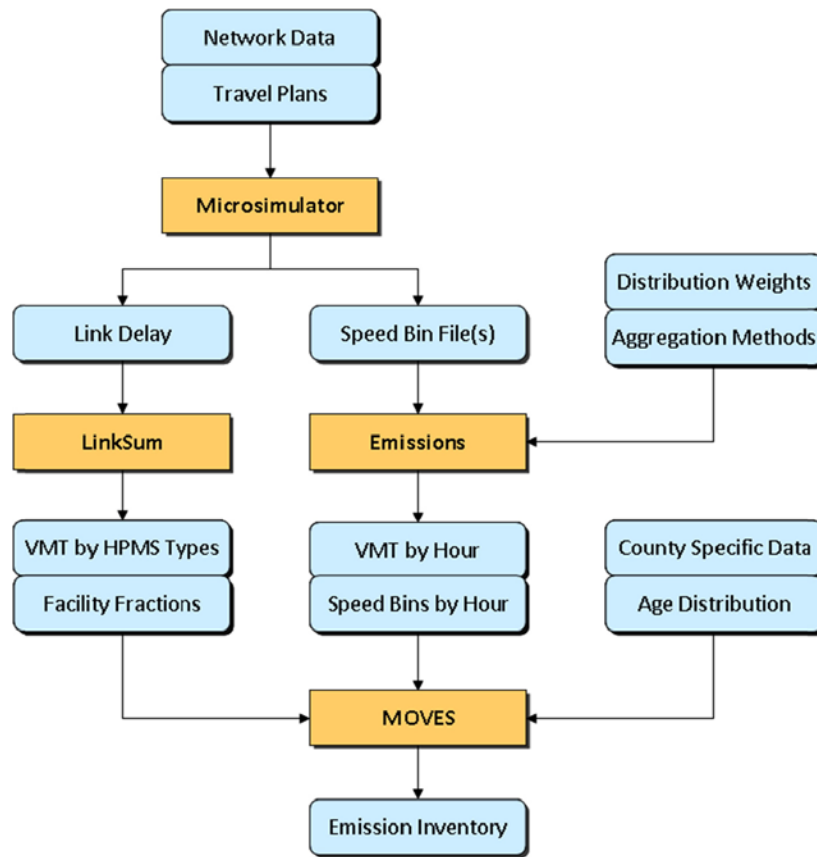


Figure 1.63. MOVES emissions inventory method.

Table 1.50. Microsimulator Control Keys

Control Key	Description
OUTPUT_SPEED_FILE	File name to be created within the project directory
OUTPUT_SPEED_FORMAT	File format to be created (default = Version3)
OUTPUT_SPEED_VEHICLE_TYPE	A vehicle type code number (default 0 = ALL)
OUTPUT_SPEED_FILTER	Minimum number of vehicles per time increment (default = 1)
OUTPUT_SPEED_TIME_FORMAT	Output time format (default = seconds)
OUTPUT_SPEED_INCREMENT	Time increment duration (default = 24 hours)
OUTPUT_SPEED_TIME_RANGE	Time period range (default = ALL)
OUTPUT_SPEED_LINK_RANGE	Link number range (default = ALL)
OUTPUT_SPEED_SAMPLE_TIME	The time frequency in seconds at which the speed bins will be summarized (default = 1 second)
OUTPUT_SPEED_BOX_LENGTH	The length in meters of the link segments for which speed bins are summarized (default = 0 = full link length)
OUTPUT_SPEED_NUM_BINS	The number of speed bins that are summarized (default = 6)

Table 1.51. TRANSIMS Speed Bin MetaData

MetaData	Description
TIME_STAMP	The time and date when the file was created
BOX_LENGTH	The segment length in meters
CELL_LENGTH	The cell length used in the simulation
SAMPLE_TIME	The frequency in which data are collected (seconds)
INCREMENT	The summary time increment
VEHICLE_SUBTYPE	The subtype of the vehicle type summarized in the file
VEHICLE_TYPE	The vehicle type code summarized in the file
VELOCITY_BINS	The number of speed bins
VELOCITY_MAX	The maximum speed in meters per second

generated for autos and trucks. If the region includes different vehicle inspection programs for different subregions, the auto vehicle types should include separate vehicle type or subtype to aggregate the travel separately. For detailed emissions estimates, the sample rate is once per second in 15-min time increments and the links are subdivided into 30-m segments (box length).

The output speed bin files include the metadata header record shown in Table 1.51 and the data fields listed in Table 1.52.

Control keys for the TRANSIMS Emissions program provide the tools necessary to compress MOVES emissions rates into values that correspond to the transportation data and

Table 1.52. TRANSIMS Speed Bin Data Fields

Field Name	Description
LINK	Link number
DIR	Direction of travel (0 = AB, 1 = BA)
OFFSET	Distance from the beginning of the link to the end of the segment
TIME	Ending time of the time increment
SPEED0	Total vehicle seconds at speed zero cells per second
SPEED1	Total vehicle seconds at speed one cell per second
SPEED2	Total vehicle seconds at speed two cells per second
SPEED3	Total vehicle seconds at speed three cells per second
SPEED4	Total vehicle seconds at speed four cells per second
SPEED5	Total vehicle seconds at speed five cells per second
SPEED6	Total vehicle seconds at speed six cells per second

the analysis requirements. This includes selecting columns and column attributes for selecting rows and providing weighting factors for combining emissions rates into weighted average values. Once the table is collapsed it can be output as a new emissions rate table for use as input to subsequent applications. An example of a collapsed emissions rate table is shown in Table 1.53.

The TRANSIMS Emissions program applies these rates to the Microsimulator speed bin data. This involves mapping TRANSIMS facility and area types to MOVES road types and TRANSIMS vehicle types to MOVES source types. Summary years, months, and weekend travel factors are specified. As the speed bin data are read for each link segment and time period, the vehicle seconds in each TRANSIMS speed bin are distributed to the 16 speed bins defined by MOVES. This distribution process ensures that the total vehicle miles traveled (VMT) and vehicle hours traveled (VHT) included in the TRANSIMS speed bins equal the total VMT and VHT represented in the MOVES speed bins. The appropriate emissions rates are applied to the VMT in each speed bin and summarized as requested. Emissions summary reports can be generated by area type, facility type, vehicle type, road type, area and facility types, area and vehicle types, facility and vehicle types, road and vehicle types, and total emissions. Emissions summary data can also be written to a file for additional processing.

EMISSIONS PROGRAM APPLICATIONS—EMISSION INVENTORY METHOD

The TRANSIMS Emissions program can also be used to generate input tables in the format required by the MOVES county-level data importers. The TRANSIMS speed bin and link delay data sets provide the information needed for five of the MOVES input tables. County or custom domain attributes such as temperature and relative humidity and vehicle population data related to fuel and age distributions need to be provided from other sources.

The interface includes many of the same elements as a lookup table application, but the process is reversed. Rather than collapse or convert MOVES emissions rates to TRANSIMS data elements, this process expands or converts TRANSIMS data to MOVES data classifications. For example, TRANSIMS facility and area types are collapsed to MOVES road types; TRANSIMS vehicle types are expanded to MOVES source types; and TRANSIMS speed bins are distributed to MOVES speed bins. As each TRANSIMS speed bin record by link segment and time period is read, the data are converted and aggregated into an appropriate MOVES-related data structure. The MOVES data are processed, formatted, and output as tab delimited data files.

The first table required by the MOVES emissions inventory process is a distribution of annual VMT by HPMS vehicle

Table 1.53. Collapsed Emissions Rate Table

yearID	monthID	sourceTypeID	roadTypeID	pollutantID	processID	avgSpeedBinID	emissionRate
2008	1	21	2	1	1	1	1.91824
2008	1	21	2	1	1	2	1.02998
2008	1	21	2	1	1	3	0.608886
2008	1	21	2	1	1	4	0.430296
2008	1	21	2	1	1	5	0.37313
2008	1	21	2	1	1	6	0.318093
2008	1	21	2	1	1	7	0.2814
2008	1	21	2	1	1	8	0.258368
2008	1	21	2	1	1	9	0.241404
2008	1	21	2	1	1	10	0.228209
2008	1	21	2	1	1	11	0.217652
2008	1	21	2	1	1	12	0.206746
2008	1	21	2	1	1	13	0.195869
2008	1	21	2	1	1	14	0.208396
2008	1	21	2	1	1	15	0.237551
2008	1	21	2	1	1	16	0.276734

types. A mapping between TRANSIMS vehicle types and HPMS vehicle types is provided along with distribution fractions as necessary. An expansion factor is provided to convert the daily TRANSIMS VMT to annual VMT. This factor may also include some consideration for travel on roadways not included in the TRANSIMS network. Table 1.54 shows an example of the HPMS VMT distribution.

Table 1.55 provides factors for distributing the VMT assigned to each MOVES source type to road types. TRANSIMS vehicle types not only need to be mapped to HPMS vehicle types, they also need to be mapped to MOVES source types. TRANSIMS facility and area types are also mapped to MOVES road types. The VMT by vehicle type is summed by road type, then the road

type fractions are calculated for each vehicle type. Since the purpose of this table is to distribute VMT assigned to a given source type to road types, the same fractions can be used for each source type associated with a given vehicle type. Table 1.55 provides an example of road type fractions for two source types.

Because MOVES road types are limited to restricted-access and unrestricted-access categories, and speed profiles on freeways are considerably different from on ramps, MOVES splits the VMT assigned to the restricted-access road type into freeways and ramps using a ramp fraction table. This fraction is simply the total VMT on ramps in urban or rural area types divided by the total VMT on ramps plus freeways (and

Table 1.54. VMT by HPMS Vehicle Type

HPMSVtypeID	yearID	VMTGrowthFactor	HPMSBaseYearVMT	baseYearOffNetVMT
10	2008	0	0	0
20	2008	0	7528117453	0
30	2008	0	3051203213	0
40	2008	0	361066.94	0
50	2008	0	3266014.62	0
60	2008	0	5935721.71	0

Table 1.55. VMT Road Type Fractions

sourceTypeID	roadTypeID	roadTypeVMTFraction
21	1	0
21	2	0.12795
21	3	0.095435
21	4	0.399313
21	5	0.377302
41	1	0
41	2	0.201374
41	3	0.030168
41	4	0.696728
41	5	0.07173

expressways). An example of the ramp fractions file is shown in Table 1.56.

Table 1.57 distributes daily VMT associated with a given source type and road type to VMT by hour of the day. The fractions can also vary for weekdays and weekends. The dayID field distinguishes a weekday (5) from a weekend (2). MOVES uses one distribution for Monday through Friday and the other distribution for Saturday and Sunday. Total weekend VMT is modeled as a fraction of total weekday VMT. Table 1.57 shows an example of the hourly distribution of VMT assigned to a given combination of source type, road type, and day type.

Table 1.58 is perhaps the most important. It distributes the VMT assigned to each combination of source types, road type, day type, and hour of the day to average speed bins. MOVES includes 16 speed bins in 5-mph increments. The amount of VMT assigned to each speed bin is critical to the emissions calculations. The shape of the distribution defines the operating mode distribution, driving schedules, and VSP bins used to calculate emissions.

The data from the TRANSIMS speed bin files are distributed to source types using the vehicle type to source type map and source type factors. The link facility and area type attributes

Table 1.56. Ramp Fractions

roadTypeID	roadDesc	rampFraction
1	Off-Network	0
2	Rural Restricted Access	0.056354
3	Rural Unrestricted Access	0
4	Urban Restricted Access	0.084319
5	Urban Unrestricted Access	0

Table 1.57. VMT Hour Fractions

sourceTypeID	roadTypeID	dayID	hourID	hourVMTFraction
21	2	2	1	0.004541
21	2	2	2	0.003671
21	2	2	3	0.003132
21	2	2	4	0.003283
21	2	2	5	0.005489
21	2	2	6	0.015789
21	2	2	7	0.039964
21	2	2	8	0.069848
21	2	2	9	0.073569
21	2	2	10	0.057104
21	2	2	11	0.051712
21	2	2	12	0.055294
21	2	2	13	0.061564
21	2	2	14	0.061838
21	2	2	15	0.064897
21	2	2	16	0.073156
21	2	2	17	0.081059
21	2	2	18	0.083631
21	2	2	19	0.066849
21	2	2	20	0.045871
21	2	2	21	0.028413
21	2	2	22	0.023375
21	2	2	23	0.015719
21	2	2	24	0.010232

map the link segment to a MOVES road type. The 15-min time periods are summed to hours of the day. The vehicle seconds in each TRANSIMS speed bin are then distributed to the 16 MOVES speed bins. This distribution process ensures that the total VMT and VHT included in the TRANSIMS speed bins equal the total VMT and VHT represented in the MOVES speed bins. The VMT in each speed bin are divided by the total VMT for the hour to set the average speed fraction. An example of the speed bin distribution for one classification category is shown in Table 1.58.

The tables created by the TRANSIMS Emissions program are then imported into the MOVES database, various MOVES parameters are set, and a MOVES run is executed. If multiple counties or custom domains are required, the MOVES databases have to be combined to create the total emissions inventory. Data can then be selected from the tables to generate summary reports.

Table 1.58. Average Speed Bin Distribution

sourceTypeID	roadTypeID	hourDayID	avgSpeedBinID	avgSpeedFraction
21	2	12	1	0.004948
21	2	12	2	0.004122
21	2	12	3	0.003
21	2	12	4	0.002265
21	2	12	5	0.002105
21	2	12	6	0.003277
21	2	12	7	0.00927
21	2	12	8	0.019876
21	2	12	9	0.04253
21	2	12	10	0.093737
21	2	12	11	0.152748
21	2	12	12	0.169864
21	2	12	13	0.125502
21	2	12	14	0.072482
21	2	12	15	0.065015
21	2	12	16	0.229258

CHAPTER 2

Model Calibration and Validation

Model System Calibration and Validation Process

Because the Jacksonville DaySim implementation was “transferred” from Sacramento—and the model coefficients and alternative-specific constants were initially estimated and calibrated for the Sacramento region—the project team had to recalibrate the core model components to reflect Jacksonville region-specific travel patterns. Calibration and validation of the entire model system is a highly iterative process that involves making changes to individual model components to better match observed data sources, as well as evaluating the impacts of these changes on other model components and on overall model system performance. One of the advantages of the disaggregate nature of activity-based microsimulation models such as DaySim is that they support more flexibility and realistic calibration adjustments than is possible with aggregate trip-based models. Note that a calibration effort was not performed for the Burlington implementation.

Observed Data Sources

Before calibrating the core behavioral components, the project team had to prepare observed data sets against which to compare the model outputs. The primary observed data source for the calibration of the core DaySim component models was the 2009 National Household Travel Survey (NHTS) data collected in 2008–2009. For some model components, such as the household vehicle availability model and the work-tour-destination model, the NHTS was supplemented with observed information from the 2005–2009 American Community Survey (ACS) data. Because the focus of the C10A effort is on a region in which choices of nonhighway modes are limited, and thus the dynamic, integrated model represents behavioral changes primarily in response to roadway conditions, detailed transit information (e.g., an onboard survey) was not used in this effort.

The observed transit mode share for the Jacksonville region is less than 1%.

To support the calibration of the DaySim models, the project team first had to process the NHTS household, person, and trip records to create a new tour record file and to append additional information to the existing NHTS household, person, and trip files. A summary of the NHTS data available for calibration is shown in Table 2.1.

Although additional NHTS “add on” survey data were collected in the Jacksonville region, the overall number of households, persons, tours, and trips was relatively small. Because DaySim models travel behavior for a typical weekday, weekend days had to be removed from the data set, further reducing the sample size. Although the NHTS contains all the data items required for activity-based model (ABM) system development, such a small regional sample is insufficient to completely estimate the coefficients in the DaySim component models. However, in the absence of any other data sets containing the information required for ABM development, the NHTS was deemed acceptable for deriving calibration targets.

In addition to the relatively small sample size, a number of other issues arose when using the NHTS data. These issues included the following:

- The absence of any person, tour, or trip information for children under 5 years of age: Although these people are reflected in the household size information, no travel behavior is recorded. As a result, all summaries of DaySim estimated travel behaviors exclude travel by young children to facilitate comparisons.
- Missing travel information for some members of the household: Typically, all travel made by all members of each household is collected during the household survey data collection process. Having this complete set of travel demand is even more critical in the context of advanced activity-based model systems which consider all travel by all household members across all times of day, and which may explicitly consider

Table 2.1. NHTS Summary Statistics for Jacksonville Region

County	Households	Persons	Tours Total	Tours Weekday	Trips Total	Trips Weekday
Clay	658	1,365	1,717	1,304	4,630	4,108
Duval	205	448	599	438	1,628	1,428
Nassau	198	415	476	373	1,287	1,153
St Johns	79	171	203	172	580	548
Total	1,140	2,399	2,995	2,287	8,125	7,237

travel made jointly by members of the household. To address these missing persons, the person weights had to be adjusted to match regional controls of persons by person type developed to support creation of the synthetic population.

- **Inconsistent expansion factors:** When the household and person expansion factors provided with the NHTS were applied, significant discrepancies with other regional person and household totals were observed, necessitating further adjustments to the expansion factors.

Finally, a number of the NHTS-derived summaries seemed inconsistent with other household travel surveys used for DaySim development. For example, the NHTS seemed to show relatively high shares of workers choosing to work at home. Notwithstanding these issues, the NHTS was used as the primary data source in the absence of any viable alternatives.

Calibration Results

The following sections present the results of the initial calibration of the Jacksonville DaySim implementation. Although all model calibration adjustments have a simultaneous impact on the model predictions, the calibration effort typically follows a sequential process from the top to the bottom of the DaySim model hierarchy because adjustments to upper-level models tend to affect lower-level model predictions more than the reverse. The calibration results described in these sections follow this hierarchy.

Note that these calibration results should not be considered final. The C10A project has involved the use of multiple sets of regional skims at different temporal resolutions, using different network simulation methods at different points in the project. For example, an initial calibration was performed using skims for four broad time periods. Subsequently, the calibration was revisited when Microsimulator-based skims for 22 time periods became available. The calibration was further revised when Router-based skims from the fully integrated model system were developed. Also note that the summaries shown are not exhaustive and that additional summaries have been prepared and used in the calibration process.

Usual Work and School Locations

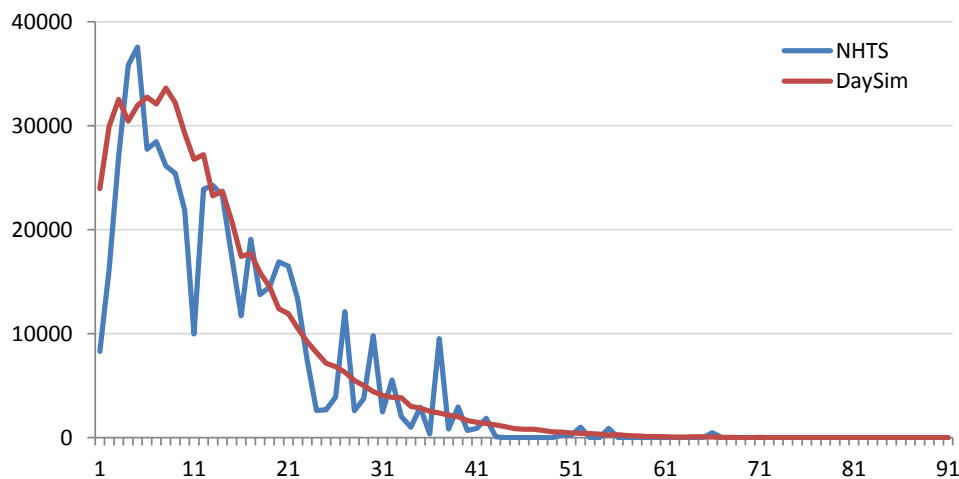
The usual work and school location models are the first models in the DaySim system; they predict the usual destination parcels for work and school tours. Information on workplace locations can then be used in subsequent model components, such as auto ownership. The work and school location models, as well as all the tour-destination-choice models, assume a single anchor point—the tour origin—from which impedance is measured, without direct consideration of the impedance for stops on the way to and from the tour destination. For the usual work and school location models, the anchor is the person's home. In these models, the home location is treated as a special location, because it occurs with greater frequency than any given nonhome location, and size and impedance are not meaningful attributes. In addition, the model incorporates availability constraints; for example, only parcels with grade enrollment are available as school-tour destinations for children.

Table 2.2 shows that the model system achieves a relatively good match between overall average work-tour lengths. DaySim predicts shorter work tours for part-time workers than observed in the NHTS, and longer student work tours. Figure 2.1 illustrates that the overall distribution of estimated work-tour lengths matches the distribution of observed work tours. This figure also illustrates that, even with relatively large travel markets, such as work purpose tours, the observed

Table 2.2. Average Work-Tour Length, by Model Type (miles)

Worker Type	NHTS	DaySim
Full-time workers	13.67	13.51
Part-time workers	9.75	8.10
Students	5.71	6.84
Total	12.99	12.53

Source: DaySim and NHTS.



Source: DaySim and NHTS.

Figure 2.1. Distribution of work-tour lengths.

data derived from NHTS show a fair amount of variation. Finally, Table 2.3 summarizes commute flows from the 2005–2009 ACS data. This table demonstrates that the model system is doing a reasonable job of capturing these flows, although Duval County (which contains Jacksonville) is slightly over-predicted as a commute destination while St. Johns County (which is along the coast) is underpredicted. Note that a “cleaned” business employment database was not available for St. Johns County, and the St. Johns existing employment had to be adjusted to match estimates of county employment derived from external sources.

Table 2.4 and Figure 2.2 summarize the usual school location model results. Overall, the current calibration of DaySim produces longer school tours than observed. DaySim predicts slightly longer school tours for grade school students and university students and slightly shorter school tours for high school students. As seen with the work tours, the observed data derived from NHTS show a fair amount of variation in school-tour lengths.

Vehicle Availability

The vehicle availability model predicts the number of motorized vehicles owned, leased, or otherwise belonging to the fleet of vehicles possessed by a household. The vehicle availability model takes as given the household characteristics, as well as the regular work location information of all workers in the household.

To calibrate and validate the model, the estimated share of households in each vehicle availability category was compared with the observed shares of households along three primary dimensions: household potential drivers, household income, and household residence county. Two primary sources for observed data were identified and summarized: the 2005–2009 ACS data and 2009 NHTS. Table 2.7 shows the difference between the original estimated (Table 2.6) and the observed (Table 2.5) shares of households by auto availability and county of residence. The tables illustrate that the model is underpredicting 0-vehicle and 2-vehicle households and overpredicting 1-vehicle and 3+-vehicle households, suggesting that further calibration of this model is warranted.

Table 2.3. Worker Flows by County (%)

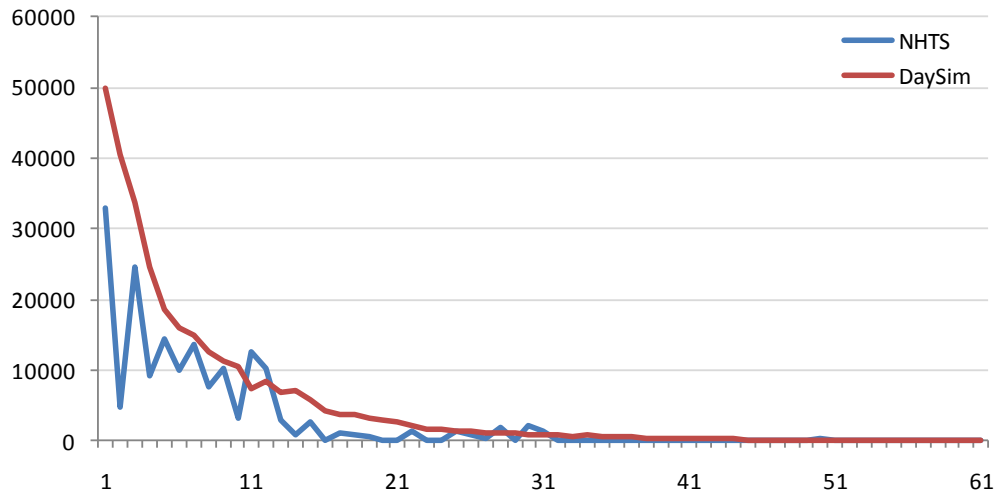
County	O–D				Total
	Clay	Duval	Nassau	St Johns	
Clay	-1.2	1.2	0.0	0.0	0.0
Duval	0.5	-1.0	0.4	0.2	0.0
Nassau	0.0	0.5	-0.5	0.0	0.0
St Johns	0.3	0.8	0.0	-1.2	0.0
Total	-0.4	1.5	-0.1	-1.0	0.0

Note: O–D is origin–destination.
Source: DaySim and 2005–2009 ACS.

Table 2.4. Usual School Location Average Distance (miles)

School Type	NHTS	DaySim
Grade school	5.25	5.41
High school	6.56	5.87
University	11.67	12.67
Total	6.64	7.14

Source: DaySim and NHTS.



Source: DaySim and NHTS.

Figure 2.2. Distribution of school-tour lengths.

Day Pattern

The day-pattern model predicts the number and purpose of tours and intermediate stops made by each individual. These predictions arise from a series of sequential submodels that address different aspects of each individual’s daily activity pattern. The main activity pattern model predicts whether a person participates in any tours and intermediate stops for

each of the seven different activity purposes and then the exact number of tours made for that purpose during the full day. Another submodel predicts the number and purpose of work-based subtours, while a final submodel predicts the number and purpose of intermediate stops.

Calibration targets for the day-pattern model calibration were derived from the NHTS. The full set of targets addressed tours by person type; tour and stop combinations by person type; exact numbers of tours and stops by purpose and person type; exact number and purpose of work-based subtours by person type; numbers of stops by tour purpose; and the exact numbers of tours and stops by person type. The estimated results produced by the activity generator were then compared with these targets. The calibration and validation process primarily involved making adjustments to alternative specific constants and reviewing and revising estimated parameters to ensure reasonability and consistency.

Table 2.8 compares the total number of tours for each of the destination purposes predicted by DaySim with the NHTS

Table 2.5. Observed Households, by Vehicle Availability (%)

County	0	1	2	3	4+	Total
Clay	0.3	3.3	5.7	2.2	0.8	12.3
Duval	5.4	26.3	27.0	7.7	2.7	69.1
Nassau	0.2	1.4	2.1	1.0	0.4	5.0
St Johns	0.5	4.2	6.6	1.6	0.6	13.6
Total	6.4	35.1	41.4	12.6	4.4	100.0

Source: 2005–2009 ACS.

Table 2.6. Estimated Households, by Vehicle Availability (%)

County	0	1	2	3	4+	Total
Clay	0.1	3.8	5.5	2.0	0.9	12.3
Duval	3.7	27.0	26.3	8.6	3.5	69.1
Nassau	0.0	1.7	2.2	0.7	0.3	5.0
St Johns	0.1	4.9	5.9	1.9	0.8	13.6
Total	3.9	37.4	40.0	13.3	5.5	100.0

Source: DaySim.

Table 2.7. Difference in Households, by Vehicle Availability (%)

County	0	1	2	3	4+	Total
Clay	-0.2	0.5	-0.1	-0.3	0.1	0.0
Duval	-1.7	0.7	-0.7	0.9	0.8	0.0
Nassau	-0.2	0.3	0.1	-0.2	0.0	0.0
St Johns	-0.4	0.7	-0.7	0.3	0.2	0.0
Total	-2.5	2.3	-1.5	0.6	1.1	0.0

Source: DaySim and 2005–2009 ACS.

Table 2.8. Tours, by Destination Purpose

Purpose	NHTS	DaySim	Diff	% Diff
work	432,006	485,234	53,228	12
school	176,802	184,635	7,833	4
escort	135,493	128,014	-7,479	-6
pers.bus	111,630	108,583	-3,047	-3
shop	216,455	225,625	9,170	4
meal	59,408	59,031	-377	-1
soc/rec	244,219	242,368	-1,851	-1
Total	1,376,013	1,433,490	57,477	4

Source: DaySim and NHTS.

observed tours by destination purpose. This table illustrates that, overall, DaySim is matching regional tours relatively well, with 4% too many tours across all purposes. Tours by individual destination purpose match reasonably well, with the exception of work tours, which are overpredicted by 12%. Further adjustment to the calibration to address this overprediction is recommended.

Table 2.9 summarizes the estimated and observed trips by destination purpose. This table demonstrates that DaySim is matching overall trips extremely well, although some of the individual purposes could use further refinement. Specifically, work trips are overpredicted, which is consistent with the overprediction of work tours, while school trips are underpredicted.

Tour and Stop Destinations

Destinations for each of the tours predicted by the daily activity pattern models are predicted by a purpose-segmented

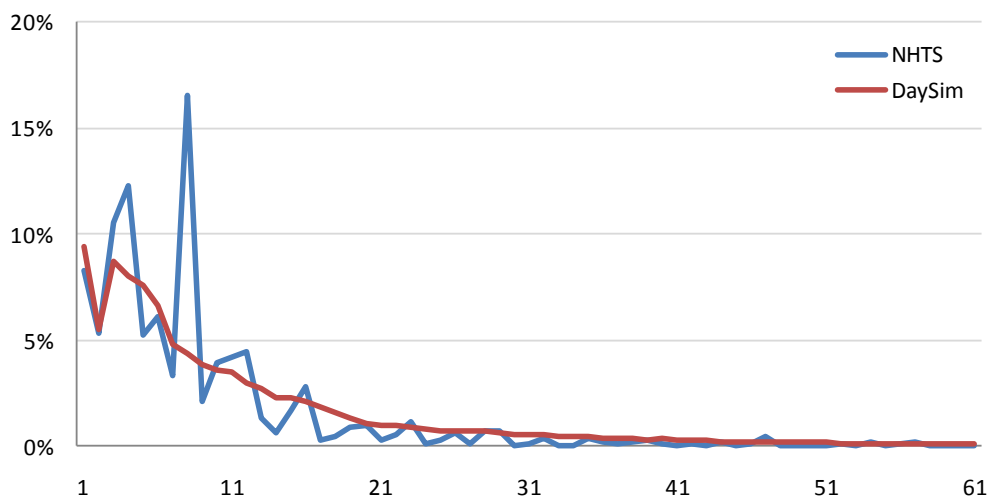
Table 2.9. Trips, by Destination Purpose

Purpose	NHTS	DaySim	Diff	% Diff
work	730,988	797,150	66,162	9
school	209,466	189,977	-19,489	-9
escort	265,299	254,821	-10,478	-4
pers.bus	251,000	250,055	-945	0
shop	646,348	651,131	4,783	1
meal	199,045	203,632	4,587	2
soc/rec	395,372	375,919	-19,453	-5
home	1,467,457	1,434,811	-32,646	-2
Total	4,164,975	4,157,496	-7,479	0

Source: DaySim and NHTS.

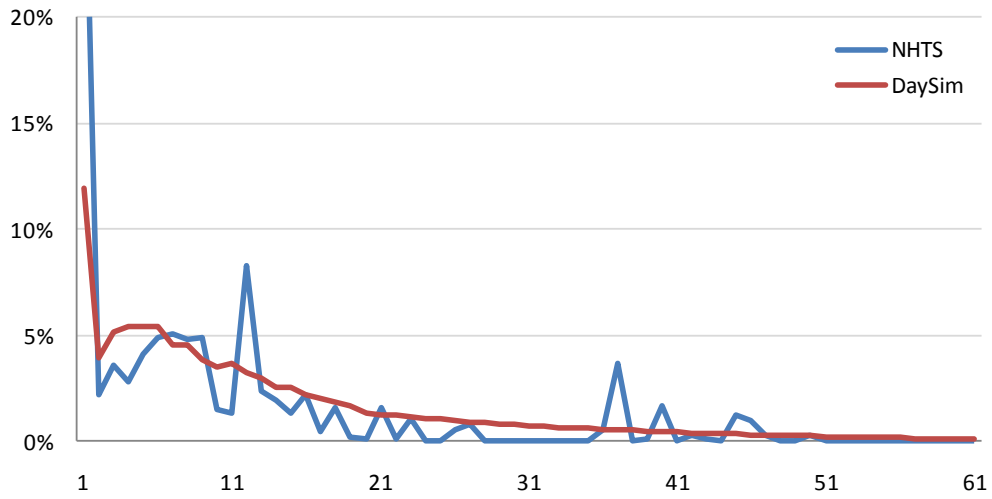
destination-choice model, using information about network impedances, purpose-specific size terms, and household and person attributes. The tour-destination-choice models predict a specific parcel as a destination and assume a single home anchor point (the tour origin, from which impedance is measured), without direct consideration of the impedance for stops on the way to and from the tour destination. Unlike the usual work location, which has a nested structure to reflect the treatment of home as a special location, the destination-choice models consider all parcels in a multinomial structure, subject to availability constraints.

Figure 2.3 through Figure 2.7 compare the observed NHTS tour length frequencies with the estimated DaySim tour length frequencies. These figures demonstrate that DaySim matches observed data reasonably well, but they also illustrate the variations in some of the NHTS data, especially for purposes not well represented in the NHTS. One example of a purpose not well represented would be meal tours.



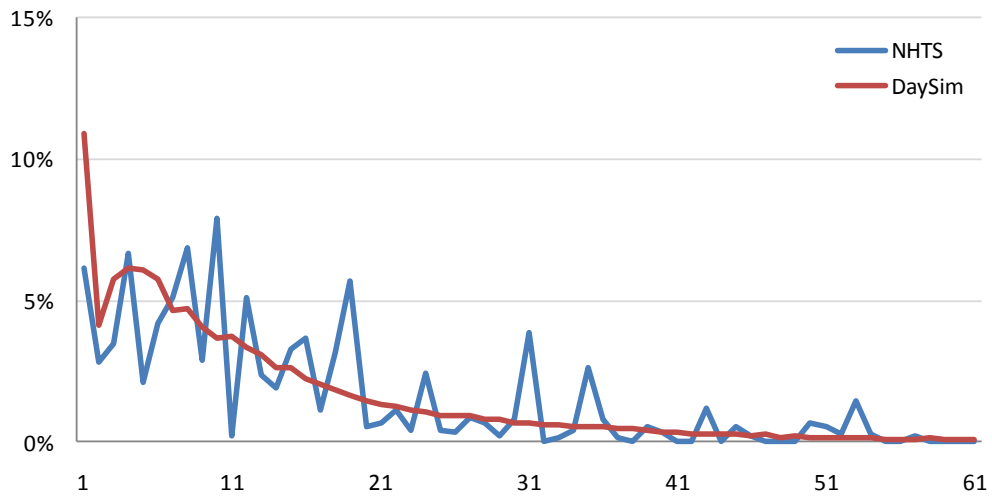
Source: DaySim and NHTS.

Figure 2.3. Distribution of shop tour lengths.



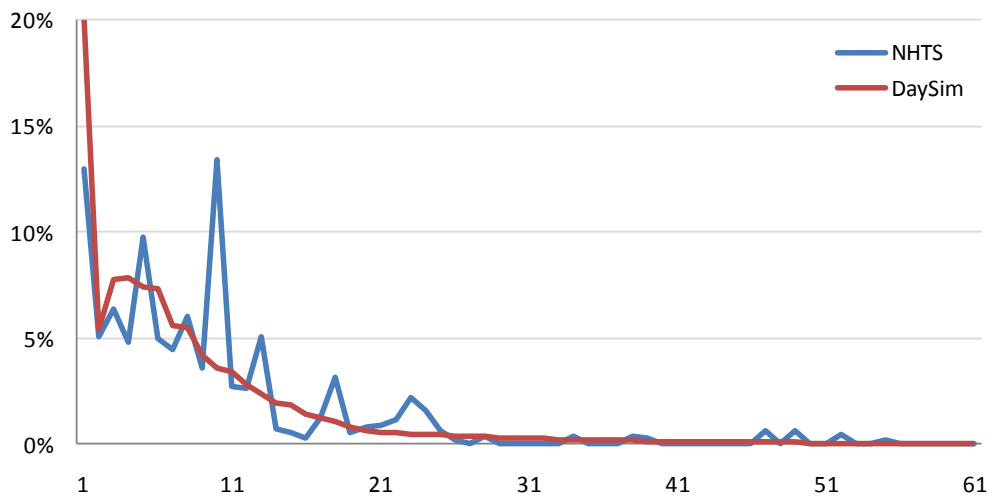
Source: DaySim and NHTS.

Figure 2.4. Distribution of social/recreation tour lengths.



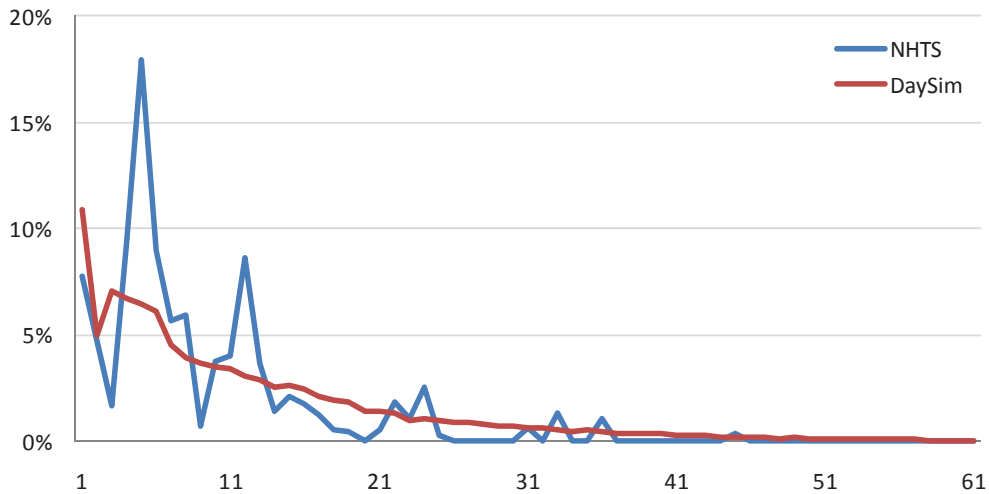
Source: DaySim and NHTS.

Figure 2.5. Distribution of personal business tour lengths.



Source: DaySim and NHTS.

Figure 2.6. Distribution of escort tour lengths.



Source: DaySim and NHTS.

Figure 2.7. Distribution of meal-tour lengths.

Trip Mode

The DaySim model system incorporates two sets of mode-choice models. The tour-mode-choice model predicts the primary mode used for a tour, while the trip-mode-choice model predicts the mode used for each individual trip on the tour, constrained by the tour mode. The tour- and trip-mode-choice models incorporate a variety of network impedance, household, and purpose attributes, and even land-use attributes. The core mode-choice models incorporate the following modes:

- Drive to transit.
- Walk to transit.
- School bus.
- Shared ride 2.
- Drive alone.
- Bike.
- Walk.

Table 2.10 through Table 2.12 summarize the observed and estimated mode shares by trip destination purpose. The mode-choice model calibration process involves making adjustments to both the tour models and trip models. However, only the trip-mode-choice model outputs are used directly in the network assignment process, so only the trip-mode results are reported in the following tables. These tables demonstrate

Table 2.10. Observed Trip-Mode Shares, by Destination Purpose (%)

Mode	Work	School	Escort	PersBus	Shop	Meal	SocRec	All Purp
Drive Alone	80.7	17.9	29.9	48.8	56.0	35.1	24.3	52.8
SR2 - Driver	8.0	7.3	33.4	17.8	14.2	24.6	8.7	12.8
SR2 - Passenger	4.6	20.8	4.9	19.4	13.3	8.2	7.5	9.1
SR3+ - Driver	3.3	3.0	18.8	3.3	5.3	9.6	9.0	6.2
SR3+ - Passenger	1.3	39.0	8.9	8.7	5.5	13.0	15.3	9.9
Drive-Transit-Walk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walk-Transit-Drive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walk-Transit-Walk	0.0	0.0	0.0	0.6	0.0	0.0	2.4	0.4
School Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bike	0.0	3.0	1.4	0.1	0.3	2.5	6.0	1.3
Walk	2.1	8.9	2.6	1.3	5.5	7.0	26.7	7.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: NHTS.

Table 2.11. Estimated Trip-Mode Shares, by Destination Purpose (%)

Mode	Work	School	Escort	PersBus	Shop	Meal	SocRec	All Purp
Drive Alone	83.5	14.4	22.4	57.4	52.6	28.4	43.7	56.4
SR2 - Driver	8.2	6.9	27.5	16.1	18.4	32.6	18.1	14.3
SR2 - Passenger	1.3	22.3	10.3	10.7	11.7	14.8	15.4	9.0
SR3+ - Driver	3.5	6.8	17.1	5.3	6.5	9.9	6.2	6.1
SR3+ - Passenger	0.8	30.1	11.0	7.0	7.7	10.6	10.7	7.9
Drive-Transit-Walk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walk-Transit-Drive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walk-Transit-Walk	0.2	0.5	0.0	0.2	0.0	0.2	0.1	0.2
School Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bike	0.8	4.0	0.2	0.6	0.5	0.2	0.7	0.9
Walk	1.7	15.0	11.5	2.8	2.5	3.3	5.2	5.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: DaySim.

that DaySim does a reasonably good job of matching aggregate mode shares, although the calibration by purpose could be improved. Overall, drive alone shares are overpredicted by 3.6%, while walk shares are underpredicted by 2.4%.

Note that the tables include additional modes not in the preceding list. In the context of existing ABM 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 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. Because it is not possible to divide discrete shared ride trips by an occupancy rate to estimate vehicle trips, driver and passenger status have to be assigned to travelers whose mode is identified as shared ride. DaySim does not predict whether a person is an auto driver or a passenger for shared ride tours and trips, so a detailed analysis was used to derive a method for assigning an auto driver or passenger designation to each auto tour and trip, based on the modes used on a given tour.

Table 2.12. Difference in Trip-Mode Shares, by Destination Purpose (%)

Mode	Work	School	Escort	PersBus	Shop	Meal	SocRec	All Purp
Drive Alone	2.8	-3.5	-7.5	8.6	-3.4	-6.7	19.3	3.6
SR2 - Driver	0.2	-0.4	-5.9	-1.7	4.2	8.0	9.4	1.6
SR2 - Passenger	-3.3	1.5	5.4	-8.7	-1.5	6.6	7.9	-0.1
SR3+ - Driver	0.2	3.8	-1.7	2.0	1.3	0.3	-2.8	0.0
SR3+ - Passenger	-0.5	-8.9	2.1	-1.8	2.2	-2.4	-4.6	-2.0
Drive-Transit-Walk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walk-Transit-Drive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walk-Transit-Walk	0.2	0.5	0.0	-0.4	0.0	0.2	-2.4	-0.3
School Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bike	0.8	1.0	-1.2	0.4	0.2	-2.3	-5.2	-0.4
Walk	-0.4	6.1	8.9	1.6	-3.0	-3.7	-21.6	-2.4
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: DaySim and NHTS.

Tour and Trip Time of Day

One of the most compelling features of ABM approaches is that they have the capability to treat time explicitly and consistently across all travel choice dimensions. Rather than using fixed factors or broad time periods, activity-based models can consider detailed time periods, as well as desired arrival times, departure times, and activity durations. This capability is essential to fulfilling the goal of the C10A project, which is to make operational a dynamic, integrated model that is sensitive to the dynamic interplay between travel behavior and network conditions.

To provide this sensitivity, DaySim includes two types of time-of-day models. Tour arrival and departure time at the primary destination models predict the time that the person arrives at the tour primary destination and the time that the person leaves that primary destination. Intermediate stop arrival or departure time models predict the time that the person arrives at the stop location (on the first half tour) or the time that the person departs from the stop location (on the second half tour). The time-of-day models operate at a 30-min time resolution, using the 48 half-hour periods of the day. In addition, the models employ time windows when scheduling, so that when a tour or stop is scheduled, the portions of the window not filled are left as two separate and smaller time windows.

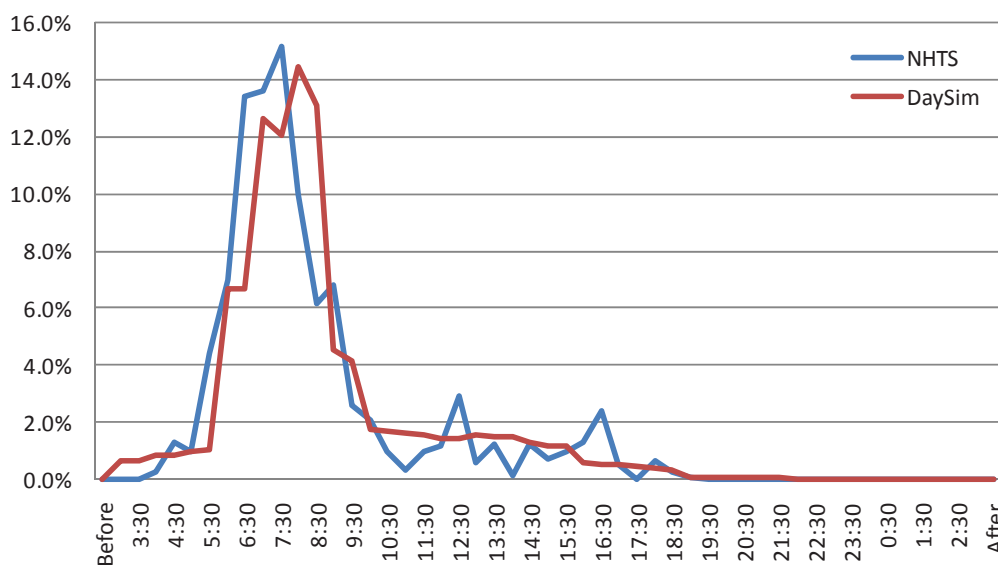
Figure 2.8 through Figure 2.11 compare the estimated and observed arrival times at tour primary destinations by purpose. Figure 2.8 shows the strong a.m. peak for arrival times at work, while Figure 2.9 shows an even stronger a.m. peak for arrival times at school. For both these tour purposes, the estimated and observed distributions of tour

arrivals by half-hour are very similar. Figure 2.10 illustrates that the tour arrival times for other purposes (shop, meal, escort, social/recreational, and personal business) are more evenly distributed across the day and that the estimated and observed distributions are similar. The estimated and observed work-based subtours, shown in Figure 2.11, do not match as closely. This subset of tours uses the work locations rather than the home locations as the anchors. The observed NHTS data show a strong peak at midday, corresponding with lunchtime, while DaySim predicts more of these tours at other times of day.

In addition to considering tour arrival and departure times, DaySim incorporates parameters related to the durations of activities. Figure 2.12 through Figure 2.15 show the estimated and observed tour durations. Overall, the estimated and observed results are similar, although DaySim predicts a stronger peak at a 9-hour work-tour activity, while the NHTS data show a stronger peak in school-tour durations at 6 hours.

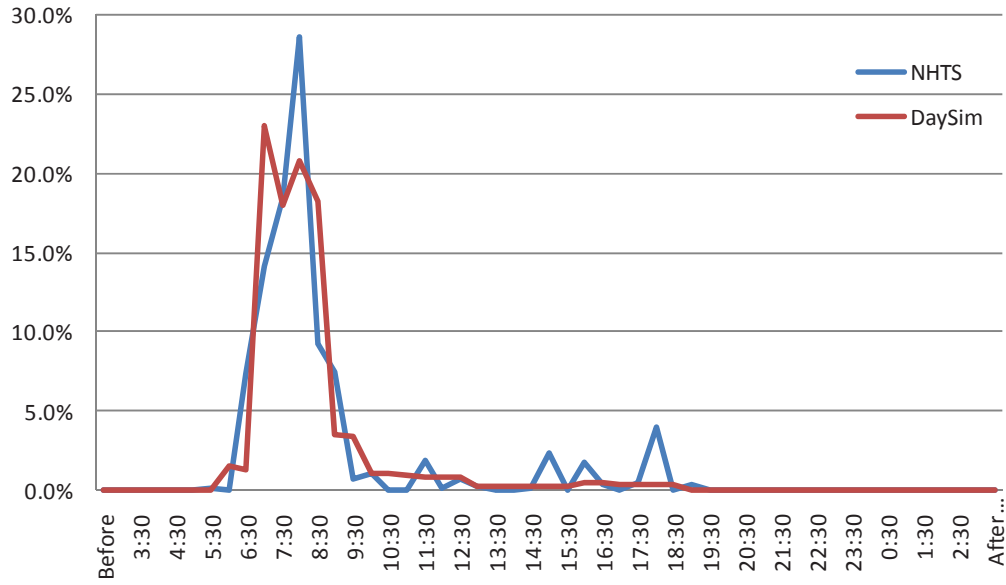
TRANSIMS Validation Process

This section documents the calibration and validation results of assigning the Northeast Florida Regional Planning Model (NERPM) trip tables to the PLANNING-level regional network. Validation tests were performed using all three network resolutions described earlier in this report, with a particular focus on the PLANNING and FINEGRAINED resolution networks. However, because of the significantly longer run-times associated with the FINEGRAINED and ALLSTREETS networks, the PLANNING network has been the primary network resolution used in the integrated model system.



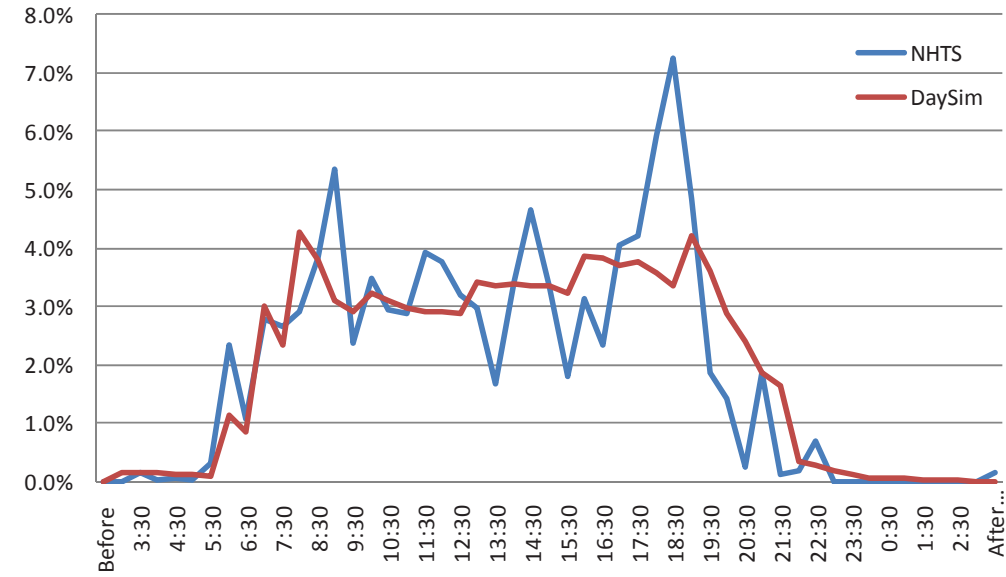
Source: DaySim and NHTS.

Figure 2.8. Work-tour arrival times.



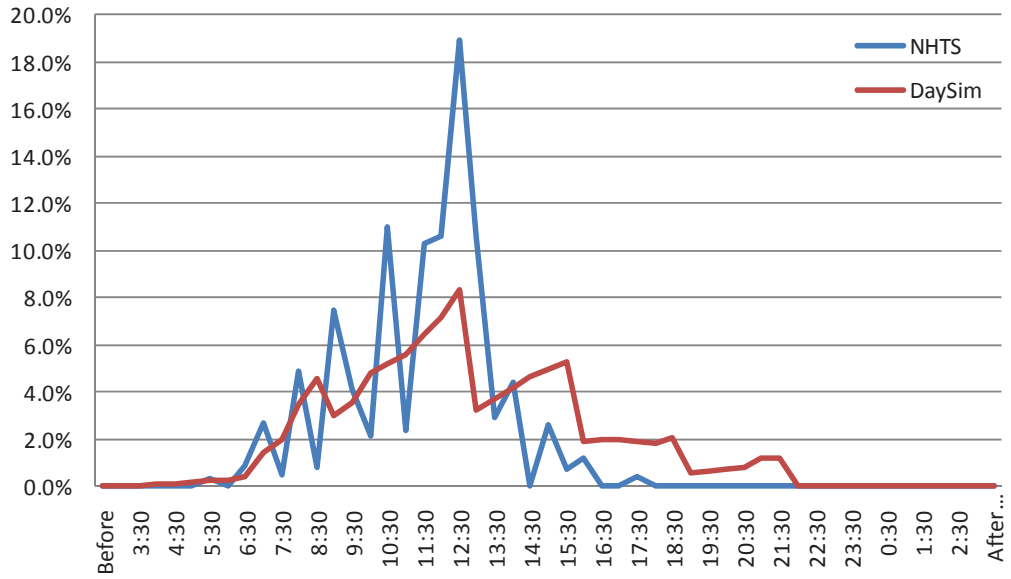
Source: DaySim and NHTS.

Figure 2.9. School-tour arrival times.



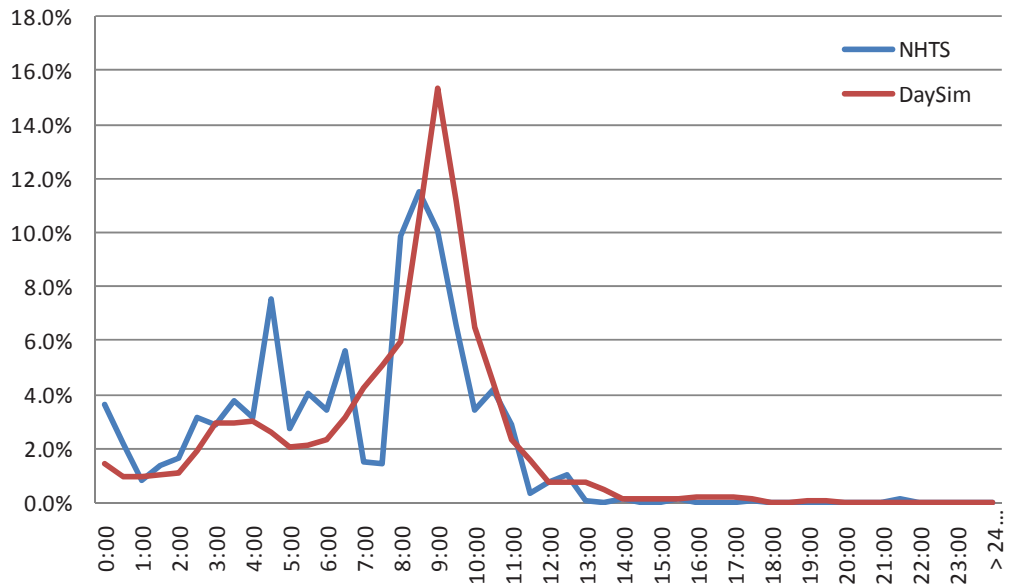
Source: DaySim and NHTS.

Figure 2.10. Other arrival times.



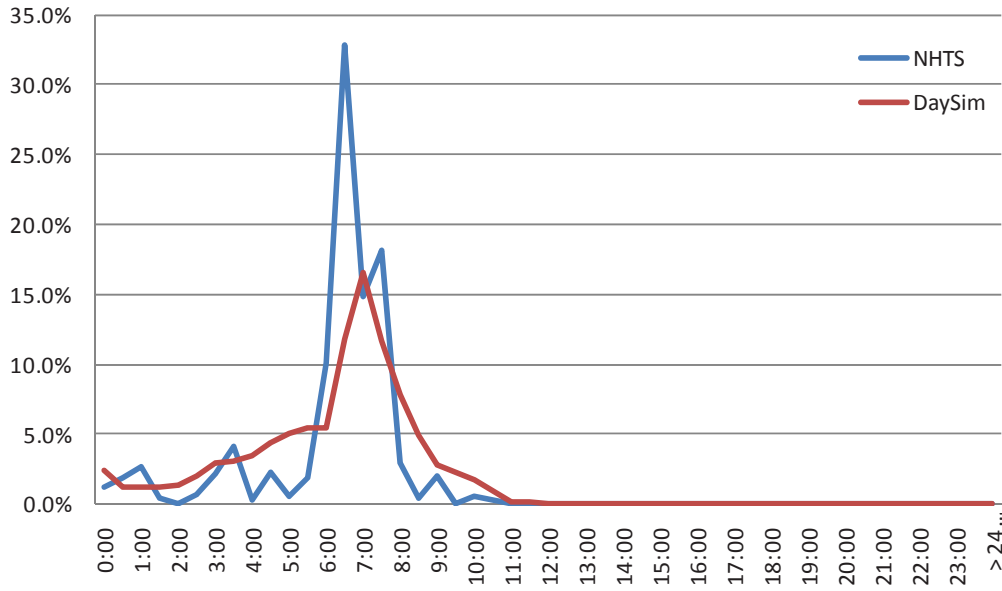
Source: DaySim and NHTS.

Figure 2.11. Work-based arrival times.



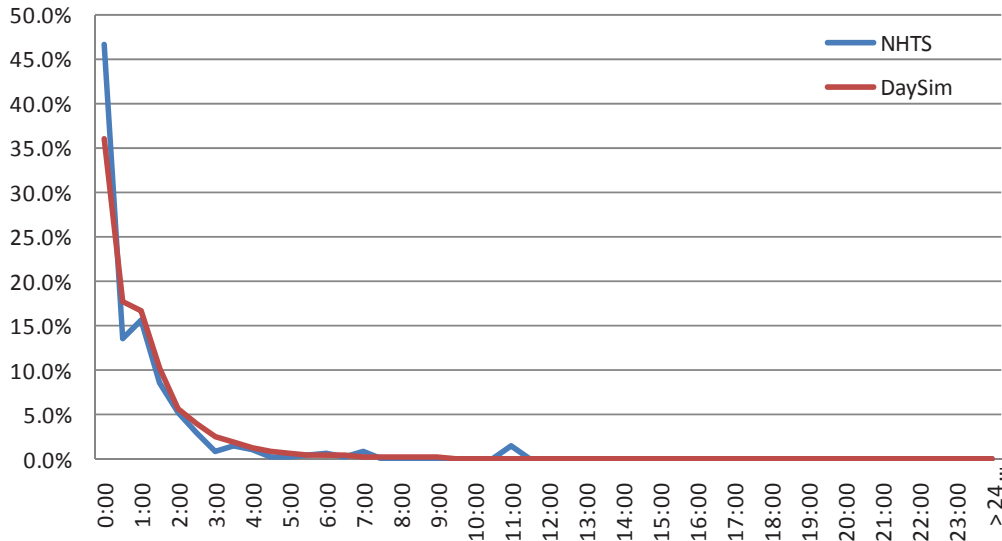
Source: DaySim and NHTS.

Figure 2.12. Work-tour durations, in hours.



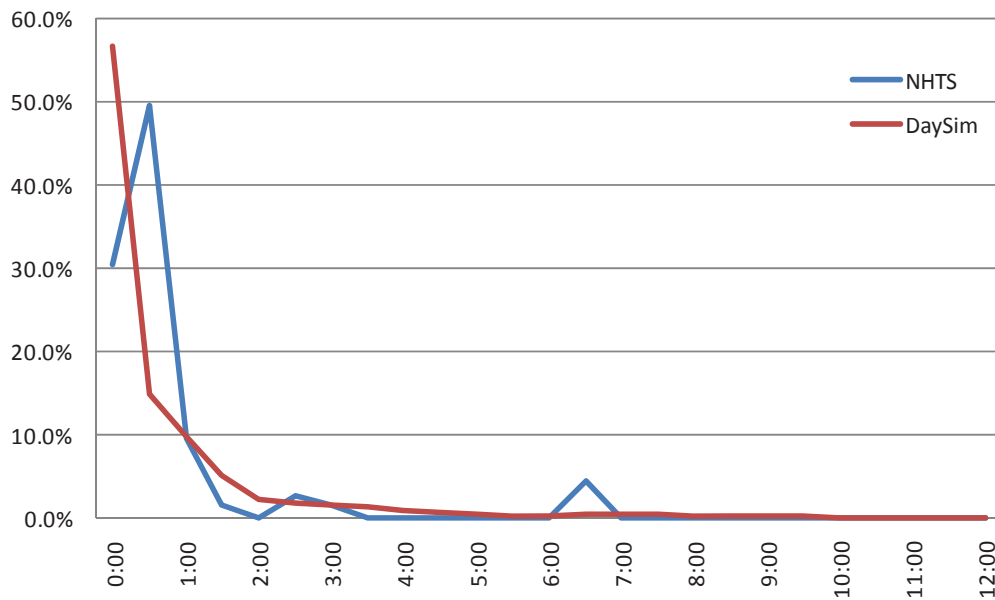
Source: DaySim and NHTS.

Figure 2.13. School-tour duration, in hours.



Source: DaySim and NHTS.

Figure 2.14. Other tour durations, in hours.



Source: DaySim and NHTS.

Figure 2.15. Work-based-tour durations, in hours.

Observed Data Sources

The following three sources of 15-min count and data were compiled from the Florida Department of Transportation (FDOT):

1. Intelligent transportation systems (ITS) detectors on I-295 and I-95;
2. Portable traffic monitoring stations (PTMS) on arterials and freeways; and
3. Telemetered traffic monitoring sites (TTMS) on arterials and freeways.

The PTMS and TTMS data were obtained from FDOT's Transportation Statistics Office (TRANSTAT) and included only 15-min vehicle counts. The ITS data included 15-min count and speed data. All of these count data were collected in 2008–2009 and were processed as described later for comparison with the 2005 model year assignments.

With the help of the project team members at Florida International University, the observed traffic counts were scrubbed for spatial and temporal consistency. The data were then tagged to the NERPM master (merged) network to identify corresponding links in the 2005 NERPM network. The tagging

process involved identifying a pair of nodes—Anode and Bnode—from the merged network for each of the count or speed locations. Tagging to the merged network ensured that the data can be transferred to the different network resolutions and modeling years without duplication of work. This process resulted in what is called a directional-data set in which each record corresponds to a link direction, whether or not it is represented as a two-way link in TRANSIMS.

During the network conversion process, a link-node equivalence file is created by TransimsNet; it lists the sequence of nodes that were merged to create each TRANSIMS link. The LinkData program uses this file to transfer the directional count and speed data sets from the NERPM network links to the link numbers created for the PLANNING network.

During this the data processing, issues with the original tagging process were identified and addressed, and further data checks were performed. Some data points needed to be merged because they were located on the same merged link. Similarly, a few data points needed to be dropped because of incomplete or erroneous data for all times of day or because of problems with proper identification of links.

The number of data points from each data source included in each step of the process is shown in Table 2.13.

Table 2.13. Number of Locations for PTMS, TTMS, and ITS Data

Data Source	Native Format	Tagged to the Merged Network	Valid Tags	Transferred to the TRANSIMS Network
PTMS	923	923	897	562
TTMS	20	7	7	7
ITS	190	123	122	84

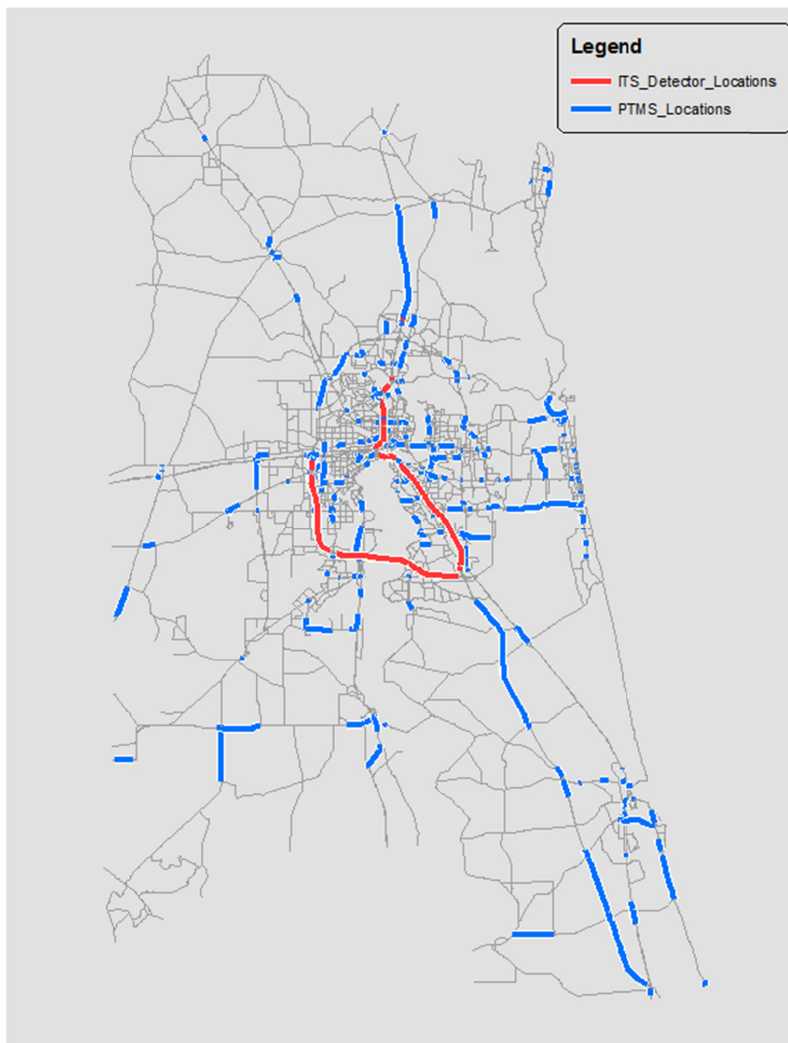


Figure 2.16. Locations of PTMS and ITS data shown on the PLANNING network.

The TTMS data points were very limited in comparison with the other two sources. However, because they are permanent traffic monitoring stations, traffic counts throughout the year at the 15-min resolution were available. This information can be used for studying the seasonal and special event traffic patterns at these select locations. Because the PTMS and ITS data provided the bulk of the validated data set, these two sources were relied on heavily for comparisons and are presented in this chapter. The locations of the PTMS and ITS data points for the Jacksonville region are shown in Figure 2.16.

Validation Results

Table 2.14 and Table 2.15 summarize the initial daily validation by facility type and area type. These tables demonstrate that overall daily volumes match relatively well, with estimated volumes approximately 3.4% higher than observed volumes and a regional %RMSE of 38.6. Higher-level facilities are

generally overpredicted, and lower-level facilities underpredicted. This is primarily attributable to adjustments made to parameters affecting the circuitry of routes during the TRANSIMS microsimulation calibration to better match highway volumes and speeds.

Table 2.15 indicates that the volumes in the denser regional core (area types 1 and 2) are generally overpredicted, with more suburban and rural areas slightly underpredicted.

Estimated roadway volumes were also compared with observed volumes for four broad time periods. Note that unlike a traditional static assignment model, the TRANSIMS assignment process does not assign demand to the network by broad time period. Rather, the entire day's demand of individual trips is loaded onto the network using minute-level departure time information provided by DaySim. However, time period summaries are still helpful in assessing the performance of the assignment model and informing adjustments to be made to both the DaySim demand and TRANSIMS supply models.

Table 2.14. Daily Validation, by Facility Type

Facility Type	# Obs.	Est. Vehicles	Obs. Vehicles	Diff.	% Diff.	%RMSE
Freeway	128	5,475,280	5,136,426	338,854	6.6	32.2
Expressway	30	929,697	767,990	161,707	21.1	35.1
Principal Arterial	52	580,435	576,392	4,043	0.7	26
Major Arterial	293	5,150,743	5,040,281	110,462	2.2	28.3
Minor Arterial	99	900,580	900,885	-305	0	48.8
Collector	18	140,057	123,639	16,418	13.3	46.6
Local Street	8	52,533	104,271	-51,738	-49.6	88.3
Ramp	80	492,855	615,063	-122,208	-19.9	72.7
External	2	3,819	5,287	-1,468	-27.8	28.3
Total	710	13,725,999	13,270,234	455,765	3.4	38.6

Note: # Obs. = number of observations; Est. = estimated; Obs. = observed; Diff. = difference.

Table 2.15. Daily Validation, by Area Type

Area Type	# Obs.	Est. Vehicles	Obs. Vehicles	Diff.	% Diff.	%RMSE
Area Type 1	45	665,453	594,015	71,438	12	32.2
Area Type 2	118	2,651,881	2,419,343	232,538	9.6	35.1
Area Type 3	451	9,004,366	8,775,450	228,916	2.6	26
Area Type 4	47	1,074,084	1,141,492	-67,408	-5.9	28.3
Area Type 5	49	330,215	339,934	-9,719	-2.9	48.8
Total	710	13,725,999	13,270,234	455,765	3.4	38.6

Note: # Obs. = number of observations; Est. = estimated; Obs. = observed; Diff. = difference.

The time period summaries illustrate that the integrated model results for the a.m., midday, and p.m. peak periods look reasonably good both in terms of matching aggregate volumes by facility type and in terms of %RMSE (Tables 2.16 through 2.18). The evening time period (Table 2.19) looks more problematic and will require

additional investigation. To some extent this may be reflective of the cascade effect. That is, because the DaySim-TRANSIMS model preserves the integrity and linked nature of the individual trips on a tour across both the demand and assignment simulations, if more time is needed to reach a given activity location than was expected

Table 2.16. A.M. Validation, by Facility Type

Facility Type	# Obs.	Est. Vehicles	Obs. Vehicles	Diff.	% Diff.	%RMSE
Freeway	128	930,670	986,919	-56,249	-5.7	34.7
Expressway	30	153,556	143,126	10,430	7.3	30
Principal Arterial	52	125,920	107,029	18,891	17.7	52.1
Major Arterial	293	999,174	898,274	100,900	11.2	35.1
Minor Arterial	99	187,351	177,146	10,205	5.8	59.4
Collector	18	23,813	22,902	911	4	36.5
Local Street	8	11,170	21,925	-10,755	-49.1	83.5
Ramp	80	105,651	122,742	-17,091	-13.9	84.8
External	2	831	750	81	10.8	33.1
Total	710	2,538,136	2,480,813	57,323	2.3	43.9

Note: # Obs. = number of observations; Est. = estimated; Obs. = observed; Diff. = difference.

Table 2.17. Midday Validation, by Facility Type

Facility Type	# Obs.	Est. Vehicles	Obs. Vehicles	Diff.	% Diff.	%RMSE
Freeway	127	1,483,157	1,405,075	78,082	5.6	2978
Expressway	30	288,789	204,735	84,054	41.1	3090
Principal Arterial	52	147,854	167,971	-20,117	-12	830
Major Arterial	293	1,455,803	1,548,916	-93,113	-6	1318
Minor Arterial	99	270,473	270,067	406	0.2	1016
Collector	18	39,580	36,260	3,320	9.2	641
Local Street	8	14,749	28,670	-13,921	-48.6	1862
Ramp	80	134,675	173,331	-38,656	-22.3	1132
External	2	1,073	1,890	-817	-43.2	409
Total	709	3,836,153	3,836,915	-762	0	42.4

Note: # Obs. = number of observations; Est. = estimated; Obs. = observed; Diff. = difference.

Table 2.18. P.M. Peak Validation, by Facility Type

Facility Type	# Obs.	Est. Vehicles	Obs. Vehicles	Diff.	% Diff.	%RMSE
Freeway	127	1,107,510	1,128,918	-21,408	-1.9	2029
Expressway	30	186,698	172,605	14,093	8.2	1325
Principal Arterial	52	114,778	127,018	-12,240	-9.6	525
Major Arterial	293	1,046,420	1,126,449	-80,029	-7.1	826
Minor Arterial	99	199,800	205,659	-5,859	-2.8	681
Collector	18	26,379	28,242	-1,863	-6.6	454
Local Street	8	10,398	23,008	-12,610	-54.8	1702
Ramp	80	97,834	134,869	-37,035	-27.5	741
External	2	847	1,207	-360	-29.8	180
Total	709	2,790,664	2,947,975	-157,311	-5.3	35.3

Note: # Obs. = number of observations; Est. = estimated; Obs. = observed; Diff. = difference.

Table 2.19. Evening Validation, by Facility Type

Facility Type	# Obs.	Est. Vehicles	Obs. Vehicles	Diff.	% Diff.	%RMSE
Freeway	256	1,937,651	1,615,514	322,137	19.9	2542
Expressway	60	300,654	247,524	53,130	21.5	1556
Principal Arterial	104	191,883	174,374	17,509	10	613
Major Arterial	586	1,649,346	1,466,642	182,704	12.5	852
Minor Arterial	198	242,956	248,013	-5,057	-2	607
Collector	36	50,285	36,235	14,050	38.8	616
Local Street	16	16,216	30,668	-14,452	-47.1	1180
Ramp	160	154,695	184,121	-29,426	-16	617
External	4	1,068	1,440	-372	-25.8	166
Total	1420	4,544,754	4,004,531	540,223	13.5	65.5

Note: # Obs. = number of observations; Est. = estimated; Obs. = observed; Diff. = difference.

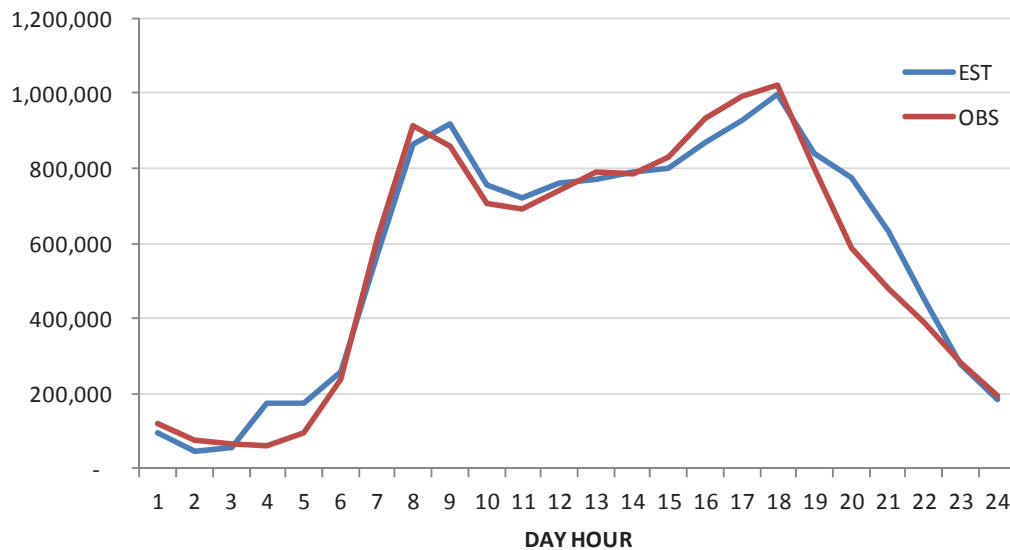


Figure 2.17. Estimated and observed total volumes, by hour.

when the demand was scheduled, then the start time and end time for that activity will be delayed; that causes a cascade effect through the traveler's entire daily activity pattern, with trips being pushed later and later in the day. This effect typically manifests in both the p.m. and evening periods; and in the current Jacksonville model, the p.m. is actually underpredicted.

Because demand is continuously assigned to the network across the entire day, estimated volumes can be compared with observed volumes using any temporal resolution. Figure 2.17 illustrates the estimated and observed volumes by hour. This chart clearly demonstrates that the integrated model is assigning more demand from 8:00 p.m. (hour 20) through 10:00 p.m. (hour 22) than observed.

CHAPTER 3

Model Sensitivity Testing

Purposes

Travel demand forecasting model systems are only able to test the effects of policies and assumptions which have been explicitly included when the system is designed and implemented; they are not intrinsically sensitive to the increasingly broad range of transportation policies and improvements of interest to decision makers. While most regional models are sensitive to large-scale assumptions about land use and demographics, few are sensitive to more detailed assumptions about pricing policies or to traffic or travel demand management strategies. Even when models have the capability to address these types of policies, they are typically not sufficiently sensitive to the dynamic interplay between travel behavior and network conditions by time of day, and are not able to reasonably represent the effects of road pricing, travel demand management, and other policies. A key goal of the SHRP 2 C10A project is to make operational a dynamic, integrated travel demand model with a fine-grained, time-dependent network, and to demonstrate the model's performance through sensitivity tests and policy analyses.

Sensitivity testing of model systems involves the evaluation of the effects of changes in model inputs on model outputs. Although sensitivity testing of model systems can be performed in many ways, two approaches to sensitivity testing of travel demand forecast models are often employed. In the first method, the sensitivity of individual model components is evaluated by adjusting model inputs and documenting the effect on outputs. Elasticities are calculated and evaluated relative to established standards. In the second method, the focus of the sensitivity testing is on the overall model system. The C10A project took the latter approach and focused on reporting the sensitivities of the model system.

Sensitivity Tests

A key motivating force behind the SHRP 2 C10A project is the need to address transportation policies that are being considered in metropolitan planning organizations (MPOs) around

the United States. These policies are not adequately addressed by the current state-of-the-practice travel-forecasting models, so the integrated modeling tool developed for this project seeks to improve how these policies are addressed. To assess the increased sensitivity of the integrated model system, a set of tests was designed, implemented, and evaluated. These tests were designed to illustrate the unique capabilities of the model system and included the following:

- *Pricing.* Pricing strategies are the costs imposed on travelers using certain roads, traversing certain screenlines, or traveling to certain areas (tolling, cordon pricing, or area pricing). These costs may either be fixed or vary by time of day, or they may respond to congestion. Two types of pricing tests were evaluated as part of this effort. In the first, a number of scenarios were defined in which freeway tolls varied by time of day. In the second, a number of scenarios were defined in which auto operating costs were modified from a baseline condition.
- *Travel demand management.* TDM approaches incorporate a wide range of strategies aimed at changing travel behavior to reduce congestion and improve mobility. Examples include increasing the number of people who work at home and their frequency of doing so; adjusting work schedules to facilitate travel in off-peak, less congested conditions; or increasing the number of people who carpool to work. This sensitivity testing focused on the impacts of a flexible work schedule in which workers worked fewer days but longer hours on those days. The overall time spent in work activities was held fixed.
- *Operations.* Operational strategies, also known as transportation system management (TSM) also address a wide range of projects and changes, including bottleneck improvements, corridor improvements, and parking strategies. For this project, the sensitivity testing focused on a scenario in which signals were coordinated along three primary regional corridors with the goal of reducing bottlenecks and improving the overall traffic flow.

The sensitivity tests documented in this report were performed using the Burlington implementation of the model system. Use of this smaller region allowed for more rapid testing and debugging of a greater number of scenarios. To ensure a sufficient congestion-related delay on the Burlington regional network (which does not have significant congestion), the socioeconomic inputs to the model system were scaled up by 50%. This increase in the population, employment, and all related inputs exceeds the forecast growth for 2030 in the Burlington region. Two points about the charts and tables that illustrate the results of the sensitivity tests are worth noting. First, DaySim and TRANSIMS were used to generate summaries of travel demand and network performance measures, respectively. Second, many of the charts employ time of day along the *x*-axis to highlight one of the distinguishing features of the integrated model system: the exchange of information between DaySim and TRANSIMS by detailed time of day.

Pricing

Freeway Tolling

The first set of sensitivity test scenarios evaluated using the model system involved assessing the effects of freeway tolling by time of day. For these sensitivity tests, a set of three scenarios were evaluated and compared with the baseline alternative. These scenarios were based on pricing alternatives tested in a pricing experiment conducted by the Puget Sound Regional Council in Seattle, Washington, to observe travel behavior and better understand regional pricing analyses. In the baseline alternative, no costs were assessed at any time. In the Pricing_3 scenario, a fixed \$0.25/mi charge was assessed for anyone using the freeways during the peak periods. In the Pricing_4

scenario, the fixed peak charge was maintained, and a fixed \$0.10/mi charge was added in midday. Finally, in the Pricing_5 scenario, the fixed peak-period charge was increased to \$1.00/freeway mi and the fixed midday charge was increased to \$0.50/freeway mi. When testing the sensitivity of the model system, testing extreme cases or scenarios such as Pricing_5 is often useful, even if they are unlikely ever to be implemented in reality.

Given the structure and linkages of the DaySim and TRANSIMS models, one would expect that increases in tolls on facilities at certain times of day will result in overall increases in user costs (unless these tolls are optimized, which was not performed as part of these tests). These changes may be reflected in decreases in the overall level of activity generation through the upward feedback of aggregate logsum measures, although this effect would likely be small. The effect on the distribution of travel demand by time of day would likely be more pronounced, with travelers choosing to reduce travel distances during the tolled time periods. The effect on mode choice would likely be small because of the relatively few transit service options offered in Burlington. And overall freeway volumes would likely decrease noticeably during the peak periods.

Figure 3.1 through Figure 3.3 show that the expected changes were all observed in the model system outputs. Figure 3.1 shows the difference in total trips by time of day relative to the baseline alternative. Pricing_3 shows declines in travel during the a.m. and p.m. peaks, when freeway tolling is in place, but little change during the midday, which is untolled. Pricing_4 and Pricing_5 both show declines in travel during all tolled time periods, with higher tolls resulting in greater reductions in travel. Interestingly, all three pricing scenarios show pronounced increases in travel demand during the evening, suggesting that travelers reschedule activities to occur when no tolls are charged and fewer scheduling constraints are present.

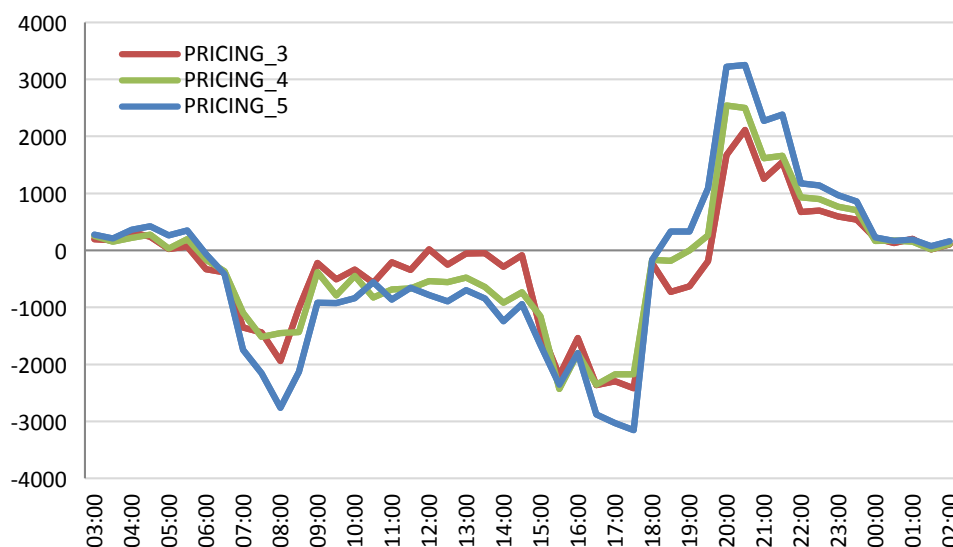


Figure 3.1. Difference in trips from base scenario, by hour of day and freeway tolling scenario.

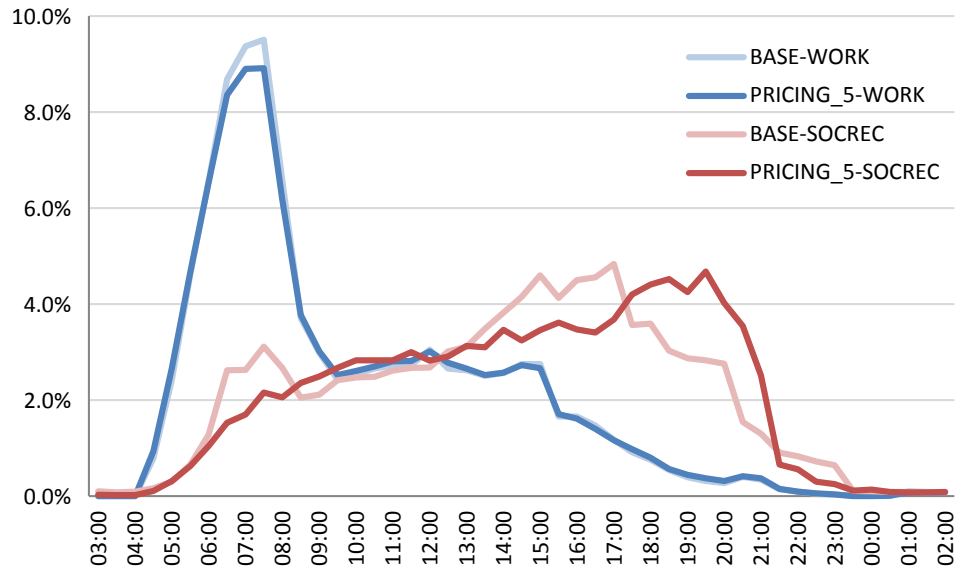


Figure 3.2. Percentage of daily work and social/recreational trips by time of day, by freeway tolling scenario.

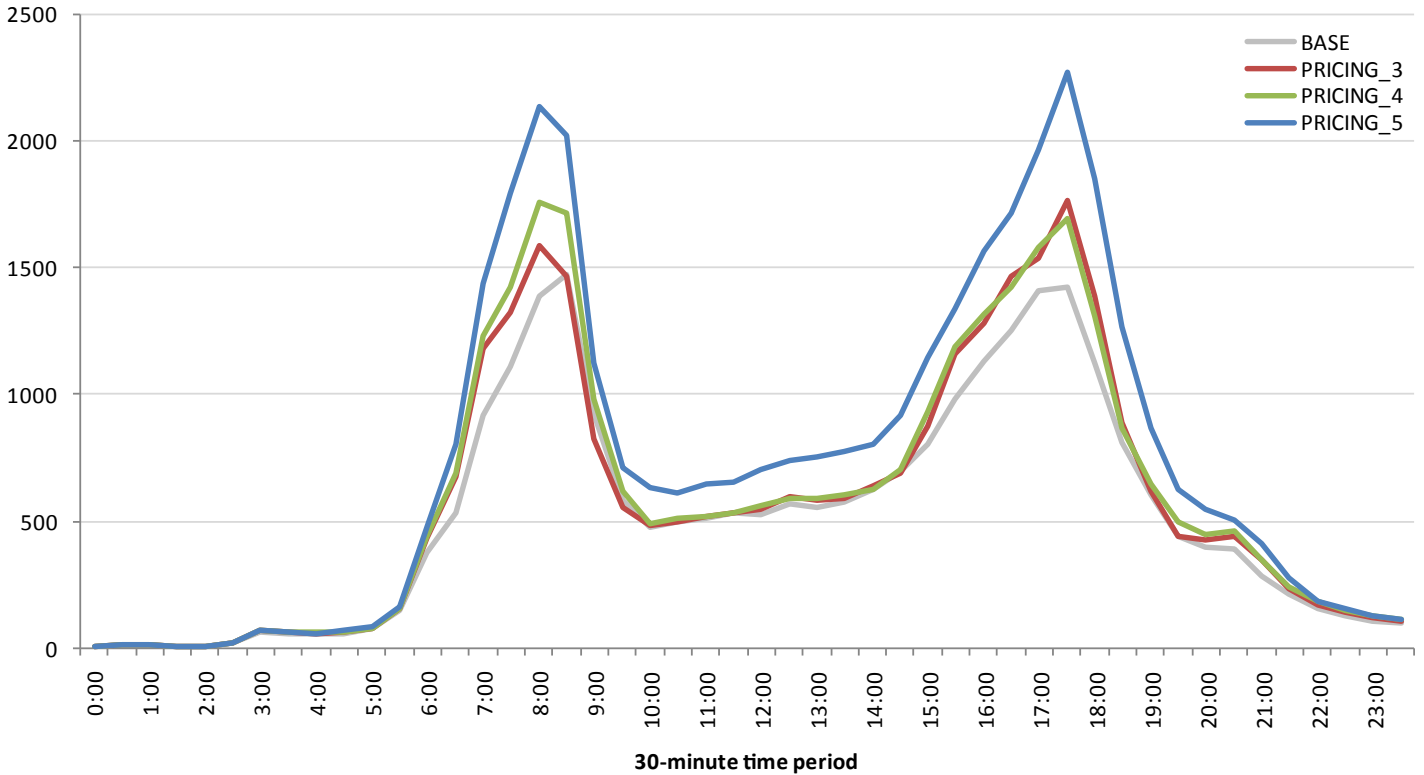


Figure 3.3. Hours of delay, by time of day and freeway tolling scenario.

Figure 3.2 illustrates that the trip making by time-of-day affects different purposes differently, with the work purpose distributions (blue) relatively unaffected, but the social/recreational distributions (red) shifting noticeably out of the peaks and into the evening. Finally, Figure 3.3 illustrates that the network-based total delay is higher than the base in all scenarios, as the tolling induces travelers to shift onto more capacity-constrained surface facilities. An analysis by facility type indicated that most of this additional delay accumulates on minor arterials. This result is likely caused by the coarseness of the sensitivity test: the specific temporal and spatial extent of congestion on the freeway system did not inform the design of the tolling scheme. Thus, some peak location congestion was likely alleviated as a result of the tolling; however, in many locations across the broad tolling time periods, increased costs were not offset by travel time reductions because of the low levels of baseline congestion.

Auto Operating Costs

The second set of sensitivity test scenarios evaluated using the model system involved assessing the effects of changing auto operating costs. Auto operating costs are represented in the model system as an average cost per mile experienced by travelers. These costs are reflected in both the DaySim demand model, through the inclusion of these monetary costs in the utility specifications of a number of component models, and in the TRANSIMS model through the inclusion of these costs in the generalized costs used for path building.

For these sensitivity tests, a set of three scenarios was evaluated and compared with the baseline alternative. The baseline alternative assumes a cost of \$0.12/mi. A lower cost scenario of \$0.06/mi (AOC_X05) was tested as well as two higher costs scenarios of \$0.24/mi (AOC_X2) and \$0.60/mi (AOC_X5).

Given the structure and linkages of the DaySim and TRANSIMS models, in general, increases in auto operating costs would most likely be manifest in overall lower levels of

Table 3.1. Household Auto Ownership Shares, by Auto Operating Cost Scenario

Autos per Household	BASE (%)	AOC_X05 (%)	AOC_X2 (%)	AOC_X5 (%)
0	5.5	5.3	5.7	6.5
1	36.7	36.8	36.7	36.3
2	39.5	39.6	39.5	39.3
3	13.1	13.1	13.0	12.9
4+	5.2	5.2	5.2	5.0

auto ownership, which is a long-term choice that exists toward the top of the DaySim model system and influences subsequent decision making. Higher auto costs would likely have only marginal effects on activity generation and time of day but might have more pronounced effects on overall trip distances (shorter) and on mode choices (more transit).

Table 3.1 and Table 3.2 confirm the expected effects on auto ownership and overall activity generation. Table 3.1 shows that when auto operating costs decline the share of households choosing to maintain 0 vehicles also declines; as the costs increase, the share of 0-vehicle households also increases. Table 3.2 illustrates changes in regional tour making by purpose and demonstrates that lower costs slightly increase tour making for discretionary purposes while higher costs slightly decrease tour making by purpose. However, the reductions in tour making by purpose are not consistent across purposes, with mandatory work and school tours declining while discretionary purposes such as personal business and social/recreational purposes are seemingly unaffected. By this measure, personal business and social-recreational trips are less discretionary than meals, escorting passengers, and shopping.

Consistent with expectations, Figure 3.4 indicates little systematic difference in changes in trips by time of day across the three auto operating cost scenarios; Figure 3.5 illustrates a slight

Table 3.2. Tours, by Purpose and by Auto Operating Cost Scenario

Purpose	BASE	AOC_X05	AOC_X2	AOC_X5	AOC_X05	AOC_X2	AOC_X5
					BASE	BASE	BASE
Work	116,928	117,475	115,898	114,321	1.00	0.99	0.99
School	44,011	44,246	43,449	41,906	1.01	0.98	0.96
Escort	41,011	42,022	41,610	41,028	1.00	0.99	0.99
PersBus	45,877	45,756	45,549	45,635	1.00	1.00	1.00
Shop	38,841	39,432	38,210	37,525	1.02	0.97	0.98
Meal	15,908	16,001	16,021	15,794	1.01	1.00	0.99
SocRec	47,181	47,436	46,999	47,076	1.01	0.99	1.00
Total	350,728	352,368	347,736	343,285	1.00	0.99	0.99

Note: Columns 6, 7, and 8 show the ratio between the tours by scenario and the tours in the base.

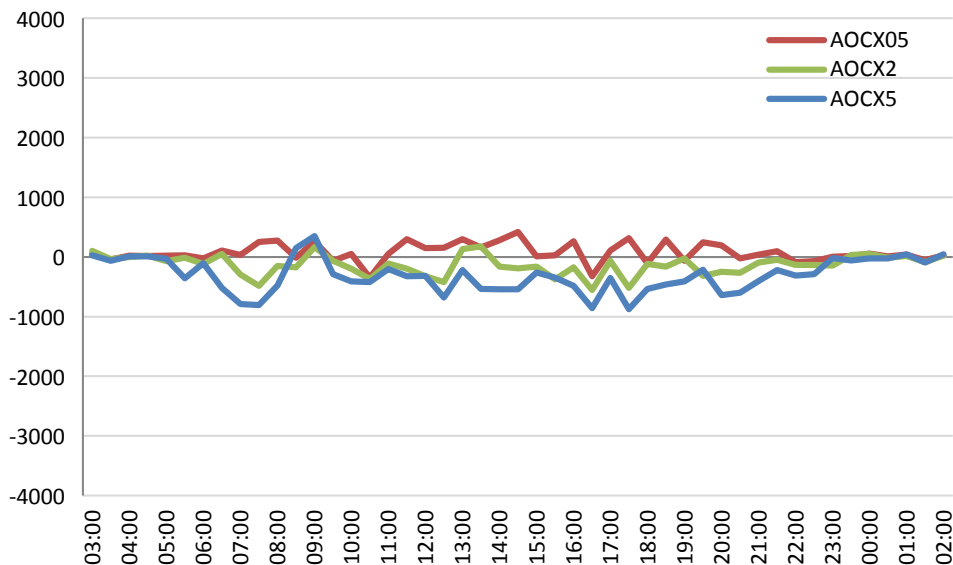


Figure 3.4. Difference in trips from base scenario, by hour of day and auto operating cost scenario.

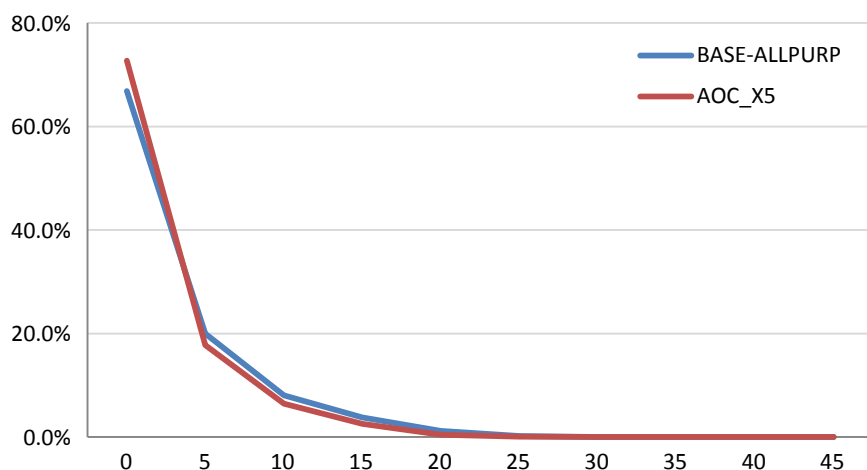


Figure 3.5. Trip length frequency distribution (in miles), by auto operating cost scenario.

increase in shorter trips and decrease in longer trips associated with the highest assumed auto operating costs. Figure 3.6 shows per capita changes in vehicle miles traveled (VMT) associated with the highest assumed auto operating costs relative to the base, indicating that the most pronounced decreases in VMT are associated with areas located at the periphery of the region. That result reflects the overall higher levels of baseline VMT in those areas and may also reflect boundary effects, in which residents at the edges of the modeled region may be forced to travel further to implement their daily activity patterns. In addition, Figure 3.6 demonstrates the parcel-level spatial resolution used in DaySim. The pattern of per capita VMT increases and decreases may illustrate the effect of the Monte Carlo simulation method used in the simulation. A unique feature, as

well as limitation, of the spatially and temporally disaggregate model system is that simulation sampling methods used in conjunction with static user equilibrium network assignment are not as easily employed.

Travel Demand Management

The third set of sensitivity test scenarios evaluated using the model system involved assessing the effects of a travel demand management strategy. TDM approaches are intended to change travel behavior to reduce congestion and improve mobility. They include increasing the frequency and numbers of people who work at home and adjusting work schedules to travel in off-peak, less congested conditions. Because DaySim predicts

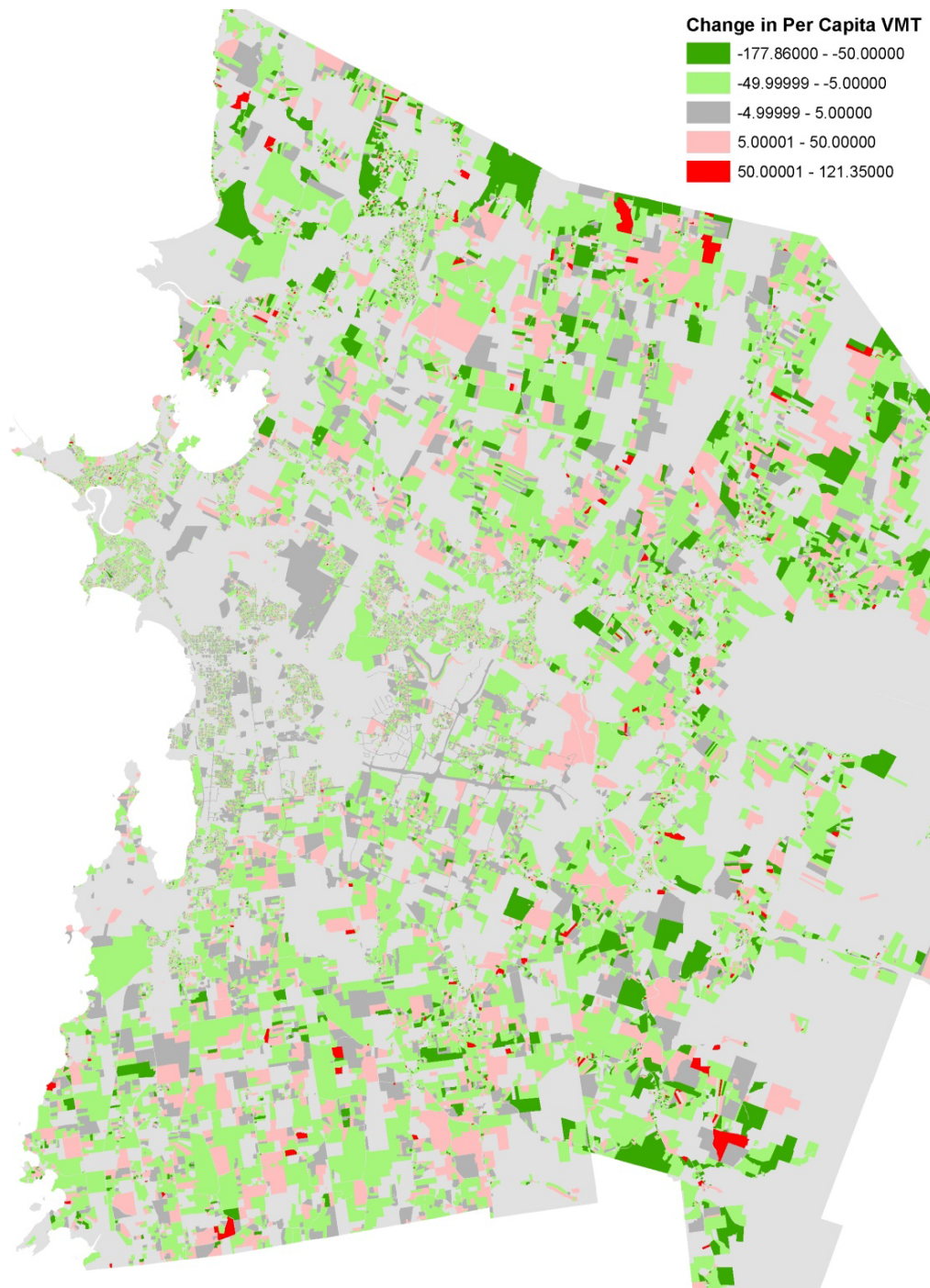


Figure 3.6. Per capita changes in VMT between baseline and x5 auto operating cost scenario.

the daily activity pattern of each individual in the region, it can be used to reflect the effect of workers working fewer days but longer hours. However, this sensitivity is purely scenario-based. DaySim cannot identify which policies will be most effective at affecting flexible work schedules, though it can estimate the impact on individual travelers' activity patterns and schedules and on the overall transportation system performance assuming that an effective policy is in place. To represent this effective policy, model parameters influencing the work tour and trip generation as well as work durations were modified to represent a shift to working fewer days but more hours, holding the total aggregate time in work activities constant.

For this sensitivity test, a single scenario was evaluated in which workers shifted from a 5-day ~7.5-hour workweek to a 4-day ~9-hour workweek. Given the structure and linkages of the DaySim and TRANSIMS models, in general, overall levels of activity generation would likely be lower, although the declines in work-related travel might be offset by increases in travel for discretionary purposes. Clearly, shifts in the distribution of travel by time of day due to the lengthened workday should be expected. Changes in the destination and mode choices would likely be marginal, though the time-of-day changes should be manifest in volumes by time of day on the roadway network.

Note that for this sensitivity test, the adjusted work activity duration distribution represents an analyst's qualitative judgment about a potential distribution, which should ideally be

Table 3.3. Full-Time-Worker-Tours, by Purpose and TDM Scenario

Purpose	Original	Adjusted	Adj/Orig
Work	94,408	78,472	0.83
School	115	140	1.22
Escort	8,070	9,023	1.12
PersBus	13,519	16,848	1.25
Shop	10,531	12,938	1.23
Meal	3,817	3,842	1.01
Soc/Rec	13,076	14,360	1.10
Workbased	27,949	23,211	0.83
Total	171,485	158,834	0.93

informed by more empirical analysis of observed changes in work-tour durations. Table 3.3 demonstrates the impact on the tour patterns of full-time workers, illustrating that as work tours decline, full-time workers tend to make more personal business, social/recreational, and shop tours. Changes in travel by time of day are evident in summaries of the DaySim travel demand model outputs and are also manifest in summaries of network performance by time of day. For example, Figure 3.7 shows a reduction in hours of delay on major arterials associated with implementation of an effective alternative work

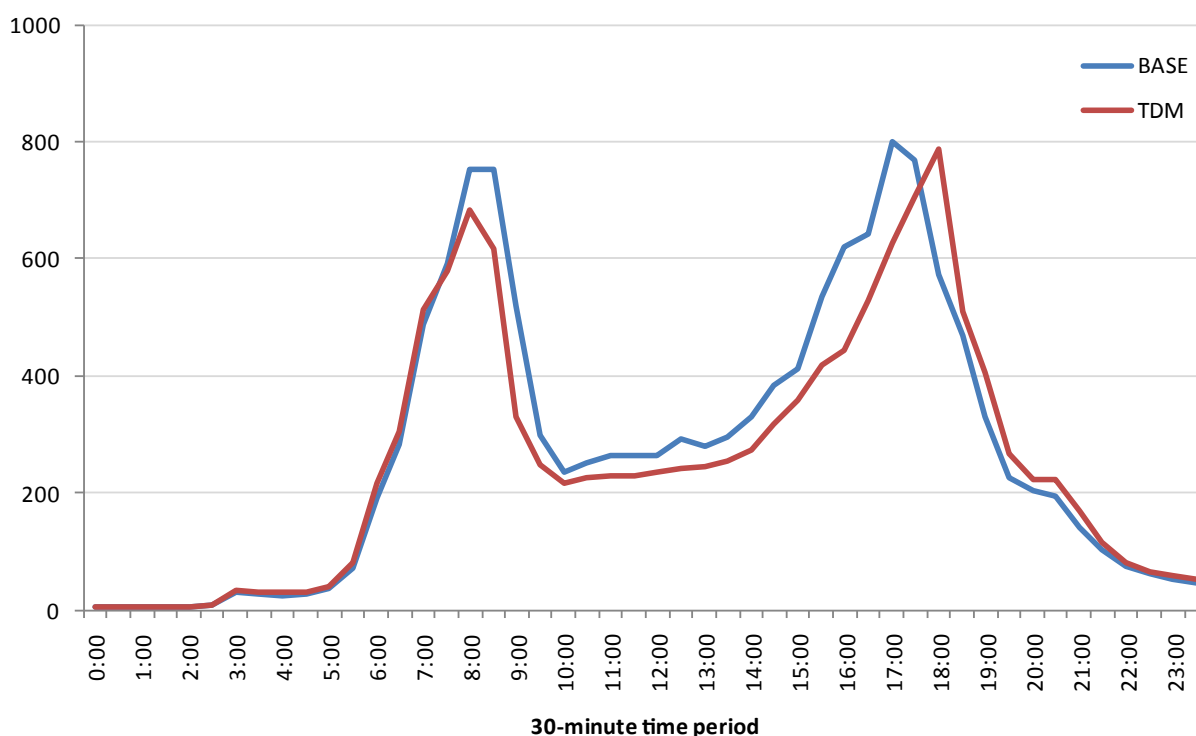


Figure 3.7. Hours of delay on major arterials, by TDM scenario and time of day.

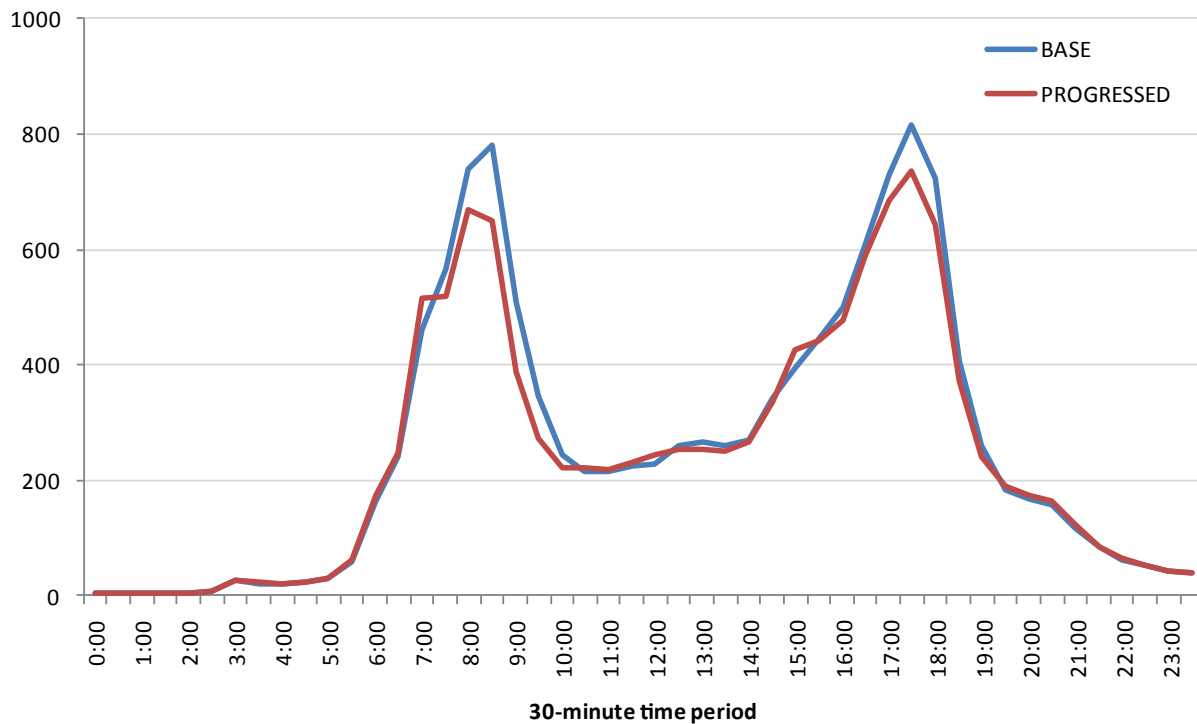


Figure 3.8. Hours of delay on major arterials, by operations scenario and time-of-day.

schedule policy; this reduction occurs across all types of facilities throughout the region.

Operations

Signal Progression

Operational strategies, also known as transportation system management (TSM), can address a wide range of projects and changes, including bottleneck improvements, corridor improvements, and parking strategies. For this project, the sensitivity testing focused on a signal progression scenario in which signals were coordinated along three primary regional corridors with the goal of reducing bottlenecks and improving the overall traffic flow. The DaySim-TRANSIMS model system provides sensitivity to these improvements. Traditional travel demand forecast models cannot typically represent such improvements because of the models' linkage with traditional static network assignment methods that lack detailed network operation attributes, as well as their coarse temporal resolution. Given the limited geographic extent of these improvements, little change should be expected in any of the aggregate regional statistics measuring activity generation, time of day, or destination and mode choice. However, one would expect to see local level changes would be

more likely, reflecting improved speeds along the targeted corridors.

The initial model results showed some reductions in delay by facility type, particularly during the peak periods, as shown in Figure 3.8 for major arterials. However, closer inspection of the speed profiles along the three targeted corridors showed more mixed results, with the signal progression producing better speeds in some corridor directions and worse speeds in other corridor directions. In implementing these operational tests, a significant number of iterations were required to establish a set of baseline signal timings for the entire region that produced reasonable performance results. Before establishing new baseline timings, all the corridor progression changes resulted in significant simulation problems. This occurrence likely reflects that such assumptions are necessarily more detailed in geographic and temporal scope—and ultimately more consequential for the performance of the network simulation. As others have noted, the sensitivity of dynamic traffic assignment (DTA) and traffic microsimulation models to detailed inputs suggests that users will encounter distinct challenges when attempting to incorporate these assumptions in a forecasting mode, especially at a regional scale. Of all the scenarios evaluated as part of this sensitivity testing, the signal progression scenario required the greatest amount of time and resulted in the least interpretable results.

CHAPTER 4

Conclusions

Model Implementation

Demand Model Data Development

The proposed model system comprises three primary components: DaySim, the TRANSIMS Router and Microsimulator, and MOVES. DaySim is a travel demand forecast model that predicts household and person travel choices at a parcel level on a minute-by-minute basis. The TRANSIMS Router and Microsimulator are dynamic traffic assignment and network simulation software that can perform regional traffic microsimulation on a second-by-second basis. MOVES is the EPA's latest software for estimating emissions and air-quality impacts. The integrated model links the three model components in an equilibrated model system that provides enhanced policy sensitivities at significantly higher levels of spatial and temporal resolution than found in a traditional regional travel demand forecasting system.

As part of the C10A project, the DaySim-TRANSIMS-MOVES model system was implemented in two regions: Jacksonville, Florida, and Burlington, Vermont. The Jacksonville region comprises four counties in northeast Florida, covering 3,100 mi². The regional population includes over 525,000 households and 1.25 million people and generates more than 4 million daily person trips. The Burlington modeling area comprises a single county (Chittenden) of approximately 620 mi² and was home to 55,000 households in the base year of 2005.

Basic inputs to the activity-based model (ABM) component include parcel-level information on the location of employment using nine industrial sectors, housing units, enrollment by school level, parking cost and supply information, access to transit, and numerous buffer-based measures of accessibility. A synthetic population representing the detailed sociodemographic attributes of the regions' residents and network performance data (or skims) are also key ABM inputs.

Parcel Data

Use of parcel-level data significantly enhances the sensitivity of the model system to smaller-scale land-use and urban-form measures and provides better sensitivity to travel modes such as bicycles and walking, which are usually shorter and more greatly influenced by attributes of the surrounding physical environment. However, developing a robust parcel-level base-year data file can be time consuming. Establishing the baseline geographic information on parcel boundaries is often a challenge, as is ensuring that data fields are defined and coded consistently across multiple political entities such as counties. To develop the Jacksonville parcel information, the project team had to perform several types of geographic data processing. These included identifying and removing non-travel-generating parcels such as highway rights of way and bodies of water, merging into a single parcel any parcels that were the same parcel but spread across separate geographic information system (GIS) shapes with multiple database rows, and developing a set of common fields across the multiple county databases.

HOUSING UNIT DATA

As was described in Chapter 1, the model system uses parcel-level housing unit information to allocate the model's synthetic population—which is developed at the travel analysis zone (TAZ) level to incorporate sociodemographic controls that are available only at more spatially aggregate levels—to specific parcels. Inconsistencies between parcel-level information, Census-block information, and the TAZ-level information used by agencies arise frequently and must be rectified. The parcel databases provided by the Jacksonville-region counties did not consistently specify the number of housing units on a parcel, so the project team had to impute this information using a combination of parcel data sources in conjunction with Census-based housing unit information. Multifamily housing presents the largest challenge when imputing housing

units because these units are prone to being undercounted in tax assessor databases.

EMPLOYMENT DATA

Employment data are not usually available at a parcel-level and must instead be developed using address-based business establishment employment information. Unfortunately, no single clean, comprehensive, public source for this information exists. Instead, the project team often had to rely on private data vendors though their data often have limitations, such as omitted information on public sector employment and self-employment, as well as other deficiencies (for example, the “headquarters effect” in which employment across all of a firm’s locations is allocated to a single headquarters location). In Jacksonville, a data file of employment locations, which had been extensively reviewed and cleaned, was provided by the North Florida Transportation Planning Organization (NFTPO), the region’s metropolitan planning organization (MPO); that greatly facilitated the rapid implementation of the model system.

ENROLLMENT DATA

School location-level information on enrollment is necessary to ensure that the proper number of students is being attracted to each school location. School enrollment data by parcel and grade level are typically easier to develop, as most state departments of education can provide enrollment by school address and grade. However, a fair amount of manual effort is required to geocode the enrollment locations, as well as to gather enrollment information on trade and other professional development schools.

Parking Data

Off-street parking location and pricing information is used in the ABM system to influence mode and other choices. Developing parking capacity and cost data can also be challenging if public agencies cannot provide them, although this information is used in the model less than the housing, employment, and enrollment data. In Jacksonville, enrollment and parking data were easily acquired from existing sources.

Transit Stop Data

In addition to using zone-level information on access times to transit, DaySim also incorporates detailed information on the distance to transit, by transit submode. This information is based on all transit stop locations in the region (as opposed to a file of only transit stops coded in the model networks). The file of all transit stops was provided by the local transit agency and required virtually no additional processing.

Intersection Data

Unique measures of urban form that DaySim incorporates are the number of intersections or nodes of different types within quarter-mile and half-mile buffers. These intersection types include dead-ends (1 link), T-intersections (3 links), and traditional intersections (4+ links) and help characterize the pattern of urban development. These measures are derived from an “all streets” network that has been updated to include the number of links associated with each intersection. Preparation of this intersection data required some cleaning and manipulation in GIS software.

Parcel Data Preparation Tools

A utility program was developed to generate the specific parcel input file for DaySim. This program combines information about parcel-level housing, enrollment, and employment and calculates additional measures, such as buffer variables that describe the amount of housing, enrollment, and employment and intersections by type within the user-specified radii of each parcel. The utility also computes the distance from the parcel to the nearest transit stop. Ultimately, the utility tool greatly simplifies and expedites the preparation of the derived measures and generates the primary DaySim parcel input file. The inputs to this tool are all straightforward and well-documented and can be ASCII text files or other user-specified formats. The sizes of the parcel file can vary significantly depending on the region’s size, and that may affect the data development schedule. If an agency can provide complete, clean data sets for use as input to the DaySim parcel data preparation tool, then the parcel data development process may be prepared in a matter of weeks. More typically, complete and clean data are not available, and 6 months or more may be needed to develop the required inputs.

Future Alternative Parcel Data

If the model will be used to support long-range forecasting efforts, then future parcel-level assumptions also need to be developed. Ideally, such assumptions would be derived from a land-use forecasting model, although such models are rarely available. In the absence of such a tool, most agencies either apply tools or methods that split parcels and then populate this new parcel geography with updated data, or simply scale up base-year parcel-level data to match regional or sub-regional employment and housing controls. For the C10A effort, the latter approach was used to develop increased-demand scenarios.

Note that not all activity-based models use detailed parcels as a fundamental spatial unit. In fact, the DaySim model can be applied at more aggregate spatial resolutions, such as Census

blocks or TAZs. Use of these larger spatial units typically reduces the data preparation burden significantly but also limits the sensitivity of the model system.

Synthetic Population

In addition to the parcel-level inputs to the model system, a synthetic population of these regions' residents has to be developed. A synthetic population comprises lists of households and persons that are based on observed or forecast distributions of household-level and person-level socioeconomic attributes and created by sampling detailed Census microdata. These lists function as the basis for all subsequent choice making simulated in the model system. All base year 2005 data required to develop the synthetic population using the DaySim population generation component were available from the Census Bureau's American Community Survey (ACS) Public Use Microdata Sample (PUMS) and Decennial PUMS, Northeast Florida Regional Planning Model (NERPM) model inputs, and the National Household Travel Survey (NHTS).

The PopGen software, developed by Arizona State University, was used to create the synthetic population, consistent with sociodemographic controls prepared by the project team. The Jacksonville synthetic sample population comprises three segments: permanent households and population, seasonal households and population, and group quarters (GQ) population. These segments were established to reflect the differences in travel patterns associated with these subpopulations, provide the ability to support seasonal analyses, and be consistent with the specification of the DaySim model. For permanent and seasonal households, the project team controlled for the following sociodemographic attributes:

- Age of the head of household;
- Household size;
- Household workers;
- Household income; and
- Presence of children.

For permanent and seasonal persons, these categories included gender and age.

The sociodemographic controls were much simpler for the noninstitutionalized GQ population because of limited Census table data for these residents. However, a person-level age distribution was used to properly locate two important GQ subpopulations: college students and retirement center residents.

Finally, a utility program was developed to allocate the synthetic households and persons to individual parcels. Only minor difficulties were encountered when developing and validating the synthetic population, and they were easily resolved with changes to the PopGen configuration.

Auxiliary Demand

Auxiliary demand refers to the regional demand that is not forecast by the DaySim model system but must be represented in the DaySim-TRANSIMS model system to reasonably assess network performance and the impacts of different policies or improvements. In the current project, this auxiliary demand is derived from the existing NFTPO model system. However, the project team had to add spatial and temporal detail to this demand to integrate it with the more detailed demand and supply simulation models.

TYPES OF AUXILIARY DEMAND

DaySim provides detailed estimates of the long-term and short-term travel choices of Jacksonville residents when traveling within the region, but this travel demand does not fully represent all trips that use the regional transportation networks. Commercial and truck traffic make up a significant share of all roadway volumes, typically up to 20% or more. In addition, nonresidents enter the region through key external gateways to access jobs, shopping, or other opportunities, or they may simply pass through the region. Similarly, residents may leave the region to satisfy other needs. Special generators may also create demand not explicitly represented by person travel demand models.

Auxiliary Demand Processing

Auxiliary demand is generated through processes exogenous to the DaySim-TRANSIMS model system. The total demand and the spatial distribution, mode, and timing of these trips are fixed within a given forecast or horizon year (but will vary across model run years). Network times and costs influence the routes used, however, so the assignment of this auxiliary demand to network paths is not fixed. Identifying and processing the data required to perform the temporal and spatial disaggregation of the demand segments was relatively straightforward. The spatial disaggregation was primarily driven by the parcel-level land-use information prepared for input to DaySim; the temporal disaggregation was informed by a variety of data sources, such as observed traffic volumes at external stations, traffic volumes by vehicle class, and airport departure and arrival schedules. Ideally, the auxiliary demand models would be revised to incorporate sensitivity to the more temporally detailed network performance measures generated by the DaySim-TRANSIMS model system.

Conclusions

Developing the parcel-level inputs to the ABM was a relatively straightforward process. The work done by NFTPO and the Florida Department of Transportation (FDOT) to clean the employment data significantly reduced the amount of

time required to implement the model. (The project team did have to make relatively crude updates to the employment data in one of the counties.) The parcel file required some additional cleaning to establish reasonable totals of housing units and to address inconsistencies in the parcel geography. School enrollment, transit stops, intersection types, and parking data were all relatively easy to assemble from existing data sources. In addition, development of the synthetic population was a relatively straightforward process given the availability of the data and tools. Nonetheless, the overall effort required approximately 6 months.

Auxiliary demand was accommodated within the integrated DaySim-TRANSIMS model system by using readily available static methods from the region's trip-based model. However, to achieve a more spatially and temporally consistent, integrated demand-supply model system, revisions to these auxiliary demand components would be necessary. A drawback of the current implementation is that the auxiliary demand is fixed for each forecast year. That is, although auxiliary demand varies by forecast year, it is not affected by changes in network impedances. Ideally, the auxiliary models would be revised to provide sensitivity to changes in network performance.

Network Model Data Development

For the TRANSIMS software to generate detailed representations of changes in network performance by time of day, the project team had to develop a representation of the network supply, identify means of configuring the network assignment process to generate stable simulations with reasonable runtimes, and establish methods for generating network performance indicators that can be used by the DaySim demand model.

Network Build Tools

As with most medium and large MPOs, NFTA maintains a detailed GIS-based all streets network. It forms the basis for building the networks used in the region's traditional trip-based travel demand model system. This all streets network was used in conjunction with a number of TRANSIMS network processing tools to synthesize a TRANSIMS network. The TRANSIMS tools provide a quick method of developing a detailed TRANSIMS network without a lot of extra data collection and arduous network coding. The tools reformat, regroup, and reconfigure that data into standard TRANSIMS input link and node data files and then synthesize the additional information needed for a network simulation such as pocket lanes, lane connectivity, parking lots, activity locations, and signal and sign warrants. These tools allowed the project team to get the network model running relatively quickly and

to use the trip assignment process to identify locations where the synthetic process requires refinement.

ALLSTREETS Network

One of the key questions of interest to the project team concerned the potential benefits of incorporating more spatial detail into the simulation networks. The networks used in most traditional static traffic assignments are relatively coarse, frequently including only minor and major arterials and freeways. Because static assignment models and networks are insensitive to many operational attributes, such as hard capacity constraints, concerns rarely arise about the mismatch between demand and supply. In the context of TRANSIMS, however, consideration was given to the trade-offs between using a coarser network that would run faster but may not provide the same degree of network sensitivity. As a result, for Jacksonville, three different network resolutions were created. The coarsest network developed was the PLANNING network. This network essentially contains all the links found in the MPO's current four-step regional modeling network, although significant operation detail was included in the TRANSIMS version. The next most detailed version of the network was the FINEGRAINED network, which pivots off the PLANNING network but also includes additional local through streets to the network. Finally, the most detailed network was the ALLSTREETS network, which is equivalent to the NERPM regional modeling network plus all other existing minor streets such as neighborhood streets and alleys.

Network Cleaning

After the networks were built, a significant amount of additional time and effort were required to correct and debug network coding errors and inconsistencies. At the most basic level, the project team had to fix network topology issues. For example, in numerous locations, freeways were found to be erroneously intersecting with surface streets. These coding errors would not have been an issue had some of these surface streets been dropped when the baseline network was used to create coarser networks for static assignment. In addition to these basic topological corrections, the project team had to devote significantly more attention to other network attributes because the simulation networks are much more sensitive to coding assumptions than traditional static assignment networks. Specifically, discontinuities in the coding of facility types, through lanes, and speeds all significantly affected the network performance.

Overall, speed issues were most common, but lane coding discontinuities proved to be most challenging in debugging the networks. *Discontinuities* refers to inconsistent coding of link attributes for adjacent links. Because lanes are the primary source of capacity information within the simulation, and lane

changing is one of the primary reasons for congestion and lost vehicles, lane discontinuity errors are extremely problematic. *Lost vehicles* refers to vehicles that are unable to complete their assignment paths and get “stuck” in the simulation for more than a user-specified number of minutes. Lost vehicles are highly undesirable because they cause inconsistencies between the demand and supply components. The project team also had to establish on a link-by-link basis whether the lane coding from the master network included parking lanes or turn lanes. Other network coding issues that arose in developing all of the different resolution networks included extremely short links, which can cause congestion problems in the simulation, and intersection geometry, which can affect simulation performance.

Intersection Controls

In addition to getting the basic network geometric details correct, all the intersection control information had to be correct. This information includes the location, timing, and phasing of signals and the locations of other intersection controls such as stop signs. Regarding signals, for Jacksonville, the project team received a data set of the locations of all signals in the region. Unfortunately, these locations were not linked to the master network data file and did not contain any information on timing. Information on stop sign locations was available only for a subset of the region.

Ideally, observed real-world signal timing, phasing, and other control information would be available in a readily usable form and coded in the base network. However, developing this real-world information to code this into the network is an onerous task. For this project, TRANSIMS tools were used to synthesize the timing and phasing of signalized intersections. TRANSIMS includes a number of ways of changing the configuration of the network by time of day. In addition to the roadway configurations, traffic controls can also vary by time of day. The signal timing and phasing plans can be adjusted to optimize time-of-day flow conditions. Signal progression tools are also available to coordinate fixed-time signals along specified corridors or throughout a grid system. Demand-actuated signals can include multiple detectors and simulate ramp metering behavior. The signal formats also allow the user to change signal types by time of day.

For unsignalized intersections, the project team had to synthesize traffic controls for the base year. Note that even if real-world information is available for developing the base networks, the challenge of developing future-year intersection controls under increased demand will remain. Use of some tools and optimization strategies presents not only technical challenges but also poses theoretical and procedural challenges for how to best prepare and analyze future-year networks and how to conduct alternatives analyses.

Finally, it should also be noted that after the initial model network build process, all subsequent alternative networks were derived from the base network and manipulated using TRANSIMS tools. Recent updates to these tools have significantly reduced the level of burden on users to simultaneously and consistently update multiple input network files.

Conclusions

Developing detailed and usable networks for microsimulation requires a significant level of effort. The TRANSIMS software comes with a wide array of tools to perform many network development tasks; and spatially detailed network data are widely available. However, users should expect to spend on the order of hundreds of hours debugging simulation networks: correcting topological errors, resolving attribute discontinuities, and coding intersection controls. The time-consuming effort involves iteratively evaluating, adjusting, and testing the networks by running simulations. In addition, users face numerous challenges when attempting to develop future-year or alternative network scenarios, a topic that was discussed earlier in this chapter.

Model Integration

The design of the integration scheme focused on a few key questions:

- What information does the DaySim demand model need to provide to the TRANSIMS network supply model?
- What information does TRANSIMS need to provide to DaySim?
- How is the network supply model iteratively executed to achieve an equilibrated, or at least stable, condition?
- How are DaySim and TRANSIMS iteratively executed to achieve a stable system solution?

Answering the first two design questions concerning the information exchange is relatively straightforward. Answering the second two questions regarding the execution and interaction of the tools is significantly more complex, forcing users to develop new measures to analyze network and system performance, prompting challenging questions about the nature of equilibration in the context of complex simulation tools, and highlighting practical issues of runtime. In addition to addressing these implementation and research questions, a key goal of the SHRP 2 C10A project is implementing the integrated demand-supply model in a dynamic modeling framework that is easily transferable to the local jurisdictions for policy analysis. In support of this goal of transferability, the model system incorporates a system manager that controls the execution of the two primary model system components: DaySim and TRANSIMS.

Information Exchange

DaySim provides trip and vehicle information to the TRANSIMS Router to perform network assignment. For the Jacksonville region, this process takes approximately an hour of computer processing time. The resulting activity file includes the internal travel demand generated by regional households. This demand is combined with the auxiliary trips to represent the complete travel demand for the region.

TRIP LISTS

To transmit the estimates of demand from DaySim to TRANSIMS, minor adjustments were made to the DaySim outputs to generate vehicle-trip records, to associate the parcel locations with the activity locations used by TRANSIMS, and to output the records in the format required by the Router. In addition, detailed traveler and purpose-specific information on trip value-of-time is included for use by TRANSIMS. Some of the key advantages of using TRANSIMS with DaySim, rather than using a traditional static assignment model, include

- Trips are kept and simulated in list format rather than aggregating them to origin–destination (O-D) matrices;
- Less spatial aggregation occurs because the activity locations used in TRANSIMS are smaller than TAZs; and
- Trip start and end times can be kept in units of individual minutes rather than aggregating them to broad time periods.

NETWORK IMPEDANCES

DaySim's core components use a variety of impedance measures to influence traveler's choices about daily activity patterns, destination choices, mode choices, and time-of-day choices. TRANSIMS produces these measures and provides the information to DaySim. The TRANSIMS supply side model assigns the DaySim internal demand and auxiliary trips on the TRANSIMS network through assignment iterations designed to achieve dynamic user equilibrium convergence of the individual travel paths. The resulting network performance by time of day is used to generate zone-to-zone travel time, distance, and cost skims for detailed periods for input into the next global iteration. In the current model implementation, the network performance information is created for 22 different time periods (as small as half-hours in the a.m. and p.m. peaks) and for all zone pairs in the model before running the DaySim demand component. TRANSIMS includes tools that can flexibly generate network impedance skims at virtually any temporal or spatial resolution with little additional runtime; this is possible because the daily microsimulation of the entire region provides information on changes in network performance by specific times of day. The current solution, which involves iteratively using new paths for all travelers, based on composite travel times across multiple assignment iterations, is effective

when the number of time periods and zones is relatively limited. However, it would be ideal to generate network performance indicators using temporal and spatial resolutions that are consistent with the underlying parcel-level spatial resolution and 30-min temporal resolution of the DaySim demand model. A number of schemes to achieve that level of detail were hypothesized, such as implementing efficient multistage sampling of destinations (and corresponding impedances) at strategic points in the DaySim looping process or tightly integrating DaySim and TRANSIMS so that DaySim can call TRANSIMS to extract the required measures quickly. Because of runtime considerations and project resource constraints, none of these methods was ultimately implemented.

Component Linkages and Execution

A critical aspect of integrated model development involved implementing and refining strategies for achieving a condition of model system convergence in the network assignment process, as well as for the overall integrated model system. Convergence is necessary to ensure the behavioral integrity of the model system.

NETWORK ASSIGNMENT

At the network-assignment level, convergence is achieved through the interaction of the TRANSIMS Router and TRANSIMS Microsimulator. The project team extensively tested a variety of configurations of the Router, Microsimulator, and other TRANSIMS tools used in the network assignment process. These included variations on rebuilding paths for all travelers at all iterations and rebuilding paths for both random and targeted subsets of travelers at each iteration, and different methods of calculating link delays and using different levels of temporal resolution when representing changes in network performance by time of day. Interestingly, the methods that seemed to perform best—as measured by traditional link-based relative gap, new-trip-based gap, and stability measures such as aggregate vehicle hours and miles traveled—were among those that are least accepted by the dynamic traffic assignment (DTA) community. The more commonly practiced network assignment methodologies, such as the use of updated paths for a successively smaller share of travelers across multiple assignment iterations, were often the worst performing. The observed TRANSIMS convergence using these methodologies was relatively consistent with the reported convergence of other DTA tools. This performance is critical, as the project team discovered that the level of convergence can significantly influence the conclusions drawn from alternative analyses.

NETWORK CONVERGENCE

Other key network assignment convergence issues are how to measure network convergence, and how many iterations are

required to achieve a converged result. The project team developed both typical measures, such as network link-based relative-gap measures, and new measures, such as person-trip-based-gap measures. These measures were calculated across the entire day, as well as by detailed time period. The project team encountered numerous challenges in developing both link-based and trip-based-gap measures. For example, when calculating link-based relative-gap measures, the total number of vehicles on a given link during a given time period is needed, as well as the travel time experienced by that vehicle during that time period. Deriving those measures is straightforward in the context of aggregate static assignment methods, but it is considerably more complex in the context of the regional network simulation model because vehicles may travel on just a portion of a link during a given time period. Similarly, the project team encountered challenges in developing trip-based-gap measures. Conceptually, the trip-based relative gap should represent the difference between the expected time for a given trip, based on the most recent detailed network link delays, and the experienced time for the trip in the Microsimulator. In practice, differences in how various TRANSIMS tools calculate travel times result in negative gaps. Extensive effort was devoted to conceptualizing and implementing reasonable gap measures.

Regarding the number of network assignment iterations needed to achieve a degree of convergence sufficient to support the use of the model, the project team extensively tested and documented the degree of convergence and stability achieved using different network assignment methodologies. The team demonstrated that running additional network assignment iterations was necessary to distinguish differences between policy and investment scenarios. Typically, each model system run comprised three to six system iterations; and within each system iteration, 40 assignment iterations were performed.

MODEL SYSTEM CONVERGENCE

Model system convergence is pursued by iteratively feeding the impedances produced at the end of each global iteration back as input in the subsequent global iteration. Convergence is achieved when the impedances are approximately equal to the travel times and costs produced by the final network assignment. As with network convergence, the degree of system convergence is significantly influenced by the number of times the overall model system is run.

SCHEDULE CONSISTENCY

Schedule consistency refers to ensuring that the detailed schedules produced by the DaySim model are implemented in the TRANSIMS network model with as much fidelity as possible. This was another concern of the project team. Both the demand and supply models incorporate (re)scheduling capabilities. An open research question is how to address rescheduling when inconsistencies are observed between the demand and supply

models. DaySim uses a model to predict arrival time, departure time, and duration at the main destination of each tour—using a temporal resolution of half-hours which is subsequently disaggregated to minutes—as well as the departure or arrival time for each individual stop on each tour. TRANSIMS uses this detailed time information when routing trips. In most cases, the travel time experienced by the Router when routing a trip differs somewhat from the travel time assumed by DaySim when it generated the trip.

The project team felt the need to define how the integrated model should accommodate these types of discrepancies. While adjusting the trip start time, trip end time, and/or activity duration time in a variety of ways is possible, identifying methods that do not lead to biased model system results is important. In the initial implementation and sensitivity testing of the model system, the project team assumed that travelers would preserve their activity durations and shift the timing of travel to accommodate differences between the expected time used to generate the estimates of travel demand and the experienced time in the network simulation of this demand. This assumption had the effect of causing trips to cascade into time periods later in the day, affecting the model calibration and consistency with the original demand. Subsequent testing, in which travelers were assumed to preserve the time of travel and to adjust their activity durations, demonstrated not only greater schedule consistency between the demand and supply components but also higher levels of link-based network convergence. Scheduling consistency measures that incorporate information on the differences between expected and experienced departure, arrival, and activity durations are necessary to ensure that the final network assigned demand is consistent with the final calibrated demand model outputs.

Conclusions

Configuring DaySim to generate temporally, spatially, and behaviorally detailed travel demand information for use in TRANSIMS was straightforward. Configuring TRANSIMS to generate the skims for input to DaySim was also straightforward. More sophisticated methods of providing TRANSIMS-based impedances to DaySim could potentially be implemented. Options include implementing efficient multistage sampling of destinations (and corresponding impedances) at strategic points in the DaySim looping process or tightly integrating DaySim and TRANSIMS so that DaySim can call TRANSIMS to extract the required measures quickly. However, the runtime implications and required resources for development were felt to be prohibitive, and the current methods provide sufficient spatial and temporal detail.

The network convergence equilibration effort revealed that the most effective convergence strategies were often the least acceptable to the larger DTA community, but they

were necessary to ensure sufficiently converged assignments within reasonable runtimes. Schedule consistency was identified as another measure of the soundness of a model solution. Extensive testing of the model system was necessary to determine the number of network assignment and model system iterations required to ensure that differences between alternative scenario model results were attributable to these policy and investments and not obscured by “noise” in the model system.

Model Enhancements

Two of the key goals of the SHRP 2 C10A model system development effort were to provide enhanced representation of travelers’ sensitivities to price and to incorporate findings from other SHRP 2 Capacity projects. A number of enhancements were made to both the DaySim and TRANSIMS model components to achieve these goals.

Incorporating Findings from SHRP 2 Project C04

For modeling highway pricing and congestion effects, the relationship between auto route choice and the other travel choices is critical. In previous implementations of DaySim, auto route choice has been handled outside of DaySim itself. For example, for single occupancy vehicle drivers DaySim did not indicate whether a person chose to pay to use a tolled facility. If both tolled and nontolled facilities were available for a traveler’s given zone pair, the network assignment model was left to determine whether a tolled or nontolled route was chosen, typically by minimizing generalized cost and excluding any information about tour purpose, traveler income, or other relevant factors. Enhancements were made to DaySim to include toll and no-toll choices nested under the drive modes and transit submode choices under the transit submodes. When toll cost and/or operating cost are key considerations in choosing a route, each traveler may have different trade-offs between travel time and cost (value of time). DaySim was enhanced to indicate whether the tolled route is used, incorporating information relevant to value of time, such as tour purpose and travel income. This information is then passed to TRANSIMS, which includes a set of 90 assignment classes that reflect both toll and nontoll choices as well as value-of-time class. DaySim also accepts as input a set of user-class skim files that include information about the predetermined best path for each of three value-of-time classes, two toll and nontoll classes, and the 22 time periods. To the greatest extent possible, the traveler-specific coefficients used in the model were derived from the findings of the SHRP 2 C04 study, *Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand*, both for the functional forms and the magnitudes (work/nonwork, income, occupancy).

Price Sensitivity

Parallel enhancements to the TRANSIMS tools were also implemented. The original version of the TRANSIMS Router was only able to vary values of time used in the generalized cost formulas at the household level, and thus could only reflect household income. The revised Router can incorporate the trip-specific values of time that DaySim generates; in the current implementation, approximately 45 value-of-time classes are used in the path building and assignment. The feature can be used in conjunction with the Router’s ability to include or exclude individual links and is configured to mirror DaySim’s toll or no-toll path type choices.

Network Microsimulator

Another significant modification to the TRANSIMS tools involved revisions to the Microsimulator. These changes provided important new capabilities, such as the ability to restart trips that are lost during the simulation, incorporation of improved speed profiles, production of better estimates of network performance at finer resolutions, and support for multithreading across multiple processors which reduces runtimes.

Conclusions

The enhancements made to the model system were necessary to improve the system’s sensitivity and to fulfill the goals of the SHRP 2 C10A project. Updates to the DaySim model system were relatively straightforward to implement, although these updates were not fully completed until a new DaySim software architecture was implemented, which took significantly longer than expected. The updates to the TRANSIMS model components were much more extensive and involved much more time to implement; many of these enhancements were under development during the C10A project. While these enhancements were necessary to fulfill project goals, they undoubtedly also resulted in schedule delays.

Model Application

The integrated model, controlled through the use of the TRANSIMS Studio software, includes four software components. All of these components are available free of charge from websites that distribute the open-source software:

- TRANSIMS Studio user interface and application management software;
- TRANSIMS and DaySim modeling software;
- Python scripts that define the modeling process; and
- A folder structure housing network and other input data.

Hardware Requirements

The model system can be run on computers using either Windows or Linux operating systems. Runtimes for the model system are influenced by a number of factors:

- The computing resources available to run the simulation (such as the number of processors, amount of memory available, and speed of storage drive input/output);
- The degree of convergence required for a given model application;
- The size of the synthetic population used as the basis for all choice making in the model; and
- The level of detail of segmentation employed in the model system (such as the number of time periods).

The project team successfully implemented the model system hardware running on Windows and Linux operating systems. Both the Linux and Windows implementations of the model system typically were configured to use between 24 and 32 processing cores, although this number can be flexibly set. Both DaySim and TRANSIMS are multithreaded applications, and TRANSIMS also includes partitioning capabilities. The project team tested a number of alternative configurations of the model system with respect to temporal detail and market segmentation of the skims. As few as four time periods and as many as 22 time periods were used in the model system; some configurations employed no value-of-time segmentation, while other configurations included up to 50 value-of-time segments. The simplest of these schemes could be run with only 2 gigabytes of RAM, while the most elaborate of the schemes required approximately 20 gigabytes of RAM. Data storage and access influence runtimes so, in addition to having sufficient RAM, the model system (specifically, TRANSIMS) also benefits greatly from the use of fast hard drives for storage—ideally solid state drives. The project team tested the model system using both the Transportation Research and Analysis Computing Center (TRACC) Linux computing cluster located at Argonne National Laboratory and the local Windows-based servers.

Application Modes

In addition to testing different iterative feedback schemes, the project team also investigated different application modes of the model system. These application modes were developed because the runtimes for a fully integrated and well-converged model run with repeated full regional simulations of Jacksonville could take up to 4 weeks. Three application modes were conceptualized. The planning application mode involves the iterative exchange of data between DaySim and the TRANSIMS Router but not the TRANSIMS Microsimulator. This mode can be used when the analysis needs are expected to result in regional-scale changes in overall level of travel demand or

changes in regional travelers' destination, mode, or time-of-day choices, but are not expected to be significantly affected by local-scale traffic dynamics. The operations application mode can be used when the analysis requires an assessment of the impacts of a policy or strategy on local traffic dynamics and when these improvements are not expected to result in changes in overall level of travel demand or in destination, mode, or time-of-day choices. The planning + operations application mode represents the fully integrated DaySim and TRANSIMS model system that has been described in this document. In this application mode, the TRANSIMS Router and Microsimulator are used to perform a regional traffic microsimulation as part of every model system global iteration, and microsimulation-based network impedance measures are fed back and used as input to DaySim. The advantage of this application mode is that it provides the full range of sensitivities both to changes in regional demand and to local and regional traffic dynamics. However, these extensive sensitivities come with the significant disadvantage of extremely long model system runtimes.

Runtimes

The project team extensively tested various iterative schemes to evaluate trade-offs between network assignment and model system convergence and overall model system runtimes. Generally, greater degrees of convergence are required for more spatially, temporally, or behaviorally detailed analysis. However, the level of convergence required for any given analysis is context specific, and the user is afforded many potential means with which to configure the model system and investigate performance and runtime trade-offs. Keys and parameters that affect DaySim and TRANSIMS runtimes can be easily configured by the user via two primary control files. Table 4.1 shows the runtimes for the Jacksonville model system given the different application modes.

Staff Resources

As with any model system, the level of staff expertise required to interact with the model system will vary depending on the specific nature of how the model is to be used. However, it is safe to say that a higher degree of knowledge and patience is required for interacting with the new integrated model system than for using a traditional trip-based model system. Both the DaySim activity-based demand model component and the TRANSIMS network supply model component are more complex than the demand and supply components of a traditional model. However, generating the input data for these model components and further modifying the inputs to reflect alternative scenarios are both generally straightforward processes, using typically available data as well as the automated tools that have been developed to support model implementation.

Table 4.1. Application Mode Runtimes

Mode	Planning	Operations	Planning + Operations
Runtime for Operations			
DaySim demand estimation (hours)	4.0	4.0	4.0
Assignment iteration (hours)	0.5	5.0	5.0
Convergence checking (hours)	1.0	1.0	1.0
Skimming procedures (hours)	1.0	0.0	1.0
Total (hours)	6.5	10.0	11.0
Iterations			
Assignment	40	40	40
System	3	1	3
Total	120	40	120
Total System Runtime			
Hours	195	244	735
Days	8	10	31
Weeks	1.2	1.5	4.4

Challenges

The challenges in interacting with the model are primarily associated with debugging the model system. As has been repeatedly mentioned, the network simulation model is very sensitive to small-scale network coding and parameter assumptions, and the network simulation is subject to frequent failures as input assumptions are being refined. Users must have the ability to understand and mine which data generated by the model system can illuminate the source of simulation problems and also to make informed decisions about how to modify model inputs to achieve the proper model sensitivity. Model users need to have a basic understanding of Python to understand the overall model system flow, as well as robust data manipulation, statistical analysis, and GIS skills. Model users need not know C# or C++, the development platforms used for DaySim and TRANSIMS, respectively.

Although the model system is relatively easy to configure and interact with, transitioning to a new model system such as the DaySim-TRANSIMS model system represents a paradigm shift. Modeling staff must have a broader set of skills and a willingness to investigate and experiment. The types of analysis that can be performed with the new model system are fundamentally different and more expansive from what can be performed with a traditional model system, and the application and interpretation of model outputs must be thoughtfully considered. Use of the fully integrated model system will

be most valuable when the proposed policies or strategies are expected to result in regional-scale changes in overall level of travel demand and changes in regional travelers' destination, mode, or time-of-day choices, and when the policies or strategies are expected to be significantly affected by local-scale traffic dynamics. These scenarios may include pricing alternatives, capacity enhancements, travel demand management policies, or operation improvements. Finally, note that the hardware requirements of the integrated model system are clearly greater than those of a traditional travel demand model.

Conclusions

The model system software can be flexibly deployed on hardware running either Windows or Linux, and the implementation can be scaled or configured to reflect available hardware resources. The availability of additional processors, more memory, and fast data storage help reduce runtimes of the model system, which can be extremely long for a region the size of Jacksonville. To avoid these long runtimes, the model can be used in different application modes in which either the regional network simulation is not used or the demand is held fixed so that multiple global model system iterations are not needed. A higher degree of staff knowledge and patience is required when interacting with the new integrated model system than when using a traditional trip-based model system. Although many DaySim and TRANSIMS tools exist to assist in data preparation and coding, the model system is highly sensitive to alternative configurations of the model system and to small-scale coding issues. The model system may take anywhere from an hour to many weeks to generate plausible alternative scenarios.

Model System Calibration and Validation

DaySim

Model Transfer

Often, the implementation of a new activity-based model system in a region for the first time involves estimating region-specific coefficients for use in the individual models that make up the overall model system. However, one of the goals of the C10A project was to use existing tools and data to implement the model system. Rather than estimate new models for C10A for the Jacksonville region (which would have involved preparing estimation data sets, testing various model specifications for some or all of the individual model components, and coding the models for application), the project team simply transferred the ABM components and associated coefficients from the existing model DaySim ABM implementation in Sacramento. This approach radically reduced the amount of time required to get the model system up and running.

Because the Jacksonville DaySim implementation was transferred from Sacramento, and the model coefficients and alternative-specific constants were initially estimated and calibrated for the Sacramento region, the project team had to recalibrate the core model components to reflect Jacksonville region-specific travel patterns. Calibration and validation of the entire model system was a highly iterative process that involved making changes to individual model components to better match observed data and evaluating the impacts of those changes on other model components and on overall model system performance. One of the advantages of the disaggregate nature of activity-based microsimulation models such as DaySim is that they support more flexibility and realistic calibration adjustments than is possible with aggregate trip-based models.

NHTS

Before calibrating the core behavioral components, the project team had to prepare observed data sets against which to compare the model outputs. The primary observed data source for the calibration of the core DaySim component models was the 2009 National Household Travel Survey (NHTS) collected in 2008–2009. For some model components, such as household vehicle availability model and the work-tour-destination model, the NHTS was supplemented with data from the 2005–2009 American Community Survey (ACS). Observed calibration targets for virtually all the components of the activity-based DaySim model system can be prepared using the NHTS or other household survey data. Because transit was not a focus of the C10A effort, detailed transit information, such as an on-board survey, was not used.

Additional NHTS survey data was collected in the Jacksonville region, but the overall number of households, persons, tours, and trips added was relatively small (only 800 households). Since DaySim models travel behavior for a typical weekday, weekend days had to be removed from the data set, further reducing the sample size. Although the NHTS contains all the data items required for ABM system development, such a small regional sample is insufficient to completely estimate the coefficients in the DaySim component models. However, in the absence of any other data sets containing the information required for ABM development, the project team deemed the NHTS acceptable for deriving calibration targets. In addition to the small sample, a number of other issues with the NHTS also affected the calibration process. These issues included the absence of any person, tour, or trip information for children under 5 years of age, missing travel information for some members of the household, inconsistent expansion factors, and unreasonable information, such as extremely high shares of individuals choosing to work at home. To address these calibration issues, persons for whom complete daily travel information was not available were

dropped, all observed and estimated calibration summaries excluded children under age 5, and revised expansion factors were developed.

Calibration Process

The results from each individual model component of the DaySim model were reviewed, and adjustments were made to model coefficients and constants. Although all model calibration adjustments have a simultaneous impact on the model predictions, the calibration effort followed a sequential process from the top to the bottom of the DaySim model hierarchy: adjustments to upper-level models, such as the day-pattern model, tend to affect lower-level model predictions, such as trip-mode choice, more than the reverse.

Overall, recalibration of the DaySim model system did not require extensive efforts. Many of the models showed reasonable consistency between the initial estimated and the observed results without any adjustments. For example, the initial estimated and observed arrival, departure, and duration results aligned closely. Note that the goal of the recalibration effort was to achieve a generally good calibration and validation across a broad range of model statistics, rather than the highly tuned calibration often desired for regional demand models that are to be used extensively in application. The greatest amount of time was spent calibrating the day-pattern models, which predict the number and purpose of tours and intermediate stops made by each individual. These models often have to be adjusted after the initial calibration to ensure that sufficient travel demand is being generated to match observed roadway and transit volumes. Recalibration of the tour-destination models was challenging because, for a few of the tour purposes, few observed tour records resulted. For these purposes, no adjustments to the calibration were made.

Calibration Challenges

One challenge of the calibration process was that model development involved the use of multiple sets of regional skims at different temporal resolutions and using different network simulation methods at different points in the project. For example, an initial calibration was performed using skims for four broad time periods. Subsequently, this calibration was revisited when Microsimulator-based skims for 22 time periods became available, even though the additional time period detail did not significantly affect the calibration. The calibration was further revised when Router-based skims from the fully integrated model system were developed. Note that noticeable differences occurred in the Router-based and Microsimulator-based skims, with the former generally being more congested. The Router-based skims are based on volume-delay functions (VDF) applied at fine time periods such as 15-min intervals, while the

Microsimulator-based skims are based on the composite speeds of vehicles in the simulation, at that same temporal resolution. These differences and their implications for model calibration and application warrant further exploration.

TRANSIMS

In concert with the calibration of the DaySim demand model components, the project team also had to calibrate and validate the TRANSIMS network supply model components. The demand and supply components interact to produce the overall model system calibration and validation. Note that the TRANSIMS network validation process involved tests performed using all three network resolutions described in this report. However, the final reported validation results reflected the use of the planning network, which was adopted because of its faster runtimes.

Observed Data

The observed network validation data set was primarily derived from temporally detailed (typically, 15-min intervals) data sources, such as intelligent transportation system (ITS) detectors located on major freeways and telemetered and portable traffic monitoring stations. One of the defining aspects of the C10A project is that both the demand and supply models operate at fine-grained temporal resolutions. The observed data used to calibrate and validate the model must also be temporally detailed; and as a result, the project team had to develop an entirely new, observed-count validation data set. A key challenge in developing the observed-count data was cleaning the available data sets for spatial and temporal consistency. The data sets were also reviewed to eliminate atypical counts, such as those that occurred on extreme weather days or during construction periods. Because of the seasonal nature of the Florida population, an analysis of variation by time of year was also performed; the analysis indicated that volumes during the peak spring period in Jacksonville were approximately 7% higher than volumes during the off-peak summer season. And, last, the observed-count locations had to be associated with specific directional links in the networks. Ultimately, approximately 1,000 directional links were tagged with observed counts.

Calibration Process

Estimated roadway volumes were compared with observed volumes for four broad time periods, as well as at a daily level. Note that, unlike a traditional static assignment model, the TRANSIMS model does not assign demand to the network by broad time period. Rather, the entire day's demand of individual trips are loaded onto the network using minute-level departure time information provided by DaySim. However,

time period summaries were still helpful in assessing the performance of the assignment model and informing adjustments to both the DaySim demand and TRANSIMS supply models. Overall, the highway assignment validation by time period looked reasonably good, although the evening time period performed worst—perhaps reflecting the cascade effect mentioned earlier in this chapter.

Conclusions

Transferring the DaySim activity-based demand component from Sacramento to Jacksonville radically reduced the amount of time required to implement this component of the model system. Additional calibration and validation of some of the subcomponents of the model—such as the daily activity pattern component of DaySim and the refinement of TRANSIMS networks—was necessary to improve model performance. However, a number of the models required little, if any, recalibration. Use of the NHTS as the primary observed data source for developing demand model calibration targets was somewhat challenging given the limited weekday sample size in the Jacksonville region and other data completeness issues. Ultimately, more time was spent refining and validating the roadway networks than refining the calibration of the DaySim demand model components. This confirms that network microsimulation models are significantly more sensitive to network coding assumptions, and more time is needed to identify and resolve these issues.

Model Sensitivity Testing

Travel demand forecasting model systems are only able to test the effects of policies and assumptions that have been explicitly included in the design and implementation of the model system; they are not intrinsically sensitive to the increasingly broad range of transportation policies and improvements of interest to decision makers. While most regional models are sensitive to large-scale assumptions about land use and demographics, few are sensitive to more detailed assumptions about pricing policies, or to traffic or travel demand management strategies. Even when models have the capability to address these types of policies, they are typically not sufficiently sensitive to the dynamic interplay between travel behavior and network conditions by time of day to do so; nor can they reasonably represent the effects of road pricing, travel demand management, and other policies. Sensitivity testing of model systems involves the evaluation of the effects of changes in model inputs on model outputs.

A key motivating force behind the SHRP 2 C10A project is the need to address transportation policies that are being considered in metropolitan planning organizations around the United States. These policies are not adequately addressed

by the current state-of-the-practice travel-forecasting models, so the integrated modeling tool developed for this project seeks to improve how these policies are addressed. To assess the increased sensitivity of the integrated model system, a set of tests were designed, implemented and evaluated. These tests were designed to illustrate the unique capabilities of the model system and included pricing, travel demand management, and operations.

Pricing

Freeway Tolls

Two types of pricing tests were evaluated as part of this effort. In the first, a number of scenarios were defined in which freeway tolls varied by time of day. In the second, a number of scenarios were defined in which auto operating costs were modified from the “baseline” condition. For the first set of sensitivity tests, three scenarios were evaluated and compared with the baseline alternative. In the baseline alternative, no costs were assessed at any time. In the first scenario, a fixed \$0.25/mi charge was assessed for anyone using the freeways during the peak periods. In the second scenario, this fixed, peak charge was maintained, and a fixed \$0.10/freeway mi charge was added in midday. Finally, in the third scenario, the fixed peak-period charge was increased to \$1.00/freeway mi and the fixed midday charge was increased to \$0.50/freeway mi. These values were chosen because a set of similar tolling scenarios was tested for a value pricing project in the Seattle region.

The expected responses to these policies—that travel would decline during tolled periods and on tolled facilities and that differences would be observed by activity purpose—were all observed in the model system outputs. In the first scenario, travel declined during the a.m. and p.m. peaks when freeway tolling was in place, but little change was observed midday, which was untolled. In the second and third scenarios, travel declined (whether measured as total trips or vehicle miles or hours traveled) during all tolled time periods, with higher tolls resulting in greater reductions in travel. Interestingly, in all three pricing scenarios, the increases in travel demand during the evenings were pronounced, suggesting that travelers rescheduled activities to occur when no tolls are charged and when fewer scheduling constraints are present. It was also observed in these tests that total trips by time of day affects different purposes. For example, work-related travel was relatively unaffected, but social/recreational travel shifted noticeably out of the peaks and into the evening.

Finally, the network-based total delay was higher than the base in all scenarios, as the tolls induce travelers to shift onto more capacity-constrained surface facilities. An analysis by facility type indicated that most of this additional delay accumulated on minor arterials. This was likely due to coarseness of the sensitivity test; the tolling scheme was not designed

with the specific spatial and temporal extent of network congestion in mind. While some peak location congestion was likely alleviated as a result of the tolling, in many locations across the broad tolling time periods, increased costs were not offset by travel time reductions because of the low levels of baseline congestion.

Auto Operating Costs

For the second set of pricing sensitivity tests, a set of three auto operating cost scenarios was evaluated and compared with the baseline alternative. The baseline alternative assumed a cost of \$0.12/mi. A lower-cost scenario of \$0.06/mi was tested as well as two higher-cost scenarios of \$0.24/mi and \$0.60/mi. These tests confirmed that when auto operating costs decline, the share of households choosing to maintain zero vehicles also declines; and as costs increase, the share of zero-vehicle households also increases. However, these changes were relatively modest: a five-fold increase in the assumed per-mile operating cost resulted in only a 1% increase in the number of households choosing to have zero vehicles. In addition, the tests revealed changes in regional tour frequency by purpose, demonstrating that lower costs slightly increased tour making for discretionary purposes while higher costs slightly decreased tour frequency by purpose. In addition, these reductions in tour making by purpose were not consistent across purposes; mandatory work and school tours declined while discretionary purposes, such as personal business and social/recreational purposes, were seemingly unaffected. The declines in work- and school-tour making are partially attributable to more workers and students choosing their home as their usual work or school location. The tests revealed little systematic difference in changes in trips by time of day across the three scenarios, although slight increases in shorter trips resulted from the highest assumed auto operating costs. These shifts did not result in significant changes in network performance or congestion.

Travel Demand Management

TDM approaches incorporate a wide range of strategies aimed at changing travel behavior to reduce congestion and improve mobility. The sensitivity testing for Project C10A focused on assessing the impacts of a flexible work schedule in which all workers worked fewer days but longer hours on those days. The overall time spent in work activities was held fixed. Because DaySim predicts the daily activity pattern of each individual in the region, it can be used to reflect such a scenario. However, this sensitivity was purely scenario-based. DaySim cannot identify which policies would be most effective at affecting flexible work schedules, though it can be used to estimate the impact on individual travelers’ activity patterns and schedules and on the overall transportation system performance

assuming that an effective policy is in place. The model results were consistent with expectations based on the structure and linkages of the DaySim and TRANSIMS models. In general, overall levels of activity generation were lower, although the declines in work-related travel were offset by increases in travel for discretionary purposes. The model produced shifts in the distribution of travel by time of day due to the lengthened workday, although—as expected—changes in the destination and mode choices were relatively small. This test did reveal noticeable changes in network performance, with reduced congestion across all facility types throughout most of the day and a slight increase in congestion in the evening. That reflects both the later return times from work and increased participation in discretionary activities in the evening.

Operations

The sensitivity testing focused on a scenario in which signals were coordinated using TRANSIMS tools along three primary regional corridors, with the goal of reducing bottlenecks and improving the overall traffic flow. The DaySim-TRANSIMS model system provides sensitivity to these improvements. Traditional travel demand forecast models cannot typically represent such improvements because of the models' linkage with traditional static network assignment methods which lack detailed network operation attributes and have coarse temporal resolution. The initial model results showed some reductions in delay by facility type, particularly during the peak periods. However, closer inspection of the speed profiles along the three targeted corridors showed more mixed results, with the signal progression producing better speeds in some corridor directions and worse speeds in other corridor directions. In implementing the operational tests, approximately 20 iterations were required to establish a set of baseline signal timings for the entire region that produced reasonable performance results. Before establishing new baseline timings, all the corridor progression changes resulted in significant simulation problems. This occurrence likely reflects that such assumptions are necessarily more detailed in geographic and temporal scope—ultimately more consequential for the performance of the network simulation. The sensitivity of dynamic traffic assignment (DTA) and traffic microsimulation models to detailed inputs suggests that users will encounter distinct challenges when attempting to incorporate these assumptions in a forecasting mode, especially at a regional scale. Of all the scenarios evaluated as part of this sensitivity testing, the signal progression scenario required the greatest amount of time and resulted in the least interpretable results. While configuring the other sensitivity test scenarios took approximately 1 day or less, configuring the signal progression test scenario took more than 1 week.

Disaggregate Framework

Because both the demand and the supply components of the model system are fully disaggregate, the impacts of policies and investments on individual travelers can be traced from long-term choices (such as usual work locations) all the way down to the specific paths taken by each individual traveler on a second-by-second basis. For example, if capacity is reduced on a key facility, the system can determine which specific travelers are affected by this change, and how they are affected. Although disaggregate model results are not reported, this disaggregate framework provides tremendous flexibility for aggregating model results for specific travel markets or communities of concern. In addition, the disaggregate framework is useful for debugging, calibrating, and refining model sensitivity.

Simulation Variation

A concern frequently expressed about detailed demand and supply microsimulation models is that of random simulation variation. On the demand side, simulation variation can result from the Monte Carlo simulation methodology used to convert the probabilities in the model system to discrete choices. However, the DaySim software has been implemented in a way that reduces simulation variation by holding the random number seeds and sequences used in the model system fixed across iterations. As a result, the changes between alternatives reflect only the changes in the probabilities for individual choices, not for the simulation method itself. On the supply side, simulation variation proved to be somewhat more complicated because of the dynamic nature of the network microsimulation. The network assignment methodology involves the iterative simulation of demand and feedback of network performance measures. Because the network simulation model is sensitive to even small-scale changes, significant and sometimes problematic variation in network performance can result from one assignment iteration to the next. To address this variation, the project team tested a number of assignment configurations and selected one that produced the most stable results. This configuration produced relative gaps and other stability measures that, while achieving a level of convergence comparable to a static assignment model, produced results that allowed the project team to distinguish between alternatives. The project extensively investigated how many assignment and model system iterations were required to produce outputs in which the differences between alternatives were truly attributable to the alternatives and not to noise within the model system.

Extracting, Managing, and Interpreting Results

Extracting, managing, and interpreting these results from the model system is not difficult. Much of the network performance data that is of primary interest is available in link-based

text files that can be easily processed. Similarly, the travel demand outputs of the model system are also easily interpretable, mirroring the structure of a typical household travel survey. Of course, given the detailed nature of the model system, the files can be quite large. In addition to supporting much more targeted analyses, another advantage of the detailed data produced by the model system is that it can be used to develop visualizations. A number of tools have been developed for TRANSIMS that provide visualizations of second-by-second vehicle movements on the regional networks, capture network performance “heat plots” of congestion, and provide other visualizations as well. These visualizations are not only effective for conveying model results to decision makers but are also essential tools for debugging the model system performance.

Conclusions

The new model system is more sensitive to a wider range of policies than a traditional travel demand model system; this sensitivity is further enhanced by the detailed representation of

temporal dimension, as well as the increased behavioral and spatial detail. In addition, the model system produces a wider range of statistics of interest to decision makers. Extracting, managing, and interpreting these results was not difficult; however, the level of effort required to effectively test different types of improvements varied widely, from as little as an hour to more than a week. Using the model to evaluate pricing and TDM scenarios was relatively easy, requiring straightforward adjustments to network coding or to model coefficients. Using the model to evaluate the operational scenarios required significantly more effort because of the sensitivity of the network simulation to different signal coordination and timing assumptions. This level of effort would undoubtedly increase if more extensive changes to operational assumptions were required. In addition, even with the additional effort, the results produced by the model system did not seem as intuitive as the results of the other scenario tests.

Random simulation variation did not compromise the ability to use the model system, provided a sufficient degree of convergence was achieved both within the network assignment and for the model system overall.

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