User Guide and Model Documentation for SACSIM19

June 30th, 2020

SACOG
Sacramento Area Council of Governments

1415 L Street, Suite 300
Sacramento, CA 95814

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Acknowledgments

This document is heavily based on work performed under contract to SACOG by the following firms and individuals:

- *Mark Bradley (Bradley Research and Consulting)* and *John L. Bowman, Ph.D. (Transportation Systems and Decision Sciences)*--Worked jointly on all phases of the data preparation and the initial development of DAYSIM during 2005- 2007, and on several subsequent updates to DAYSIM used for analysis of the 2012 Metropolitan Transportation Plan (MTP) and the region's first Sustainable Community Strategy (SCS), and for the 2016 MTP/SCS.
- *DKS Associates*—Served as prime contractor for the initial iterations of SACSIM, with Mark Bradley and John L. Bowman, Ph.D., as sub-consultants. In particular, John Gibb at DKS Associates developed the overall SACSIM application and the approach implemented for overall model equilibration and assisted in implementation of Citilabs® Public Transport software in SACSIM, described in greater detail below.
- *Resource Systems Group (RSG)* – Provided technical assistance to comprehensively update DAYSIM (e.g. updating the program code and improving the user interface and overall flexibility and adaptability of the program) and recently contracted to develop and implement the model capability to evaluate tolling strategies. In particular, Joel Freedman, Mark Bradley, and Albab Noor contributed significantly to this effort.

A significant amount of the content of this document is either drawn from, or based upon, technical memoranda and other written materials prepared by the above individuals and firms. Where material was directly copied, attribution is given; however, their influence and thinking are peppered throughout the document in ways impossible to specifically attribute.

SACOG staff was responsible for the organization and update of the document. SACOG staff who contributed significantly to the document are: *Bruce Griesenbeck*, *Kyle Shipley, Shengyi Gao, Darren Conly, Yanmei Ou.*

1 Introduction

SACOG, as the designated Metropolitan Planning Organization (MPO) for the Sacramento region, has the primary responsibility for the development and maintenance of its travel demand forecasting methods and models. These models are used by agencies like SACOG for regional-scale policy analyses of land use and transportation plans, as well as for analyses of the effects of exogenous variables, like fuel prices and demographic change (e.g. aging of the population). The travel demand model currently used by SACOG is the Sacramento Activity-Based Travel Simulation Model, or "SACSIM".

1.1 SACSIM Version

Versions of SACSIM are identified by the year the model code and data files are first utilized for a publicly released analysis. This report provides a detailed description of SACSIM19, which was developed and used for evaluation of the 2020 Metropolitan Transportation Plan/Sustainable Community Strategy (MTP/SCS). Table 1-1 lists the substantial changes and improvements made to SACSIM models since SACSIM15 was released.

Table 1-1 SACSIM15 to SACSIM19 Comparison

Feature	Used for…	SACSIM15	SACSIM19	Change in Modeling
New generation DAYSIM with updated choice models and software structure	Simulation of individual's daily travel activities	Software constraints on number of skims allowed.	Re-estimated choice models; Fully object-originated programming; Shadow pricing to maintain supply/demand of work and school locations	Easy to use & add network skims by modes, VOT classes, time periods; better estimation / forecasting of travel patterns etc.
Proximity buffering (# of households, jobs, K12 enrollments, etc. within travel distance of each parcel)	Modeling attractiveness of parcels as destinations	-Simple radial buffers (¼ & ½ mile) -Unweighted (i.e. activities at far edge of buffer count same as near edges	-Buffers based on network distance -Buffers decay weighted—closer activities count more	-Captures linearity of many activities clustered along major arterials -Captures accessibility "shadows" created by freeways, rivers, etc.
Valuation of time (VOT)	-Assessing trade-offs between cost of travel and time of travel -Useful for any model—but necessary to correctly model pricing	-Three levels of VOT, based on household (HH) income range -All members of high income HH have high VOT -All members of low income HH have low VOT	-Distributed VOT -VOT varies for all persons -Higher VOT more likely for high income HH… -…but VOT mixes across HH income -Some high income have low VOT, some low income have high VOT	-Necessary for implementation of pricing -Necessary for fairly capturing equity impacts of pricing -Causes some trade-offs on shorter, slower routes and longer, faster routes
Transit and Traffic Assignment Time Periods	-Identify peak hour travel -Congestion levels, accessibility, boarding/alighting during peak hours of travel.	4 daily transit periods 4 daily traffic periods (AM,MD,PM,NT)	5 daily transit periods 9 daily traffic periods	-Better control over hourly diurnal flows.

Feature	Used for…	SACSIM15	SACSIM19	Change in Modeling
Vehicle Equivalence on Traffic Assignment (weighting trucks more heavily in estimates of congestion)	-Identifying congested segments and bottlenecks -Reflecting higher congestion impact of bigger trucks	No weighting of bigger trucks	-passenger vehicles =1 -smaller commercial vehicles = 1.5 -3+ axle commercial vehicles = 2.0	-Better practice—called out in last peer review -Overall higher congestion levels
Transit sub-modes (rail, commuter bus, standard fixed route bus)	-Reflecting preferences for different types of transit in mode choice	-Transit mode choice only accounts for mode of access (drive vs. walk) -All transit treated generically	-Continue to account for mode of access -Sub-modes allowed as part of mode choice (rail, commuter bus, fixed route bus)	Better balance of transit trips & boardings amongst the sub-modes
Facility-based Pricing	Modeling toll roads, high-occupancy/toll roads, express lanes	n/a	Full suite of options for modeling toll facilities with dynamic tolling and occupancy class exceptions. User settings for minima/maxima tolls, tolling periods, etc.	New functionality, allows for modeling the impact of tolling on travel behavior and on revenue
Pay-As-You-Go Pricing (PAYGO)	Modeling of mileage-based user fees	Limited to single-point auto-operating cost, inclusive of PAYGO. Fixed by time period, geography. Does not affect path-building.	PAYGO added as roadway network variable, captured in path-building and skims. Can vary by time period or geography.	Captures effects of PAYGO more realistically, and affects path-building and skims for auto modes.

Source: SACOG 2020.

1.2 Version History

SACSIM19 – Current

SACSIM15 – Released in 2016 as part of the 2016 MTP/SCS

SACSIM11 – Released in 2012 as part of the 2012 MTP/SCS

1.3 Public Access

The updated SACSIM modeling scripts and data files are made available for review and comment by local member agencies and the transportation consulting community in the following ways:

SACOG maintains a basic description of SACSIM on its website for the public at large to get a basic understanding of the model and its uses, and to connect members of the public to SACOG staff members that can provide additional information as needed. https://www.sacog.org/modeling

SACOG hosted a SACSIM19 users' conference in January 2019. The conference included a one-day session providing a general overview of the SACSIM19 model, directed at non-modeling planning professionals and representatives of community and advocate groups in the morning session, and a deeper dive into SACSIM19 model functionality for transportation planners and modelers in the afternoon session. Input from the attendees was solicited on the usefulness of the users' conference as a way of disseminating information on SACSIM19, and on user preferences for improvements to SACSIM19 moving forward. https://www.sacog.org/pod/travel-demand-model-user-conference

SACOG implemented a formal beta-test process, call for participants announced in November 2018, group starting in January 2019 and ending in March 2019. The beta-test process allowed for early access to the draft SACSIM19 for learning and testing purposes. Ten organizations and firms participated. The beta-test included a one-day training session on SACSIM19, technical support as needed, and bi-weekly teleconferences calls to check in on testing progress and to address questions or issues experienced by the beta testers. More information about beta testing can be found under https://www.sacog.org/pod/travel-demand-model-beta-testing-group.

SACOG scheduled an early release of the SACSIM19 MTP/SCS draft preferred scenario land use and transportation network files, data files, scripts, and executables to local agencies and their consultants, enabling them to review the MTP/SCS and provide a baseline for local project analyses. Agencies took advantage of this release of the draft MTP/SCS for projects such as the Placer Sacramento Gateway Plan and Caltrans Managed Lanes studies.

Modeling changes were presented to ARB staff in discussions related to the proposed technical methodology for assessment of greenhouse gases for implementation of SB 375, pursuant to Section 65080 of the Government Code.

1.4 Organization of the Report

The report is organized into 12 chapters with several Appendices.

1.4.1 Chapter 1 Introduction

Chapter 1 describes organization of the documentation, version history, and public access.

1.4.2 Chapter 2 Model Overview

Chapter 2 is oriented toward model users and provides information relevant to setting up and running the model such as hardware/software requirements, setting up model inputs, a review of model outputs, and troubleshooting common issues that arise when running the model.

1.4.3 Chapter 3 Model Structure

Chapter 3 describes the overall structure and flow of the SACSIM model, along with descriptions of each SACSIM submodel. The submodels include:

- *DAYSIM* is the person-day activity and travel simulator, which is the only true activity-based tour component of SACSIM. DAYSIM accounts for all travel by residents of the SACOG region for their travel within the region. The simulation is at person level, so the major outputs of DAYSIM relate to personal travel for work, school, social/recreational, and other non-work purposes. DAYSIM includes a set of *long-term choice* models at the highest level, and a larger set of *short-term choice* models at lower levels.
- *Airport ground access* to the Sacramento International Airport is modeled separately, at the traffic analysis zone (TAZ) level. This model is adapted from work done by the Sacramento Regional Transit District for its evaluation of the Downtown-Natomas-Airport transit corridor.
- *Commercial vehicle travel* is also modeled separately from resident travel and is modeled at the TAZ level. It includes all trips made for transportation of goods and services. This submodel was adapted from SACMET, and operates with conventional four-step trip generation, distribution, and assignment.
- *External trips* include both internal-external (trips made by region residents to points outside the region), external-internal (trips made by residents from outside the region to points within the region), and trips that pass through the region without stopping. These trips are fixed as exogenous, scenario variables. Only the portion of these trips that occur within the SACOG region are modeled.

Trips from all the submodels are aggregated to create conventional trip matrices which are assigned to the highway and transit networks. This process includes a *trip aggregator*, plus all the usual trip assignment programs.

SACSIM runs within an application shell, scripted in Citilabs® TP-Plus software. DAYSIM itself is a stand-alone program written in C#, and compiled to run within the SACSIM application. All trip aggregation, plus the non-DAYSIM components, are TP-Plus scripts.

1.4.4 Chapters 4 and 5 Land Use and Demographics

Chapters 4 and 5 cover key land use and demographic input data files required by SACSIM. Chapter 4 provides a description of the *parcel land use file*, which is the SACSIM equivalent of a zonal data file in a conventional four-step model. In addition to descriptions of the key variables included in the file, Chapter 4 provides an overview of how the file is produced, starting from SACOG's land use model. Chapter 5 provides a description of the *representative population file*, which is a person-level representation of the region's household population. The population file is required to run activity-based tour models like SACSIM. The cumulative demographics (household size, workers, income distribution, age) of the representative population file reflect key demographic projections and forecast assumptions which underlie SACOG's travel demand forecasts. Chapter 5 provides an overview of how the population file is produced.

1.4.5 Chapters 6, 7, and 8 Transportation Networks

Chapters 6, 7, and 8 cover transportation network input files and assumptions. Chapter 6 provides a detailed description of the *highway network files* used by SACSIM. Highway networks are required for generating cost or level of service matrices (also called *skims*), which represent the level of accessibility of travel by automobile.

Chapter 7 describes SACSIM's transit network. By their nature, transit networks are more complicated than highway networks. First, more attributes need to be represented in transit networks, including stop locations, service frequencies, transfer locations, access points (e.g. park-and-ride lots), and hours of operation. Second, access to transit (i.e. how a traveler gets from his or her origin location to the first transit stop) is more difficult to characterize in computer models, and additional network features and coding are required to capture the options which can be used to access transit. Finally, transfers and fare policies vary among operators and passenger types, which results in a large variety of potential fares for each trip itinerary and person type. Together, these transit inputs allow creation of transit skims, which represent the level of transit access between TAZs.

Chapter 8 discusses SACSIM's bike and walk network, which is a subset of its highway network. It also discusses the method by which SACSIM takes advantage of its detailed, parcel-level land use data to estimate the distances of short trips (e.g. trips that start and end within the same TAZ, or between nearby TAZs) more accurately than can be done by the SACSIM highway network on its own.

1.4.6 Chapter 9 Auto/Transit Cost and Pricing

Large variations in fuel prices over the last several years have initiated a re-evaluation of fuel price and auto operating costs as it affects travel costs and behavior in travel demand models. Chapter 9 provides a SACOG-specific and California perspective on actual fuel prices and recent changes, and describes how fuel prices are represented in SACSIM. The chapter also explains how transit fares are represented in the model.

1.4.7 Chapter 10 System Equilibration

Chapter 10 describes the theoretical foundation behind and process by which SACSIM iterates in order to reached system equilibration and describes the relationships between the network assignment and DAYSIM to determine person trip travel patterns and mode choices relating to congestion.

1.4.8 Chapter 11 Sensitivity Tests

Chapter 11 presents the results of several sensitivity tests applied to SACSIM, which test to see if the model's responses to changes in factors like fuel price, transit fare, income, land use density reasonably align with observed responses in travel behavior to changes in these factors. Chapter 11 also summarizes the results of a "random variation" test, which test to see how much variation there is in model outputs due to the probabilistic nature of many of its choice models.

1.4.9 Chapter 12 Model Calibration, Validation and Reasonableness Check

Chapter 12 describes the observed travel and transportation system data sources used for estimating, calibrating, validating, and reasonableness checking SACSIM along with a discussion on the quality and limitations of each source.

2 Model Overview

2.1 Key Concepts and Parameters

SACSIM is a *typical weekday* model. It represents travel demands for a typical weekday, defined as a mid-week day (Tuesday, Wednesday or Thursday) during a Spring or early Fall month (March, April, May, September or October). Mid-week days are used because Mondays and Fridays are often affected by holiday or weekend activities or events. Spring or Fall months are used because those are months when schools are normally in session, weather does not often affect peoples' activities or travel, and a lower percentage of workers are on vacation. Activities and travel in late Fall and Winter months (November through February) are strongly affected by major holidays (Thanksgiving, Christmas, New Years Day, etc.) and inclement weather. Where required, typical weekday performance measures are annualized to represent travel through the course of the year, rather than only for a typical weekday. Figure 2-1 provides a high-level overview of the SACSIM model.

The term *simulation* is used in so many ways related to transportation modeling and analysis, that its use causes confusion, even to transportation professionals. The dictionary definition of *simulation* which is applicable to SACSIM is "…the imitative representation of the functioning of one system or process by means of the functioning of another <a computer ~ of an industrial process>; examination of a problem often not subject to direct experimentation by means of a simulating device…"[1] This general definition fits SACSIM, but also fits many other four-step travel demand models. Two characteristics of *transportation simulations* which apply to SACSIM, and distinguish SACSIM from four-step travel demand models are: 1) disaggregate application; and 2) explicit treatment of time.

In truth, only one key submodel which makes up SACSIM is truly a simulation, and that is DAYSIM. DAYSIM is disaggregate in its application—its units of analysis, or agents, are people. The units of analysis for conventional four-step models are TAZs. DAYSIM applies models estimated on a household travel survey of individual people to a representative population file with one record per person, and all person-level variables in the estimation accounted for explicitly in the model. Calibration aside, the model estimated is the model applied. For conventional four-step models, many of the key variables included in the estimated model are aggregated and simplified, with true distributions of behavior represented by the averages for groups of individuals.

DAYSIM also explicitly treats time. Durations of activities and travel times are constrained by the length of a day, and travel choices as modeled account for time explicitly in 30 minute blocks. Most conventional four-step models actually model a complete day's travel as a number of trips, with those trips blocked into times post-hoc, using fixed time factors or aggregate "choice" models.

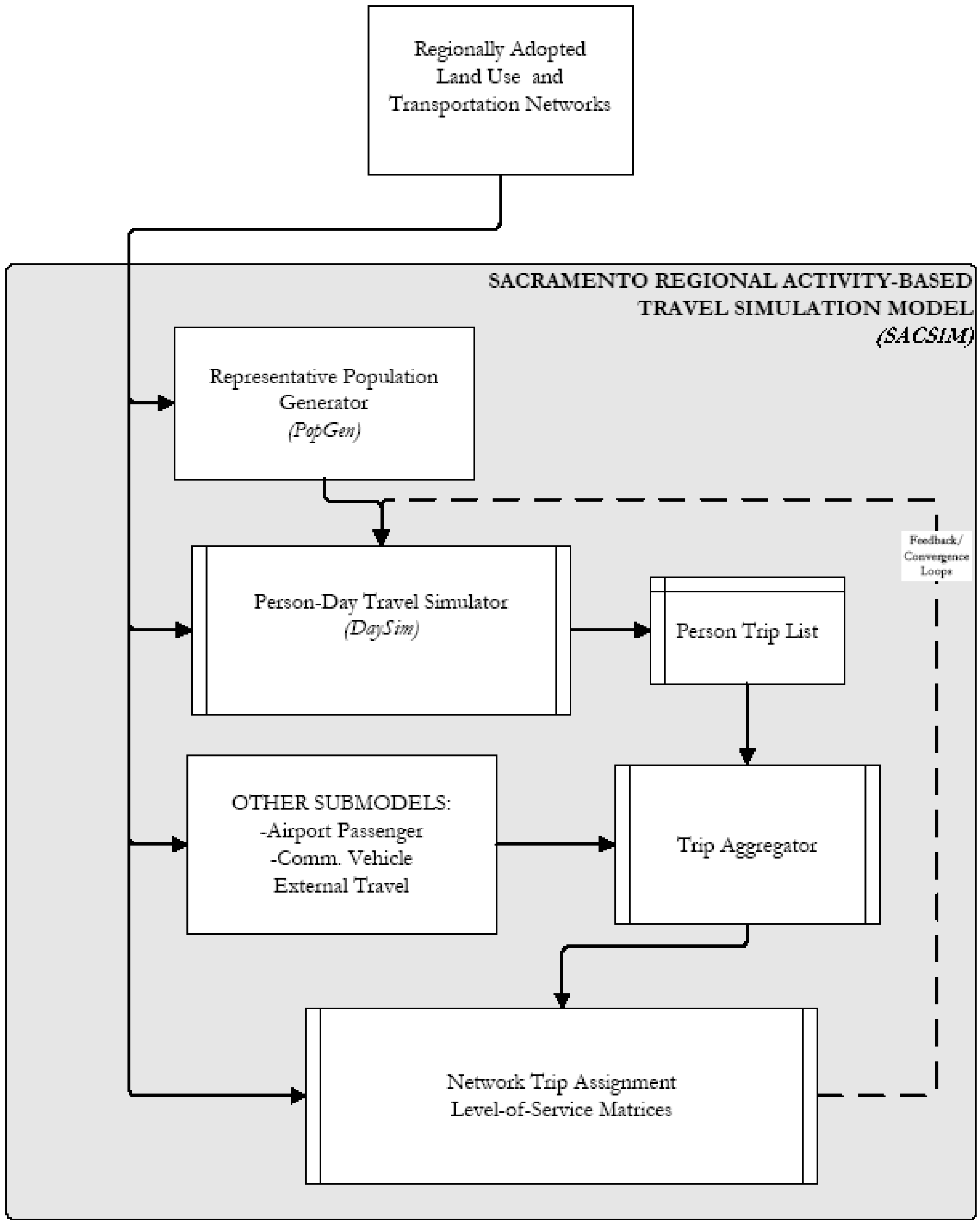
No other submodel within SACSIM is a true simulation. The airport passenger ground access model is a pseudo-simulation, with the model applied by enumerating the actual passenger survey

[1] Webster's Ninth New Collegiate Dictionary, Merriam-Webster, 1987.

database. The remaining submodels (commercial travel, external travel) are applied to TAZ's as the unit of analysis, and treat time post hoc through fixed factors.

When many transportation professionals hear *transportation simulation* what they think of is one of the increasingly prevalent *traffic operations simulations*, which show cars, or in some cases, cars, transit vehicle, and pedestrians, in animations. Some of the animations have vivid detail, e.g. three-dimensional vehicles and people, set in a world with buildings, streets, and even street fixtures and furniture shown in 3-D. SACSIM is NOT this sort of simulation. In fact, SACSIM skims and assigns trips in same old, TAZ-based, static way that is used by conventional four-step travel demand models. DAYSIM simulates the demand for travel, but the actual assignment of that demand to highway and transit networks is not simulated.

Figure 2-1 SACSIM Model System



2.2 Hardware and Software Requirements

As noted in the public access section above. SACSIM19 files and software are open to the public. However, the current version of the model does require specific hardware and software to run. Table 2-1 provides minimum recommended hardware specific to run SACSIM.

2.2.1 Hardware

Table 2-1 Minimum Hardware Recommendations

CPU Speed	Minimum: 1.5 GHz single core Recommended: 2.0 GHz dual-core or better With Cluster: 2.0 GHz quad-core or better
Processor	Minimum: Intel Pentium 4, AMD Athlon Recommended: Intel Core i5, i7, Xeon or better; AMD Phenom II, Athlon II, FX-Series, A-Series APU or better
Memory/RAM	1 GB minimum; 4 GB or higher recommended With Cluster: 2 GB per core recommended
Hard Disk	Minimum: ATAPI IDE; 5,400 rpm Recommended: SATA 3 Gb/s or 6 Gb/s; SAS; 7,200 RPM or better; SSD
Hard Disk Space	10 GB for the application and supporting applications and data (like GIS)100+ GB for output files
Screen Resolution	Minimum: 1024 x 768 at Normal size (96dpi); 16-bit color depth Recommended: 1440 x 900 or higher at Normal size (96dpi); 32-bit color dept
Video/Graphics Adapter	Minimum: 24-bit capable graphics adapter; 64 MB video memory Recommended: 32-bit capable graphics adapter; 512 MB or more video memory
Networking Hardwar	100BT or 1000BT TCP-IP compatible Ethernet or Wireless adapter
Peripherals	DVD-ROM drive(1) available USB port, parallel port, ExpressCard slot, or PCMCIA slot for hardware dongle
Operating System	Recommended: Windows 10
Server Configuration	
CPU Speed	2.0 GHz quad-core or higher; multiple CPUs are ideal

Processor	Recommended: Intel Xeon E3, E5, E7; AMD Opteron 42xx, 43xx, 62xx, 63xx, 83x
Memory/RAM	4 GB minimum; 16 GB or higher recommended, For Cluster, used in SACSIM19: 2 GB per core recommended
Hard Disk	Recommended: SATA 3 Gb/s or 6 Gb/s; SAS; 7,200 RPM or better; SSD
Hard Disk Space	10 GB for the application and supporting applications and data (like GIS)100+ GB for output files

Source: SACOG 2020. Hardware recommendations based primarily on Bentley (formerly Citilabs) Cube Base Reference Guide Recommended workstation and server configurations for Cube Base Version 6.4.4.

2.2.2 Software

SACOG staff uses a variety of software applications to develop, run, and analyze SACSIM19. The section is broken out into two primary categories. Required software is necessary to run SACSIM19. Nonrequired software is additional software that SACOG staff use to develop and maintain SACSIM19, however the model does not explicitly need any of these to be run.

2.2.2.1 Required Software

2.2.2.1.1 Operating system

Microsoft Windows (64-bit version), such as Windows 10.

2.2.2.1.2 Cube Voyager 6.4.4 Software

Cube is a proprietary software package, which is produced, licensed, and marketed by Bentley Systems. Inc. Thus, to run the regional travel model, you will need to purchase the Cube software from Citilabs (www.citilabs.com). Cube software license is required to run SACSIM19.

Cube Voyager: Cube Voyager is the numerical engine that powers the Cube suite of software and includes its own proprietary scripting language. SACSIM19 was developed and applied by using Cube versions 6.4.4.

Cube Cluster

Cube Cluster is also part of the Cube software package used for distributed processing, by running processes across multiple cores. Cube cluster significantly reduces model run times. If not available, Cube clustering can be turned off in SACSIM19 script, but model run time will significantly increase and this is not recommended.

2.2.2.1.3 DAYSIM

DAYSIM a travel demand microsimulation software package that works in conjunction with network modeling software packages to forecast a population’s response to changes in transport infrastructure and policy. DAYSIM uses an integrated system of discrete choice models to simulate long term choices for each household, and the activity and travel choices for a 24-hour period for each household member. It uses 48 half-hour time periods across the day as the basic units of temporal resolution, and uses either individual parcels of land or block-sized microzones as the basic units of spatial resolution. DAYSIM is licensed under an open source license.

2.2.2.2 Nonrequired

2.2.2.2.1 Cube Base

Cube Base is the network Graphic User Interface (GUI) part of the Cube software package. While this is not technically needed to run SACSIM19, it is strongly recommended. Cube Base is needed to make any edits to the network variables and visualize any SACSIM19 model run results.

2.2.2.2.2 ArcGIS

ArcGIS is an ESRI platform for organizations to create, manage, share, and analyze spatial data. It consists of server components, mobile and desktop applications, and developer tools. SACOG staff uses various desktop and developer tools to develop and display SACSIM data. None ESRI GIS platforms may also be used to display the modeling spatial datasets. During release of this document SACOG staff developed data using Arc Desktop 10.7.0 and Arc Pro 2.5.2

2.2.2.2.3 PopGen version 1.1

PopGen, software developed by the Mobility Analytics Research Group alongside multiple universities and Metropolitan Planning Organizations (MPO), was used to generate a representative synthetic population with person and household-level attributes. More information and PopGen software can be downloaded from the Mobility Analytics webpage https://www.mobilityanalytics.org/popgen.html. Distributed as free software.

2.2.2.2.4 SQL Server

Microsoft SQL Server is a relational database management system developed by Microsoft. SACOG staff use to preform general data processing and analysis tasks. Version used as of release: SQL Server 2019. SQL Server Management Studio v18.3. SQL Server Software is proprietary software, license required.

2.2.2.2.5 Python

Python is an interpreted, high-level, general-purpose programming language. SACOG staff use to preform general data processing and analysis tasks. Version used as of release: Python 3.6.8 (Anaconda, Inc). Python 2.7.9 used for PopGEN version 1.1. Distributed as free software.

2.2.2.2.6 Notepad++

Notepad++ is a text and source code editor for use with Microsoft Windows, distributed as free software. Used to view and edit large text files. Version v7.8.5 used as of release.

2.3 Model Inputs

2.3.1 Scenario

Table 2-2 lists the files required for each model scenario folder.

Table 2-2 SACSIM19 Input File Descriptions for Scenario Folder

Folder	File Name	Type	Description
scenario_folder (can be any name)	SACSIM_Run.s (Can be any name)	Cube Voyager Script	SACSIM Cube Voyager primary script for model.
scenario_folder (can be any name)	config.sacsim.trips.xml	Trip Configuration File	User input control file for DAYSIM configurations.
scenario_folder	config.sacsim.wkscloc.xml	Work Location Configuration File	User input control file for DAYSIM configurations.
scenario_folder	tolls.csv	Toll Facility Cost Input File	User input controls for dynamic tolling during assignment.
scenario_folder	RAD_UserFee.csv	Milaged Based Fee Input File	User input for spatial adjustments for mileage based user fie.
scenario_folder	2016_thru.dbf	Landuse/transportation	Through Trips
scenario_folder	2016_taz.dbf	Landuse/transportation	Transportation Analysis Zones
scenario_folder	2016_ixxi.dbf	Landuse/transportation	Internal (i) External (e) Production and Attractions
scenario_folder	2016_base.net	Landuse/transportation	Roadway Network
scenario_folder	2016_tranline.txt	Landuse/transportation	Transit Line
scenario_folder	2016_transit_links.csv	Landuse/transportation	Transit Network
scenario_folder	2016_station_links.csv	Landuse/transportation	Transit Station Nodes
scenario_folder	2016_pnr.dbf	Landuse/transportation	
scenario_folder	2016_raw_person.txt	Landuse/transportation	Person Inputs
scenario_folder	2016_raw_household.txt	Landuse/transportation	Household Inputs
scenario_folder	2016_raw_parcel.txt	Landuse/transportation	Parcel Inputs

Source: SACOG 2020.

2.3.2 Input

Table 2-3 lists the files in the “input” folder. The “input” folder sits in the parent directory of each model run scenario folder and contains higher-level inputs.

Table 2-3 SACSIM19 Input File Descriptions for Input Folder

Folder	File Name	Type	Description
input	airportsurvey.dbf	Airport module input	Airport survey input for SACSIM airport module
input	Ptfactor.mustcom.txt	Transit input	Sub transit mode control file: commuter buses
input	Ptfactor.mustlrt.txt	Transit input	Sub transit mode control file: light rail
input	Ptfactor.onlyloc.txt	Transit input	Sub transit mode control file: local bus
input	Ptfactor.txt	Transit input	Transit all mode control file
input	Ptfare.txt	Transit input	Transit fares for all modes
input	Ptsystem.txt	Transit input	Transit wait curves by sum mode and operator
input	sacfftpp.txt	IXXI input	Friction Factors input by trip type
input	todfactors.txt	IXXI input	Time of day factors by trip type

Source: SACOG 2020

2.3.3 daysim

Table 2-4 lists the files needed in the daysim folder. The daysim folder sits in the parent directory of the scenario folder and contains parameter and coefficient files related to the daysim submodel.

Table 2-4 SACSIM19 Input File Descriptions for DAYSIM Folder

Folder	File Name	Type	Description
daysim	sacog_roster.combinations.csv	Roster	DAYSIM Mode Roster
daysim	sacsim_roster_mat.csv	Roster	DAYSIM Input Roster
daysim	sacog_taz_indexes.dat	TAZ	
daysim	WorkLocationCoefficients_SACOG-v1.5.f12	Coefficients Files	
daysim	SchoolLocationCoefficients_SACOG-v1.8.f12	Coefficients Files	
daysim	PayToParkAtWorkplaceCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	TransitPassOwnershipCoefficients_SACOG-v1.5.f12	Coefficients Files	
daysim	AutoOwnershipCoefficients_SACOG-v1.5.f12	Coefficients Files	
daysim	IndividualPersonDayPatternCoefficients_SACOG-v1.8.f12	Coefficients Files	
daysim	PersonExactNumberOfToursCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	WorkTourDestinationCoefficients_SACOG-v1.8.F12	Coefficients Files	
daysim	OtherTourDestinationCoefficients_SACOG-v1.8.F12	Coefficients Files	
daysim	WorkbasedSubtourGenerationCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	WorkTourModeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	SchoolTourModeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	WorkBasedSubtourModeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	EscortTourModeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	OtherHomeBasedTourModeCoefficients_SACOG-v1.5.F12	Coefficients Files	

daysim	WorkTourTimeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	SchoolTourTimeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	OtherHomeBasedTourTimeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	WorkbasedSubtourTimeCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	IntermediateStopGenerationCoefficients_SACOG-v1.5.F12	Coefficients Files	
daysim	IntermediateStopLocationCoefficients_SACOG-v1.8.F12	Coefficients Files	
daysim	TripModeCoefficients_SACOG-v1.5.f12	Coefficients Files	
daysim	TripTimeCoefficients_SACOG-v1.5.f12	Coefficients Files	

Source: SACOG 2020.

2.4 Model Outputs

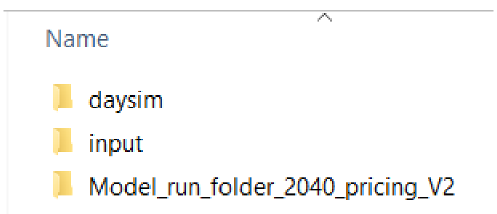
Refer toAppendix A DAYSIM Reference Guide.xlsx. Appendix A contains DAYSIM data tables describing required inputs, intermediate files and outputs such as output person, households, tours and trip tables.

Other SACSIM19 output files include loaded Cube trip skim matrixes, loaded assignment Cube network files by time period, roadway pricing costs, and Transit boarding's /alighting's files. Further information on these outputs can be found in Chapter 6 Highway Networks, Chapter 7 Transit Networks, and Chapter 9 Auto Operating Costs, Pricing, and Transit Fares.

2.5 Preparing a model run

This section is to provide practitioners of SACSIM how to set up the SACSIM19 input structure to create a scenario to run. The scenario requires three subfolder directories as shown in Figure 2-2. The model inputs section above provides files names and descriptions of the required files. If multiple scenario have the same input daysim and input folder inputs, which is common for multiple scenarios using the same scenario forecast year, you can create multiple "Scenario" in the same directory to call the daysim and input files. Each scenario will require its own SACSIM19 run script (.s file) and associated inputs

Figure 2-2 SACSIM Run Folders



2.5.1 Model run scenario structure

The following figures represent examples of a model files and folder structure ready to be ran. For more information on files review model inputs section above and Appendix A DAYSIM Reference Guide.xlsx for descriptions, requirements and file type information.

Figure 2-3 Example Scenario Input Folder Setup

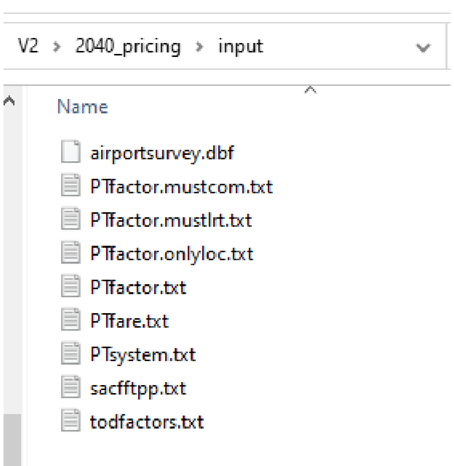


Figure 2-4 Example Scenario daysim Folder Setup

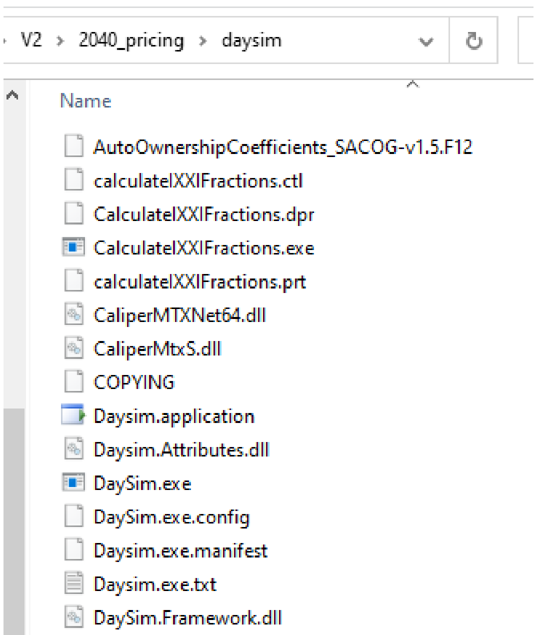
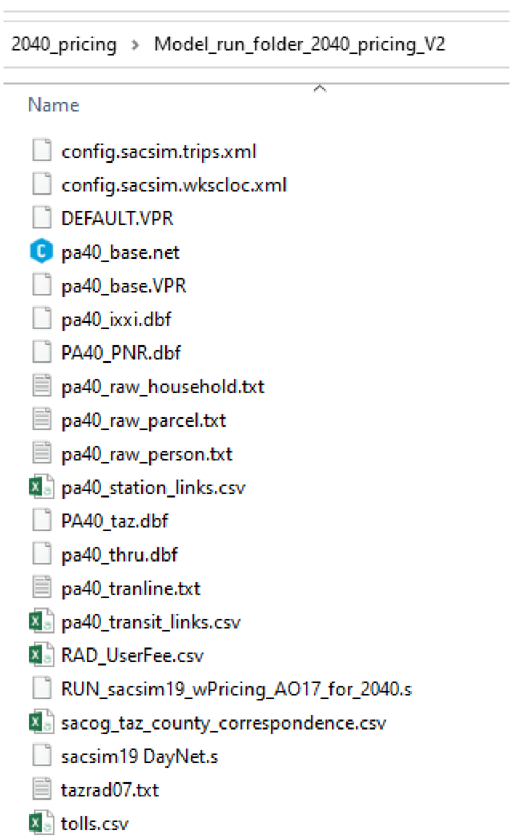


Figure 2-5 Example Scenario Run Folder Setup



2.5.2 Setup for Model Run Pricing Parameters

As part of the 2020 MTP/SCS, SACSIM19 was updated to run a variety of policy-based scenarios. These scenarios vary SACSIM19 base assumptions and require slightly different setups. It's important to understand and check the following scenario files to determine if a baseline, mileage-based user fee, and/or managed or toll lane pricing scenario is setup in the input structure. Further details on costs, fees and pricing can be found in Chapter 9.

2.5.2.1 Setup Mileage Based User Fee

2.5.2.1.1 SACSIM19 run script

To incorporate pricing alternatives into SACSIM's utility cost of travel function, SACSIM19 breaks out auto cost, typically referred to as the "Cost of Driving" and a separate mileage-based user fee. This is a model feature that can be turned on or off by the user based on a few input parameters. Figure 2-6 illustrates variable in SACSIM19 model run script to update mileage-based user fee and auto operating cost. For example, if a model run is testing a mileage-based user fee compared to today's California gas tax, the user would need to factor in the reduction by subtracting a portion of the auto cost per mile input. Therefore, if Mileage Based User fee is tuned off, variable *"userfee_per_mile" is equal to 0.00. If Mileage based user* fee variable turned on, "userfee_per_mile" is equal to a value greater than zero. Important Note: all auto operating costs need to be converted to 2000 dollars for model input. Further description on SACSIM19 pricing implementation is in Chapter 9.

Figure 2-6 SACSIM19 Auto Cost and User Fee Inputs

```
;======================================================================

;Set per-mile auto operating cost here
auto_cost_per_mile = 0.162
userfee_per_mile =   0.014
```

Spatial and Time Period Fee Adjustments

In addition to a mileage-based user fee, spatial and temporal components can be set using the RAD_Userfee.csv input file in the Scenario run folder. Table 2-5 describes the four inputs in the RAD_Userfee.csv required and an example with and without the mileage-based fee adjustments. Source: SACOG 2020.

Figure 2-7 shows an example of the RAD_Userfee.csv.

Table 2-5 Spatial and Temporal Mileage-Based Fee Adjustment

Header (Not in actual file)	RAD	Multiplicative Factor	Peak Adjustment	Off Peak Adjustment
Required input description	Regional Analysis Distract Spatial Geography where factor will apply to roadways. **Default is all RAD Zones within region.**	Factor used to multiple userfee_per_mile input. **Default is 1.**	Peak congestion rate adjustment factor applied to AM (7am-10am) and (4PM – 6PM) peak hours. **Default is 0.**	Off Peak period discount rate during non-congested times applied to Evenings (7-9), Nighttime (10-5am) and Midday. **Default is 0**
Example Spatial Adjustment **Turned On**	1	2	0.007	-0.007
Example Spatial Adjustment **Turned Off**	1	1	0	0

Source: SACOG 2020.

Figure 2-7 RAD_Userfee.csv Example

26	26	1	0.007	-0.007
27	27	2	0.007	-0.007
28	28	1	0.007	-0.007

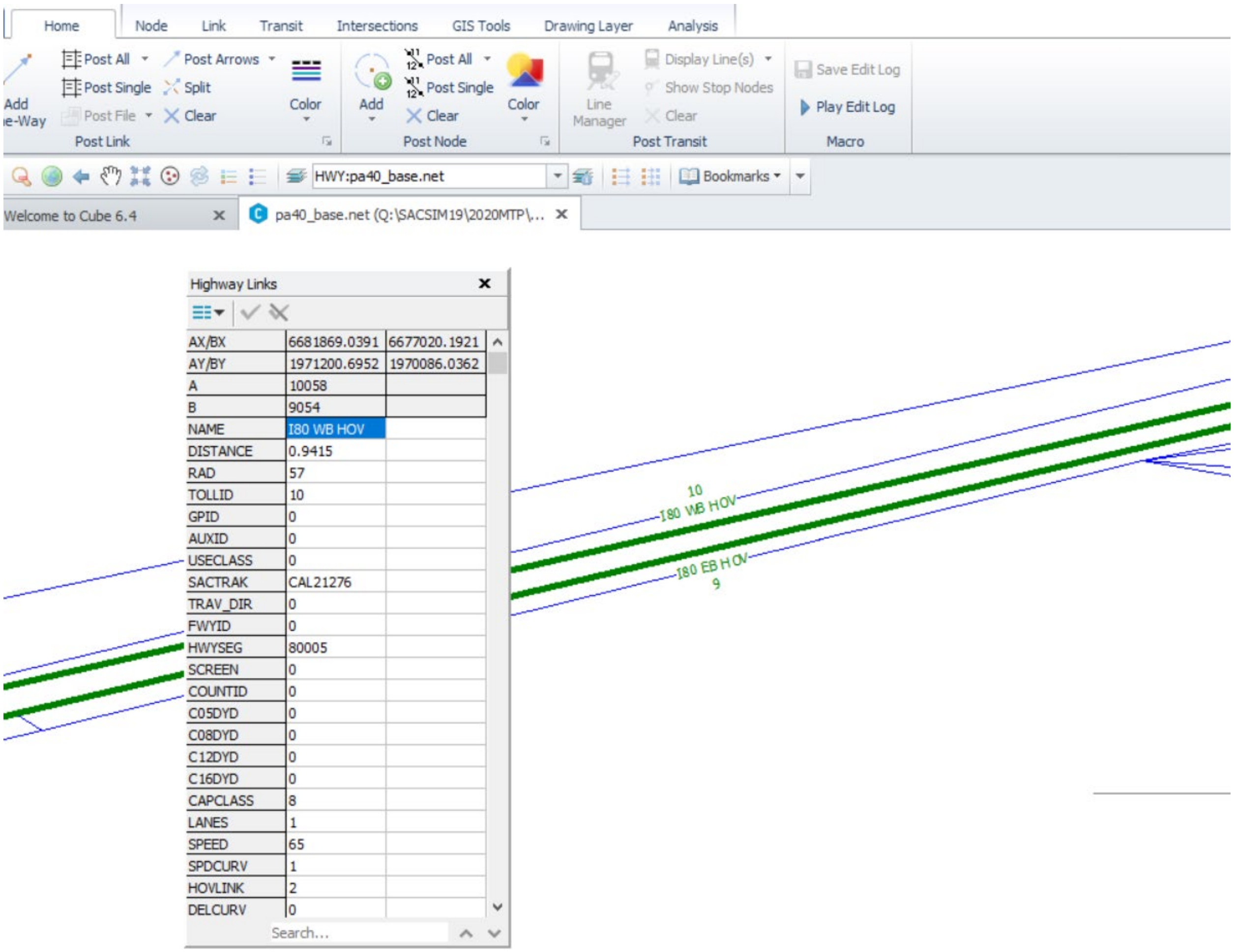
RAD_UserFee

2.5.2.2 Setup Managed Lanes Tolling

2.5.2.2.1 Base Scenario Model Network

A scenario's model highway network is typically named **<scenario year>_base.net.** Every priced facility must have a TOLLID number associated. For parallel general purpose and auxiliary lanes, the same ID number must be assigned to GPID (general purpose lanes) and AUXID (auxiliary lanes). This is used to determine the cost of the managed facility relative to the congestion on the parallel "free" facilities. Depending on the type of managed lane, USECLASS must also be set with a value of 0, 2, or 3 to determine the allowed vehicle type on the managed facility. Zero allows all users to drive on the facility being priced, 2 allows only vehicles with 2 or more passengers, while 3 allows only vehicles 3+ passengers. Note, USECLASS does not determine which vehicles are *priced*; it just determines which vehicles are allowed to use the facility. Prices are set in the Toll Input File described below. Figure 2-8 shows an example of a managed lane facility coding on the base network. In this example all vehicle types are allowed on the managed lane facility.

Figure 2-8 Base Network Toll ID Coding



2.5.2.2.2 Toll Input Cost File

The TOLLID coded on the network identifies the toll segments. The costs by vehicle type then need to be associated and defined to the network toll segments. This is done in the Toll Input Cost File **tolls.csv.** Each row represents a unique TOLLID segment by time period. For every tolled segment there will be nine additional rows added to the input file (1 TOLLID X 9 SACSIM time periods). The user must specify initial, minimum, and maximum values for each row for each of the four modes:

- drive alone,
- SOV2,
- SOV3+,
- commercial vehicle.

Table 2-6 shows an example of how the Toll Input Cost File may look. If a scenario requires no toll pricing, Inputs columns 4-22 should all be set to zero. For more information, review Chapter 9 on Roadway and Mileage Based Pricing.

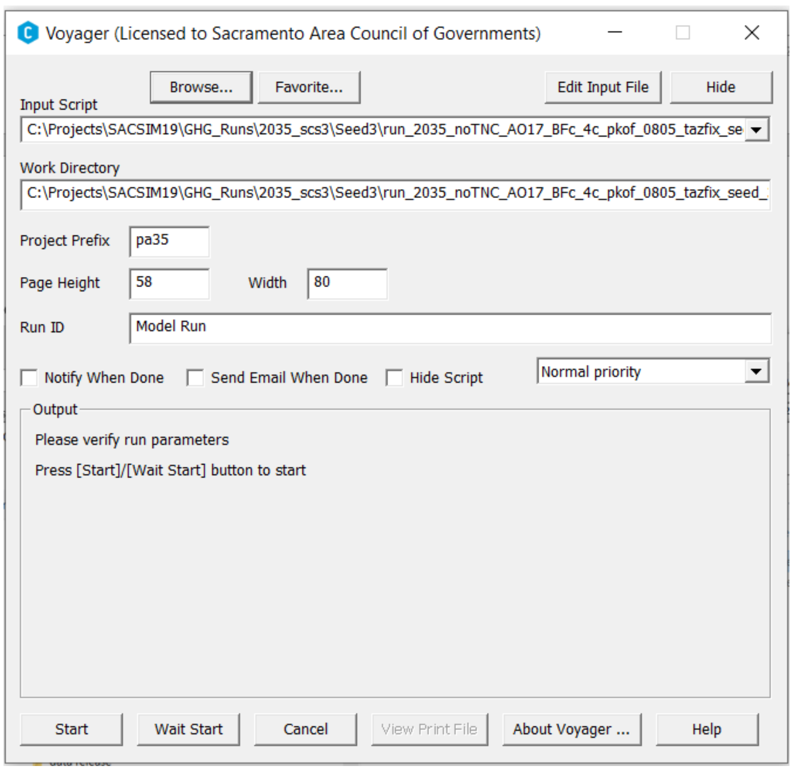
Table 2-6 Toll Cost Input Example

Fac. Index	Seg.	Per.	Fac. Type	Adjust	Toll DA	Toll S2	Toll S3	Toll CV	Min DA	Min S2	Min S3	Min CV	Max DA	Max S2	Max S3	Max CV	Reversable Lane AM	Reversable Lane PM	Shoulder lane AM	Shoulder lane PM	Take a Lane AM	Take a Lane PM
101	1	1	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
102	1	2	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
103	1	3	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
104	1	4	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
105	1	5	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
106	1	6	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
107	1	7	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
108	1	8	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
109	1	9	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0

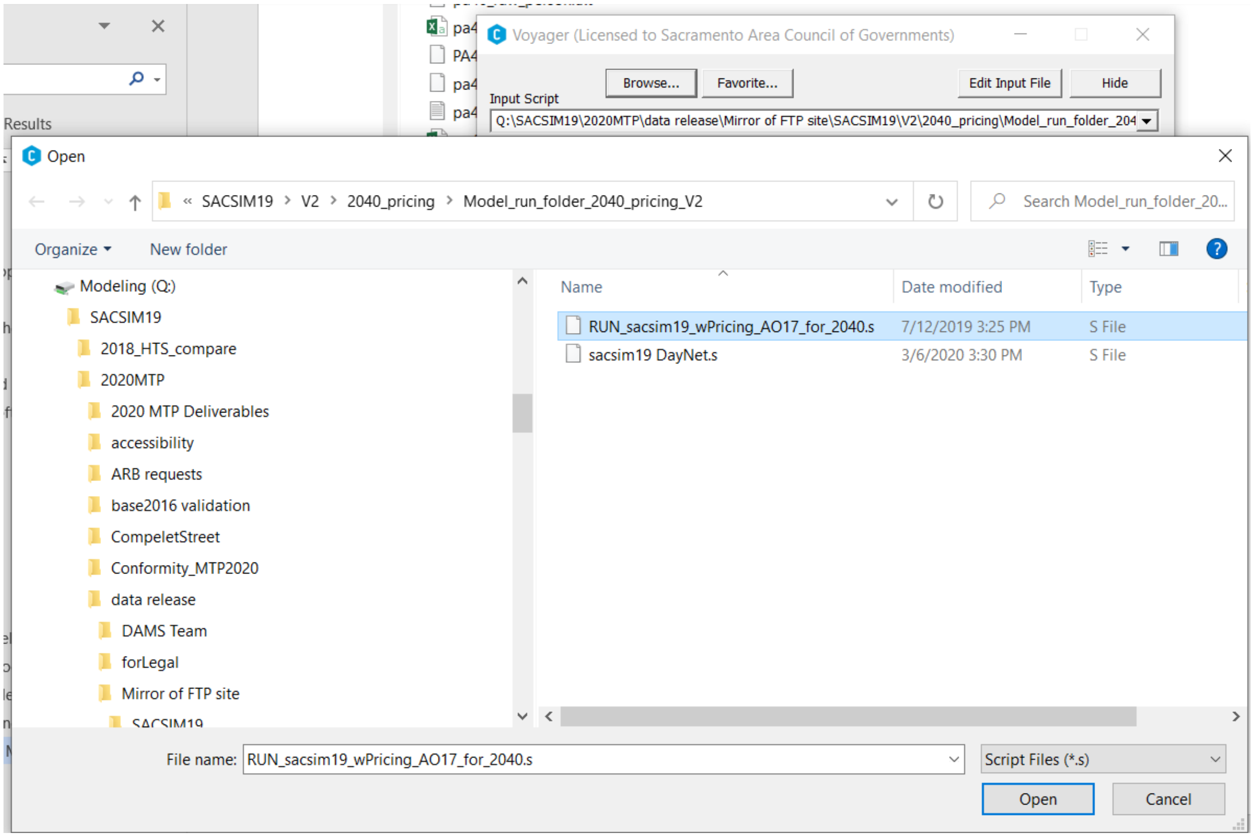
Source: SACOG 2020.

2.5.3 Start Scenario Model Run with Cube Voyager

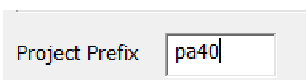
1. Open Cube Voyager Application



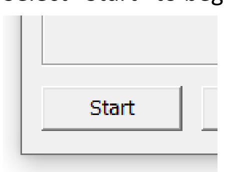
2. Select Browse and navigate the SACSIM model run script in Scenario folder created.



3. Check Prefix matches with files structure. For example, for SACOG SACSIM19 2040 modeling scenarios, prefix pa40 is used for all input files using Cube special “Token” inputs in naming.



4. Select “Start” to begin model run.

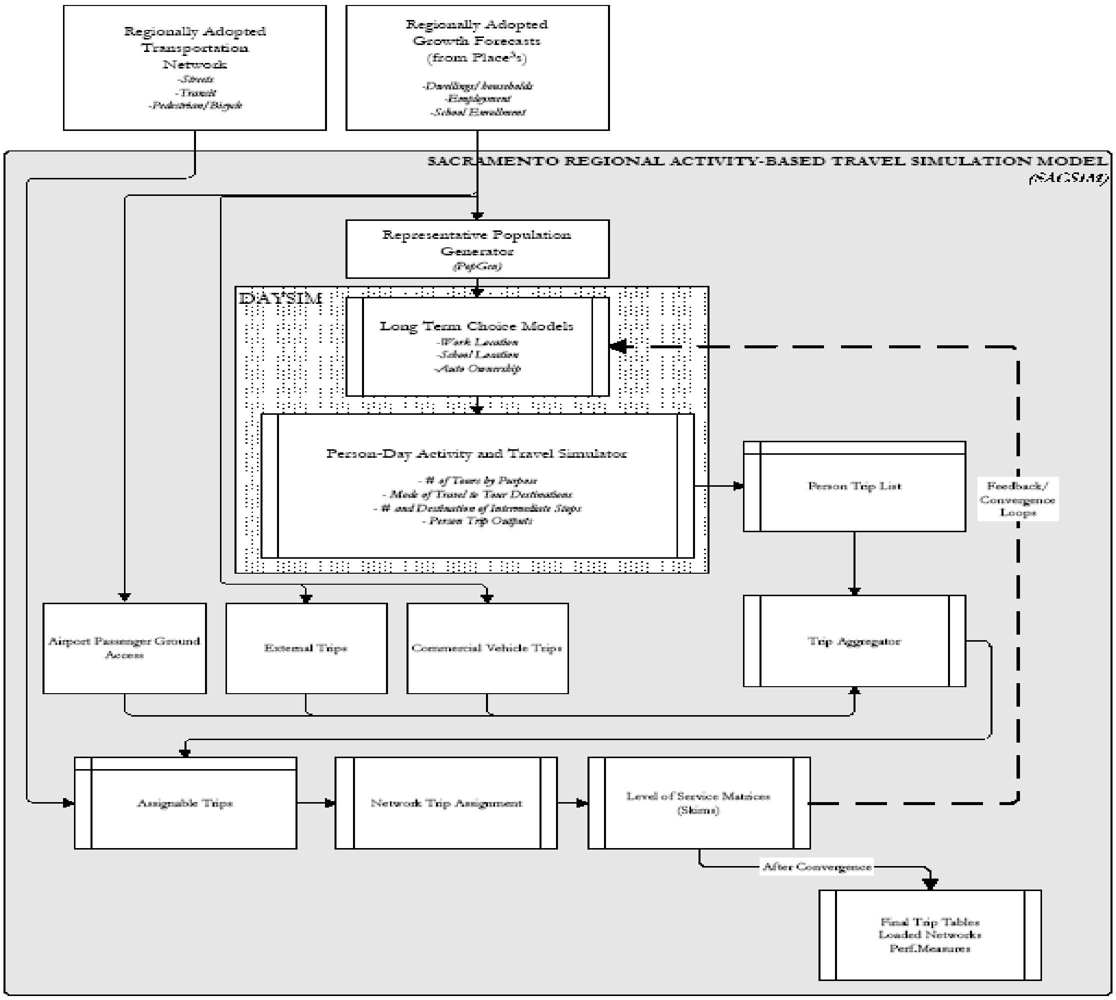


3 Model Structure

This chapter will expand upon the model concepts and parameters from Chapter 2 and describes the theory and relationships between submodels of SACSIM. The overall SACSIM model system is illustrated in Figure 3-1 below. Each submodel captures a component of travel behavior. The key submodels are:

- 3.1 DAYSIM – Person Day Activity-Based Tour Simulation Model
- 3.2 Commercial vehicle travel
- 3.3 External travel
- 3.4 Airport passenger ground access
- 3.5 Vehicle trip table preparation and assignment
- 3.6 Transit path building and assignment

Figure 3-1 SACSIM Model Structure



3.1 DAYSIM - Person Day Activity-Based Tour Simulation

DAYSIM is a regional activity-based, tour (ABT) simulator for the intra-regional travel of the region's residents only. Around the country, ABT models are increasingly used as replacements for more conventional, four-step trip models. ABT models seek to represent a person's travel as it actually occurs: in a series of trips connecting activities which a traveler needs or wants to participate in during the course of a day.

This chapter gives high level introductions about DAYSIM. Please refer to Appendix A – DAYSIM Reference Guide for details.

3.1.1 DAYSIM Terminology and Concepts

The specific definitions of *activities* and *tours* as used in this documentation are as follows:

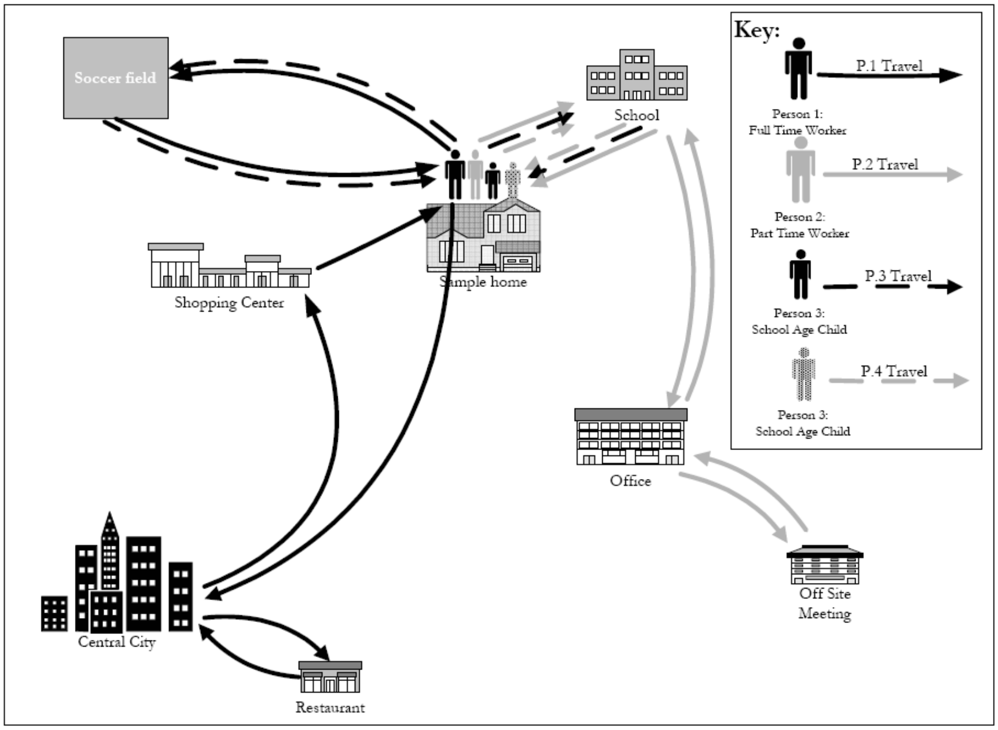
Activities are the things that people do during the course of the day, either to meet basic needs or for pleasure. The range of activities which people engage in is nearly infinite. For purposes of DAYSIM, activities are simplified into a set of seven generic categories, as follows:

- Work (full time or part time)
- School (K12, college, university, or other education)
- Personal Business (e.g. medical appointment)
- Shopping
- Meal (i.e. having a meal outside of the home)
- Social/Recreational (e.g. going to health club, visiting a friend or family member)
- Escort (i.e. accompanying another person to an activity they are engaging in, e.g. a parent driving a child to school)
- Home (any activity which takes place within the home)

Tours are series of trips which a person does from their home in order to engage in one of the above activities. A single tour is all of the activities and travel one person does between leaving home and returning home. Each person in a household may engage in one or more activities in the course of a single tour. Also, each person may make no tours (i.e. stay at home all day), or they make many tours. A tour may be very simple, consisting of as few as two trips (i.e. one trip away from home to work, for example, and a return trip home), or it may consist of many trips, with lots of intermediate stops along the way.

illustrates a typical set of activities and travel for a sample family of four. provides a tally of the trips and tours for that sample family. The sample family makes a total of 19 person trips, which are grouped into eight tours. The most complicated tour is that by Person 2, who escorted two children to school, proceeded to work, and returned to pick up children on the way home. This tour included one work-based subtour, with two trips going from work to an off-site meeting, and a return trip to work. Including the subtour, Person 2 made a total of six trips in the course of the work tour. The simplest tours include four with only two trips each, by Person 1 (escort tour for Person 3 to/from soccer), two school tours made by Persons 3 and 4, and a social/recreational tour (to/from soccer) for Person 3.

Figure 3-2 Activities and Travel for a Sample Four-Person Household



Source: SACOG 2020.

Table 3-1 Trips and Tours for Sample Four-Person Household

Trip Origin/Destination	Person Trips Person 1	Person 2	Person 3	Person 4	Description
Home to Work Work to Shopping Center Shopping Center to Home	X X X				Pers. 1: *Work Tour* with 3 trips
Work to Restaurant Restaurant to Work	X X				Pers. 1: ***Work-Based Subtour*** with 2 trips
Home to School School to Office Office to School School to Home		X X X X	X X	X X	Pers. 2: *Work Tour* with 4 trips Pers. 3, 4: ***School Tours*** with 2 trips each
Office to Off Site Meeting Off Site Meeting to Office		X X			Pers. 2: ***Work-Based Subtour*** with 2 trips
Home to Soccer Field Soccer Field to Home	X X		X X		Pers. 1: *Escort Tour* with 2 trips Pers. 3: ***Soc/Rec Tour*** with 2 trips
Person Trips Person Tours	7 3	6 2	4 2	2 1	**Household Trips: 19** **Household Tours: 8**

Key: X = Person Trip Shaded box = Tour

Source: SACOG 2020.

DAYSIM also distinguishes *long term* and *short term* choices in representing activities and travel. Long term choices are those which are taken relatively infrequently, and are unlikely to change in the course of a few months or even a year. Short term choices are those which are made quite frequently, and may vary day-to-day for most people. Again, in reality the number and range of choices which might be *long term* or *short term* in nature for any individual or household is nearly infinite. Additionally, each household makes choices on many different timeframes, not just long or short term. DAYSIM simplifies these choices to a relatively limited number:

Long term choices:

- Household automobile availability (i.e. the number of vehicle owned and available for use by a household)
- Usual work location for each worker (i.e. the location where a worker normally reports for work, for each worker)
- Usual school location (i.e. the location where a student normally goes to school, for each student)

Short term choices:

- The number and type of tours made by each person
- The main destination of each tour
- The main mode of travel for each tour
- The arrival and departure times for each activity on each tour
- The number and purpose of intermediate stops made on each tour
- The location of each intermediate stop
- The mode of travel for each trip segment on each tour
- The arrival and departure time for each intermediate activity on each tour

DAYSIM places these choices in a hierarchy, with the highest-level choices being the long term choices, and the lowest level being the short term choices.

Other DAYSIM terms are:

Locations vs. destinations— In DAYSIM, the terms location and *destination* both refer to parcels. Usually, in DAYSIM documentation, the term *location* is associated with long term choices, like usual workplace, or to intermediate stops on tours. *Destination* usually refers to the main place that a traveler chooses on any given tour. For example, the usual workplace location is the place a worker usually reports for work. However, on any given day, that worker may report to another place for their work tour destination. For most workers, the usual work location and the work tour destination on any given day are one-in-the-same.

Tour purpose—tours are "branded" by the main activity which is engaged in during the tour. Given that multiple activities of different sorts occur during some tours, this branding requires that a hierarchy of activity purposes be established, with the tour branded by the highest-level activity engaged in on the tour. Tour purposes are keyed to the seven of the eight categories of activities defined above[2], with the following hierarchy:

- Work
- School
- Escort
- Personal Business
- Shop
- Meal
- Social/Recreational

Tour destination— the parcel selected as the destination for the main activity on the tour. If there are two or more activities along the tour with the same, highest priority tour purpose, then the location of the activity with that purpose of the longest duration is designated as the tour destination, often referred to as the "primary" destination.

Half-tour—the trips from home to the primary destination of the tour, or the trips from the primary destination of the tour to home.

Person type—in reality, the variety of activities that any person engages in, and the degree to which any single activity typifies an individual, is highly complex and variable, with practically infinite possible classifications. DAYSIM uses many person and household characteristics to capture differences in activity and travel preferences. One useful composite variable used extensively to classify persons for purposes of estimating and applying the DAYSIM models is the person type:

- Full-time worker (more than 32 hours worked)
- Part-time worker (less than 32 hours worked)
- Non-worker, aged 65 years or older
- Other non-worker, non-student adult
- College/university student (full time student)
- Grade school student aged 16 years or older (i.e. driving age)
- Grade school student aged 5-15 years
- Child aged 0-4 years

[2] "Home" activities are not used for classifying tour purpose, since every tour has a home end. Tours are classified only by the non-home activities which are engaged in by the tour-maker.

Intermediate stop—places (parcels) on a half-tour where a person stops to engage in activity other than the activity at the main destination. Examples of intermediate stops in the sample household () are the stop at the shopping center on the way from work to home by Person 1.

Day pattern— The overall number of tours made by a person, the combination of purposes of those tours, and the purposes of intermediate stops on those tours, constitutes the *day pattern* for that person. Participation in tours and intermediate stops of the seven purposes is predicted for each person. This set of predictions is referred to as the day pattern. The exact numbers of stops on tours is predicted by lower level choice models.

Random seed and Monte Carlo selection process— Choice models predict probabilities of selecting each of several options, based on the characteristics of the person choosing and the relative attractiveness of the options available to that person. Aggregate models (not DAYSIM) utilize those probabilities by splitting the choices to all members of the applicable segment of the population according to the probabilities. E.g., if a mode choice model predicted a probability of 0.20 of using transit and 0.80 of using automobile for a particular segment with 100 persons, 20 of the persons would be assigned to transit and 80 to automobile. Person level simulations (including DAYSIM) require another process to allocate individuals to particular choices at the person level. In DAYSIM this is accomplished by assigning a random seed[3] to each possible outcome for each person. Monte Carlo selections are made based on the predicted probabilities and the random seed. For example, if a person's choice probability is 0.20 for the first of two possible outcomes in a choice situation, and their random seed for that choice is 0.20 or less, then the simulator assigns the first outcome to that choice for that person. This is the source of a unique characteristic of simulation models: random variation in result for exactly the same input files and processing, arising from differences in the random seeds from one run to the next. This issue will be revisited in Chapter 11 Sensitivity Tests of this report.

[3] The random seed is a real number between 0 and 1, assigned randomly to each individual in the representative population.

3.1.2 DAYSIM Structure and Flow

DAYSIM is structured as a series of hierarchical or nested choices models. The general hierarchy places the long-term models at the top of the choice hierarchy, and the short-term models at successively lower levels in the hierarchy. The detailed hierarchy and flow through the model are illustrated in Figure 3-3. Note that the general flow is down from the long-term models to the short-term models. Moving down from top to bottom, the choices from the long-term models influence or constrain choices in lower level models. For example:

- Choices of usual locations for work and school affect the choices of work and tour destinations, since the usual locations are the most likely destinations.
- Auto ownership affects both day pattern and tour (and trip) mode choice, by generating auto ownership market segments used in the model.

In addition to these direct influences, utilities from lower level models flow upward to higher level models, too. Logsums of tour destination and tour mode affect other short-term models, as well as the upper level, long-term models. Some of the logsums from lower level models are aggregated for use in the long-term models, in order to reduce the computational load of using true logsums in such a complex nesting structure. The details of the process of utilizing logsums both “upward” and “downward” in the overall model structure is described in more detail in the DAYSIM technical memoranda[4], and in other published work[5,6]. Figure 3-3 provides more detail on the upward and downward flow of logsums and other variables in the location and destination models.

[4] Technical memoranda for DAYSIM development are available at http://www.jbowman.net/.

[5] Bowman, John L. and Bradley, Mark A., “Upward Integration of Hierarchical Activity-based models or Sensitivity to Impedance and Spatial Attributes in Activity Based Models”, January 17, 2006, available at http://www.jbowman.net/.

[6] Bowman, John L., Bradley, Mark A., and Gibb, John, “The Sacramento Activity-based Travel Demand Model: Estimation and Validation Results”, presented at the 2006 European Transport Conference, September 2006, available at http://www.jbowman.net/.

Figure 3-3 DAYSIM Structure and Flow

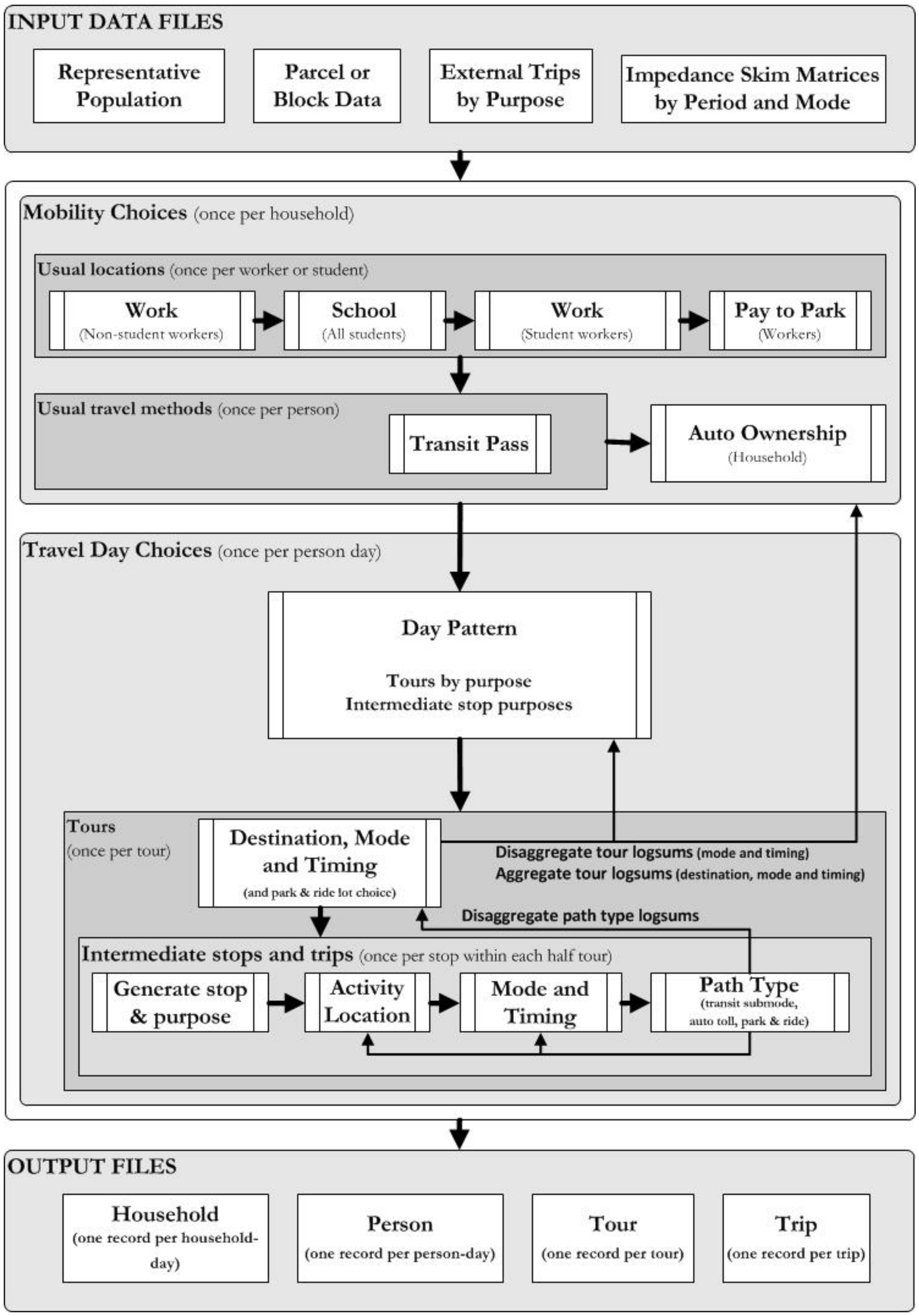


Table 3-2 Utility Function Variables in the Location Choice Models

Attributes	Models			
	Usual work location	Work tour destination	Usual school location	Non-work tour destination
Binary Choice				
Choice between…	…home vs. other	…usual vs. other	…home vs. other	n/a
Constants	By person type	By person type & tour type	By person type & HH size	
Disagg. Logsum For Usual Locations	Yes	Yes	Yes	
Conditional MNL choice among regular locations				
Disaggregate Mode Choice Logsum to Destination	Yes	Yes	Yes	Yes
Piecewise Linear Driving Distance Function	For full-time workers		For children under age 16	By Purpose Priority Pattern type
Natural Log of Driving Distance	For other then fulltime workers by person type & income	By person type & tour type	For persons age 16+ by person type & ??	By tour type, Income, person type & time available
Distance from Usual Work Location		Yes	For not-student-aged	
Distance from Usual School Location	For student-aged	For student-aged		Yes
Aggregate Mode+Dest Logsum at Destination	By person type	By person type	By person type	By purpose
Parking and Employment Mix	For daily parking in parcel and in TAZ	for daily parking in parcel and TAZ		For hourly parking in parcel and TAZ by car availability
Ratio of "Good"-to-Total Intersections	Yes	By car availability		By car availability
Employment, Enrollment and Households by Category	By person type & income	By person type & income	By person type	By purpose (and by 'kids-in-household' for escort tours)
Zonal density	Yes	Yes	Yes	Yes
Parcel size	Yes	Yes	Yes	Yes
Person Type Categories in the Models	Full-time worker Part-time worker Not full- or part-time worker	Full-time worker Part-time worker Not full- or part-time worker	Child under 5 Child 5 to 15 Child 16+ University student Not-student-aged	Full-time worker Part-time worker Retired adult Other adult Child under 5 Child 5 to 15 Child 16+ University student

Source: SACOG 2020.

3.1.2.1 Recent Major Improvements and Updates

Every component model of DAYSIM has been re-estimated using the 2008 parcel and skim data, and using the new DAYSIM estimation capabilities, described later. Two new pricing-related models have been added as well. Technical details of the models are provided in the Appendix A DAYSIM Users Guide. This section provides a high-level summary of the changes.

3.1.2.1.1 Changes to support the treatment of policy-based pricing

Before re-estimating the various DAYSIM models, several new features were added to DAYSIM to support the treatment of pricing effects in the models. Many of these were based on the research done as part of the SHRP 2 C04 project on model improvements to address pricing and congestion. These include:

Distributed value of time: Each tour simulated in DAYSIM has its own time/cost tradeoff, with the functions used to set the cost coefficient (c[i]) and time coefficient (t[i]) shown in Figure 3-4 below. The cost coefficient is based on an inverse power function of income and car occupancy, with the power exponents differing for work and non-work tours. The time coefficient also has different functions for work and non-work tours, and uses a log-normal distribution (see) to simulate random variation around the mean.

Note that this random variation in VOT is not used in model estimation, and can also be switched off by the user for model application, in which case the mean value is assumed. Also note that this value is for auto in-vehicle time. Relative values for other types of travel time can be specified by the user as part of the DAYSIM configuration (as can all of the parameters used in) and should be set so as to be consistent with the relative values of time assumed in the generation of the network skims. Within DaySim, the SOV cost coefficient and time coefficient are set once for each tour, and the resulting values of time for all modes (based on the just-mentioned configuration parameters) are used for all models associated with that tour. The VOT associated with each simulated trip is included in the Trip output file.

Figure 3-4 Functions from SHRP 2 C04 for Tour-Specific Value of Time

Work tours

c(i) = -0.15/$ / [((income(i) / 30,000) ^ 0.6) * (occupancy(i) ^ 0.8)]

t(i) = -0.030/min * draw from a log-normal distribution, with mean 1.0 and std. deviation 0.8

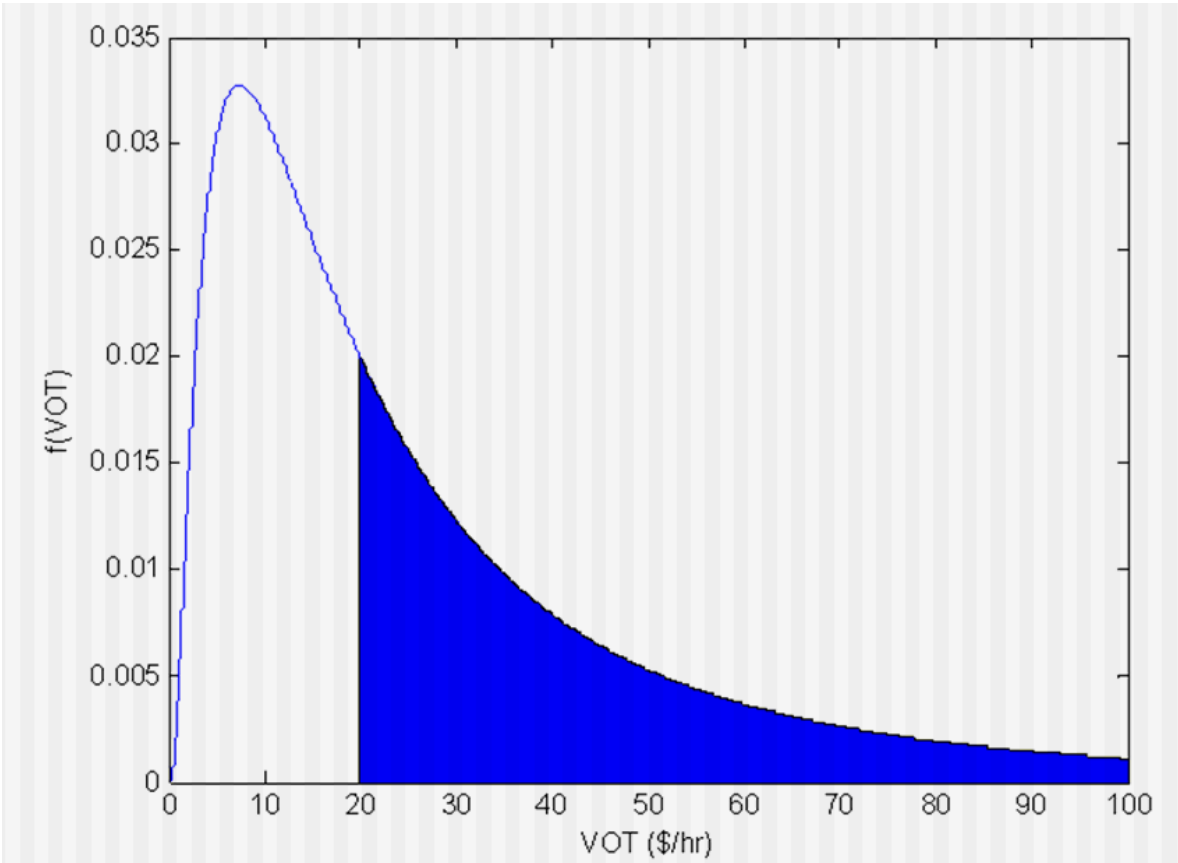
Non-work tours

c(i) = -0.15/$ / [((income(i) / 30,000) ^ 0.5) * (occupancy(i) ^ 0.7)]

t(i) = -0.015/min * draw from a log-normal distribution, with mean 1.0 and std. deviation 1.0

Source: SACOG 2020.

Figure 3-5 Shape of the log-normal probability frequency distribution



Source: SACOG 2020.

Flexibility in using impedance matrices: Another new feature of DAYSIM that supports pricing analysis is a great deal of flexibility in defining and using network impedance skim matrices. This flexibility includes:

- Matrices for a given mode can be specified for different path types. This can be used for auto (i.e. the full network versus a network that excluded tolls) and for transit (i.e. the local bus network versus a light rail network)
- Matrices for any mode can be defined to be for a specific range of VOT, allowing tours with different VOT to use different matrices reflecting differences in their "best" path. In retrieving skim values, DAYSIM uses the tour's VOT to retrieve the skim value for the correct VOT range. The endpoints of the VOT ranges are set as DAYSIM configuration parameters, and should be set to correspond consistently with the VOT assumed for each VOT-specific skim.
- Matrices can be for any minute, hour or period of the day, and these periods do not need to correspond to any fixed time periods used elsewhere in DAYSIM or in supporting trip-based models. This allows a great deal of flexibility to reflect time-of-day pricing policies.

- The same input matrix can be used to reflect multiple combinations of mode, path type, time period and VOT class, providing efficiency in memory usage and I/O.

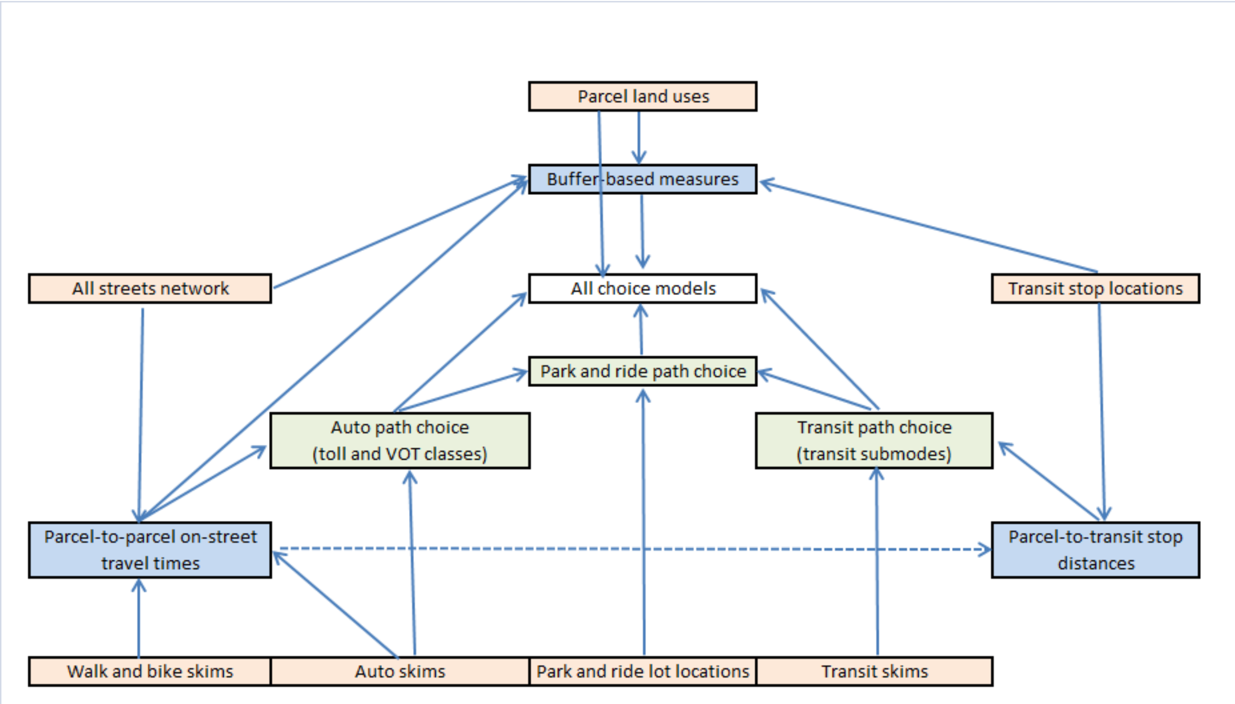
Consideration of transit fare passes and discounts: Although the transit fare values in the transit impedance skims reflect the full fare, DAYSIM no longer assumes that everyone pays that fare. Fare reduction is simulated in two ways:

- First, transit users can receive a percentage discount based on their age and student status. This is controlled via discount factors input by the user in the DAYSIM configuration.
- Also, a new Transit Pass Ownership model has been added to DaySim. This is a binary choice model predicting whether or not each person age 16+ owns a transit pass, as a function of person type, age, employment status, student status, and accessibility by transit from their home, workplace and/or school location. The user can also vary the price and price-sensitivity for transit passes via configuration inputs. If a person is predicted to own a transit pass, then their marginal fare cost for transit is 0 (100% discount factor).

The use of path type choice models for all modes: This reflects a fundamental change to how DAYSIM uses impedance information in the choice models. Figure 3-6 illustrates how all skim information works through the path type model, which performs the following functions in a consistent way:

- For a given mode/origin parcel/destination parcel/time of day, it determines if a valid path is available via one or more path types for that mode. ("Valid" meaning that there is a network path, and that the total travel time is less than a user-defined maximum.) The path can be one-way (for trip-level models) or round trip for two different times of day (for tour-level models)
- For each possible path type, a utility is determined, using the tour-specific time and cost coefficients (VOT) as well as additional time weights provided by the user.
- If one or more path types is available, a logsum across those path types is calculated and passed back for use in higher-level models such as mode choice or time of day choice.
- The travel time, cost, and distance via a chosen path type is also generated. For most uses, this is deterministic, via the path type with the best utility, although at the trip-level where the path type is predicted for the final simulated trips, a stochastic choice can be simulated instead.

Figure 3-6 Schematic of the use of path choice models to support other DAYSIM choice models



Source: SACOG 2020.

Further technical detail on the path type models is provided in the DAYSIM Users Guide. Some highlights for specific modes include:

- For bicycle, the user can define additive weights for distance on specific types of links, to calibrate the usage of different facility types.
- For auto, the user can define different VOT ranges for the skim matrices, and also specify the size of a constant term to be used for toll routes to calibrate/reflect resistance to using tolled facilities.
- For walk, bicycle, and auto, the parcel-based circuity factors are applied to get a more accurate estimate of distance and travel time for short trips, particularly intra-zonal trips for which the network skims provide little useful information.
- For transit, the user can define additive in-vehicle time weights, as well as path type-specific constants, in order to calibrate the usage of different types of transit services (as well as vary their attractiveness in higher level models such as mode choice). DAYSIM uses the tour's simulated value of time in modeling the choice of transit submode (path type).
- For transit, access and egress walk distance are determined based on parcel-specific walk distances to the nearest stops, and the user can change parameters related to the maximum walk distance and the characteristics of walking to direct paths versus paths that involve transfers.

- For park and ride, the model is similar to the transit model, but substituting drive access time for walk access at the home end. (Park and ride is always evaluated round trip, assuming the same lot on both halves of a tour.)
- For park and ride, DAYSIM will search across all park and ride lots and find the one that provides the best utility for the given O/D/mode/path type/times of day. Alternatively, the user can find the best park and ride lot node with other software outside of DAYSIM and provide a matrix of the best park and ride lot for each O/D pair.

A few more features of the path type models:

- Even if the user does not define different path types for a mode, the path type model will be used for the single, default path type in order to calculate the generalize time utility for that alternative. This ensures that the calculations are done consistently whether or not there are multiple path types available. For example, only the “full network” path type is currently available for the walk and bike modes, and this is why no “walk/bike path choice” is shown in Figure 3-6, even though those modes are also evaluated via the path type model. Furthermore, DAYSIM could be used to evaluate multiple path types even for those modes—an example would be to use completely separate bike skims for path types with and without Class 1 or 2 bike lines.
- As shown in Figure 3-6, the use of the path type model means that all DAYSIM models access and use the skim information consistently via path type choices and logsums. This also extends to the accessibility logsums used by the upper level DAYSIM models.
- The ability to do park and ride lot choice within DAYSIM is new, and more advantage of this will be taken in the future. For example, lot capacity constraint is not currently included. In future versions of DaySim, it will be possible to incorporate capacity constraint via a time of day-specific shadow-price mechanism.

3.1.2.1.2 Changes to specific DAYSIM choice models

All models were re-estimated using the new DAYSIM estimation capabilities and the new parcel data and skim data. The new model coefficients are given and annotated in the DAYSIM Users Guide. This section provides some key points for each model, starting from the “bottom” up:

Mode choice models: Mode choice models at the tour and trip levels were estimated using the logsum from the path type model for each mode as a key input. (Note: Upon first pass, this approach appears to be predicting too many long trips for walk, bike and transit, so the models will be estimated using different weights on the time component for those modes.) The use of the new parcel buffer variables also improved the land use effects on mode choice somewhat.

Time of day models: These models were also estimated (and applied) using the generalized logsums from the path type model for each time of day, rather than simply the travel time, enhancing the response to time-of-day pricing. Also, the use of time window variables and availability constraints in these models was improved to ensure that more realistic schedules are simulated.

Location choice models: The new parcel buffer variables were useful in re-estimating neighborhood effects, in combination with the size variable effects. Time window effects and availability constraints were also enhanced. Distance functions were consolidated and simplified somewhat, as recommended by the peer review panel.

Day pattern models: These include the main person-day pattern model, as well as models of the exact numbers of tours, work-based subtour generation, and intermediate stop generation. These models were re-estimated to include enhanced accessibility logsum effects via the disaggregate and aggregate logsums. Other minor changes to the specifications were carried out as well.

Vehicle availability model: The auto ownership model was re-estimated, taking advantage of new accessibility logsum variables, but otherwise the specification was not changed.

Transit pass ownership model: This is a newly-added binary choice model predicting whether or not each person age 16+ owns a transit pass, as a function of person type, age, employment status, student status, and accessibility by transit from their home, workplace and/or school location. This model was estimated using data from the Seattle (PSRC) region, since this variable was not available in the SACOG 2000 survey data.

Pay to park at workplace model: For each worker, this model predicts whether or not the person has to pay to park at/near their workplace—i.e. that they do not receive free or totally subsidized parking. It is a binary model, mainly a function of income, employment status, and the land use and parking supply around the workplace. If the model predicts that a worker does have to pay, then the parking cost at their workplace is determined by the average daily price for paid off-street parking in the (smaller) buffer around the work parcel. Otherwise, the parking cost is set at 0 (free). This model was estimated on SACOG 2000 survey data.

3.1.2.1.3 DAYSIM Software Improvements

The new software improvements have been referred to several times in the preceding sections. This final section provides a concise overview of the key improvements.

- The new code is written in C#, which is a standard language now used by software engineers for creating professional software. It is programmed in the Microsoft Visual C# integrated development environment (IDE), using 64-bit code.
- The new code was co-designed and created by RSG's top software engineers (Bryce Lovell and Leo Duran), and is maintained using state-of-the practice software version control (Subversion, with Tortoise SVN Windows interface) and project management tools (Redmine). Each revision of the code is reviewed to maintain professional standards of code legibility, efficiency, and manageability.
- The code is fully object-oriented, enhancing legibility and adaptability.
- The code uses multi-threading (parallel processing) wherever it is most efficient, making optimal use of hardware.

- The code uses advanced memory handling features, allowing most regional model systems to be run with less than 8 GB of RAM (depending mainly on the number of zones used for network skims)
- Most of the constants and parameters in the code are user-configurable, enhancing legibility of the code and avoiding the need for revising and re-compiling.
- The formats for the input and output files are now consistent, enhancing the capability to do partial runs.
- DAYSIM now includes a model estimation capability that produces data and control files that can be used “as is” to immediately estimate models using the ALOGIT software. DAYSIM also reads the coefficient files generated by ALOGIT as a result of model estimation. This has multiple advantages:
  - Ensures consistency between model estimation and application, avoiding a major source of potential bugs
  - Makes it very quick and efficient to re-estimate the models when new data becomes available or when minor changes are desired.
  - Ensures consistency across the different choice models and the way they are coded, making it easier for new users to understand different models.
- The new “skim roster” capability makes it possible (and fairly easy) to change many aspects of how the network skims are used (adding or subtracting submodes and path types, use of different VOT classes, changes in time period definitions, etc.) without needing to change or recompile the DAYSIM code.
- In addition to the above features, the new DAYSIM has maintained key distinctive features that were present in the old version:
  - The ability to work with parcel-level spatial alternatives. This is now configurable, also allowing inputs at the zone, or micro-zone (e.g. block) level.
  - A facility for synchronizing random seeds, reducing differences between runs/scenarios that is due solely to random simulation error.
  - Shadow pricing to maintain supply/demand consistency for choices of work and school locations.

3.1.2.2 Long Term Choice Models

As mentioned above, three choices are treated as long-term choice models, and are at the top level of the choice hierarchy:

- Usual work location (for workers)
- Usual school location (for students)
- Household auto availability

For persons who are both worker and student, a usual work location and a usual school location are modeled.

3.1.2.2.1 Usual Work Location Choice Model

Usual work location is the top-level model in the DAYSIM hierarchy. Except for auto ownership, logsums from lower level models influence choice; auto ownership logsum flows down to lower level models. Auto ownership is assumed to be conditioned by usual work and school locations, not the other way around. Choice sets are constrained by ratios of maximum travel times reported in the survey; alternatives which meet the time constraints are sampled for the final choice sets. In application, each choice is simulated from a sample of the available alternatives. Work-at-home utilities are determined by constants and person type.

In addition to the constraints applied to choice sets, total work location choices are constrained to TAZ-level total jobs at the work location. In application, this is accomplished by tallying the usual workplace locations to TAZ through the course of the simulation. As TAZs become “filled” they become unavailable in subsequent choices sets. This process effectively fills the equivalent of doubly constraining matrices in a gravity distribution. This accounting process is currently being replaced by a shadow price process.

Level-of-service variables are primarily home-to-work location distance, and three logsums: destination choice, mode-destination choice, and mode choice. Several parking supply and street pattern variables are included: paid, off-street parking supply (+ effect), and the “good” intersection ratio within ¼ mile (+ effect). Density variables split into two primary effects: density of service and education employment, and households (- effect); and other employment density (+ effect). Size variables enter the model at parcel level, and have similar effects by variable as density.

3.1.2.2.2 Usual School Location Choice Model

Structurally, the usual school location choice model is similar to the work location model, but with person types focused on students (K12 and college/university). Because of the strong relationship between usual school location and enrollment at the school site, and the generally shorter trip length associated with school trips, the array of land use variables is simpler compared to the work location choice model. Like work locations, alternative sampling is used in the model application.

For purposes of this model, “college/university” students are students enrolled at University of California at Davis, Sacramento State University, one of the public community colleges, or one of the private colleges or graduate schools. Students enrolled at technical or trade schools are not counted as college/university students.

3.1.2.2.3 Automobile Ownership/Availability choice model

Auto ownership here implies outright ownership, leasing, or availability of an automobile to a household for general use by other means. The submodel includes constants for ownership "choices" of no cars, one car, two cars, three cars, or four-or-more cars. Separate constants for households with one through four-plus driving age persons in the household are included. Other demographic variables relate to life cycle (e.g. presence of retired persons, school age children, or college/university students) or to household income level.

An array of accessibility and land use variables is included. Mode choice logsums to work (for workers) or to school (for students). One logsum formulation compares the mode choice logsum assuming every driver had a car, with that assuming the household owned no cars; as that difference expands (i.e. the difference between having full access to autos and no access to autos expands), the likelihood of the household owning no cars decreases. Proximity of residence to the nearest transit station or stop is included (+ for owning no cars, or for owning less than one auto per driver). The amount of accessible residential service land uses (defined as food, retail, medical, and service employment within ½ mile of the place of residence) is included (also + for owning no cars, and for owning less than one car per driver).

3.1.2.3 Short Term Choice models

Short term choice models include choices which are presumed to be more transitory in nature than usual place of work, usual school location, and auto ownership. These short term choices are: the day pattern for each person; the primary destination for each tour made; the main (but not only) mode of travel for each tour; the scheduling and timing of each activity; and subsequent choices related to the number of intermediate stops on tours, the mode of travel for each trip segment on a tour, and the timing of the trip segments. As described above, logsums from these lower level models (e.g. tour mode/destination choice, tour mode choice, etc.) are included in the upper level, long-term models. The logsums for the upper level models are also available.

3.1.2.3.1 Day Pattern and Exact Number of Tours

The day pattern consists of the number of tours of different purposes a person makes during the course of a day, plus the numbers of stops made on each tour.

The day pattern submodel consists of seven parts:

- A set of binary choices of making 0 or 1+ tours, and 0 or 1+ stops on tours, for each of the seven tour purposes.
- Constants were estimated for each of seven person types, along with additional coefficients for household composition, income, auto ownership, and land use at place of residence, and accessibility variables.
- A set of constants for predicting multiple tour+stop purpose combinations (i.e. 1 tour purpose + 1 stop purpose, 1 tour purpose + 2 stop purposes etc.).
- A set of demographic variables and accessibility variables, which affect predictions of the exact number of tour purposes and stop purposes.

- A set of constants for various combinations of multiple tour purposes and stop purposes.

The submodel shows that personal and demographic characteristics strongly influence the number and purpose of tours.

- Work tours most likely by full time workers, less likely by part-time workers, least likely by retired adults, etc.).
- Adults aged 18 to 25 are the most likely of all adults to make a school tour.
- Adults with children of school age are most likely to make escort tours, and females are more likely than males to make escort tours.
- Persons in higher income households are more likely to make tours than those in lower income households.
- Adults who are the only adult in the household are more likely to make more non-work tours.
- Accessibility variables (logsums from lower-level models like tour mode choice, and home-work intermediate stops) generally increase the likelihood of making tours.
- Mixed use density at place of residence increases the likelihood of making shop tourTour Primary Destination Submodel

Tour destination choice occurs below the usual location choices for work and school, so for workers and students (and student-workers), the usual locations of those work and school activities are already modeled. In fact, the tour destination for the majority of these persons for work and school is the usual work or school location. The work tour destination model is structured as a nested choice, with the highest level choice being the usual work location vs. other locations, with the other locations nested. No school tour destination choice submodel was estimated, since such a high percentage of students travel to the usual school location.

For non-work/non-school tour destinations, no "usual" location has been chosen at a higher level of the submodel, so tour destination choice is more complicated. The tour destination submodel includes a set of coefficients applied to logsum variables (mode choice to destination, purpose-specific aggregate mode/destination choice at destination), and other coefficients by purpose for drive distance ranges.

An array of parking supply, street pattern, and land use variables are included in the non-work/non-school submodel:

- Combination of parking and commercial employment increase the attractiveness of parcels within a TAZ.
- Street pattern (the so-called "good intersection ratio") within one-quarter mile of a destination increases is attractiveness. The street pattern variable is computed as a proportion of the 3 or 4 leg intersections, compared to all intersections within one-quarter mile.
- A large array of density and parcel size variables by different tour purposes and density is included in the submodel. The following general patterns emerge, though:
    - Some more obvious matches between land use variables and tour purposes are captured in the submodel (e.g. higher numbers of food service employees make parcels more attractive for meal tour destinations; higher numbers of K12 enrollments make parcels more attractive for escort tour destinations; etc.).

- Higher household density and higher numbers of households on parcels reduce the attractiveness of a parcel as a destination for most purposes.

3.1.2.3.2 Tour Main Mode Submodel

Tour main mode is the predominant mode chosen for making a given tour: the actual mode chosen for each segment of the tour is modeled as “trip mode” at a lower level. The relationship between tour main mode and trip mode for trips within a single tour for a given person has an analogous relationship as that between usual work and school location, and work and tour destination—the higher level choice is highly determinative of the lower level choice. That is, the predominant mode chosen for a tour is the most likely mode for each segment within that tour. The exceptions to this general pattern will be discussed below, in the trip mode choice section.

The tour main mode submodel is structured as a multinomial logit with the following eight mode options:

- Walk
- Bicycle
- Drive Alone
- Shared Ride (2 persons)
- Shared Ride (3-or-more persons)
- Walk-to-transit
- Drive-to-transit (work tours only)
- School Bus

Non-mandatory trip purposes (personal business, shop, meal, social/recreational) were combined for the mode choice estimations. Submodels were estimated for the following trip purposes:

- Work tour
- School tour
- Non-mandatory tour
- Work-based subtours

3.1.2.3.3 Work Tour Mode Choice

The estimation included a set of four generic level-of-service variables (cost, in-vehicle time, wait time, and walk and bike time). Walk or bike time for drive-to-transit, walk-to-transit, walk and bike were split out from wait time, with coefficients estimated rather than fixed.

In addition to a mode constant, drive-to-transit variables included two auto-availability variables (- for no autos, - for autos less than workers), and a ratio of drive time to total in-vehicle time (the coefficient for which is useful for weighting drive access time in transit path building). Walk-to-transit had only a constant and a dummy variable, if the closest transit stop is an LRT station (+ for walk-to-transit).

Shared ride modes included variables on numbers of persons in the household, with likelihood of choosing shared ride declining steeply if the number of persons in the household is one (for 2 person shared ride), or less than three (for 3+ person shared ride). Shared ride is also more likely for households with school age children, with fewer cars than drivers, or households with a higher share of escort stops during the course of the day.

Drive alone included variables on auto availability (- for autos less than workers), income (- for household income less than $25,000), and share of escort stops during the course of the day (- for higher share).

Bike mode is more likely for males, younger travelers (- for age greater than 50 years), and for areas with good land use mix (+ for mixed use density at place of residence). Bike mode also includes a Davis constant (+).

Walk is less likely for males, and more likely in areas with good land use mix and density at place of residence.

3.1.2.3.4 School Tour Mode Choice

Three generic level-of-service variables are included in the estimation: cost and in-vehicle time (both constrained); and combined out-of-vehicle time).

School bus mode is less likely for very young students (- for age under 5 years), and for older students (- for age 18 years and older).

Walk-to-transit mode choice includes auto availability (+ for no cars, + for fewer cars than drivers). A constrained constant is included for children under 5 years. Walk-to-transit is more likely for older students (+ for age 16 or 17 years, + for age 18 or older). Walk-to-transit is also more likely in areas with good land use mix and density.=

Auto modes (shared ride and drive alone) include the same constellation of variables used in the work submodel.

Bike mode is more likely for male students, and students 18 years or older. A Davis constant (+) is also included.

Walk mode is more likely in areas with good street pattern (+ for higher proportions of “good” intersections).

3.1.2.3.5 Escort Tour Mode Choice

The escort tour mode choice model is relatively simple, and relies primarily on personal and family composition constants and variables. Walk mode is more likely in areas with good street pattern.

3.1.2.3.6 Work-Based Subtour Mode Choice

Work-based subtours are the only non-home-based tours in DAYSIM. Work-based subtours begin and end at the place of work, while all other tours begin and end (albeit with other destinations and stops) at home. The mode of travel used to get to work is influential in determining the mode used for work-based subtours.

3.1.2.3.7 Non-Mandatory Tour Mode Choice

This submodel predicts tour mode choice for home-based personal business, shop, meal, and social/recreational tours. The submodel includes many of the same variables at seen in the other purposes. However, the street pattern and land use density and mix variables are more prevalent and significant in this model: the street pattern variable or mixed use density variable is included in walk-to-transit, bike, and walk modes.

Each alternative in the models is characterized by three separate dimensions: arrival time, departure time, and duration of stay. Constants are included for ten arrival time blocks, departure time blocks, and activity durations per purpose. The arrival and departure blocks differ by tour purpose; for example, work arrival blocks are the shortest for the normal, morning work start times, while the time blocks for the late morning and afternoon time blocks are longer.

Activity and travel scheduling models were estimated for four trip purposes (or aggregated purposes):

- Work activities and tours
- School activities and tours
- Non-mandatory activities and tours (i.e. personal business, shop, meal and social/recreational)
- Work-based subtours

An additional scheduling submodel was estimated for intermediate stops. For intermediate stops, the departure time is fixed for stops on the outbound half tour, so those observations only contribute to the constants for arrival time and duration, and the arrival time is fixed for stops on the return half tour, so those observations only contribute to the constants for departure time and duration.

In addition to the time block constants, the submodels included various other variables, described below.

> *"Shift" variables by person type*--These variables effectively adjust the time block constants for arrival or duration by person type. For example, part time workers and student workers tend to start work activities later than full time workers—the shift constant for arrival time for part time workers is positive, indicating later arrivals. Negative-sign shift coefficients arrive earlier, or participate in the activity for a shorter duration, than other person types; positive-sign shift coefficient arrive later or participate longer.

"Shift" variables by tour complexity--Some shift variables account for complexity of tours, either by quantifying the numbers of stops for tours of different types, or the number of tours.

Income variables--Lower income workers tend to work for shorter durations, and higher income workers, longer.

Purpose specific variables--Especially for the non-mandatory purpose submodel, arrival and duration shift variables are included to differentiate the differences in each purpose.

Time pressure/constraint variables--Several variables were used to represent the constraints imposed on scheduling by inclusion of longer activities in a daily pattern, or by overall schedule complexity (number of tours, number of stops on tours):

- Duration of the adjacent empty window before period starts
- Duration of the maximum consecutive empty window before the period starts
- Total duration of all empty windows in the day before the period starts
- Duration of the adjacent empty window after the period ends
- Duration of the maximum consecutive empty window after the period ends
- Total duration of all empty windows in the day after the period ends

Level of Service and Congestion Variables--Auto and transit travel time enters the model, along with the time spent in severe congestion. Note that for purposes of the estimation, the marginal skims for the i-j TAZ interchange was used, not any actual surveyed information about the path actually taken for the trip.

Major effects captured in the models are as follows:

Work activities and tours:

- Lower income workers tend to have shorter duration activities, and higher income workers, longer activities.
- The more work-based subtours that are part of the tour, the longer the total duration of the work activity (including the subtour).
- Making more intermediate stops to/from primary destination reduces time spent at primary activity.
- Workers with 2+ tours to schedule will tend to try to leave a large consecutive block of time rather than two or more smaller blocks.
- For both AM and PM, the tendency is to move the work activity earlier as the time in very congested conditions increases.
- School activities and tours.
- Many time pressure/constraint effects are similar to work activities and tours.

Non-mandatory activities and tours:

- Relative to personal-business activities, people tend to arrive earlier for escort activities and later for shopping, meal and social/recreation activities.
- Escort and shopping activities also tend to be much shorter in duration, while social/recreation activities are much longer.

- Escort and shopping activities are likely to last less than an hour, and shopping and meal activities are likely to last 1-2 hours.
- Shopping activities are unlikely to begin before 7 AM or end after 9 PM. Meal activities are also unlikely to end after 9 PM.
- Escort activities are relatively likely to end after 9 PM.
- Time pressure/constraint effects are similar to those found for work and school tours. The main difference is that the overall time pressure effect is stronger, but the other effects are weaker, and there is evidence that people will try to space tours more evenly in the day.
- The PM peak was found to shift both earlier and later with high congestion.

Work-based activities and tours:

- Relative to work-related activities on subtours, escort, meal and shopping activities tend to start later and be of shorter duration.
- Social/recreation activities also tend to start later, while personal business activities are also of shorter duration.
- People try to leave consecutive windows both before and after the tour, meaning a tendency to “center” the subtour during the duration of the work activity.
- Intermediate stop activities and tours
- Compared to work-related activities, stops for escort, shopping, meal, and personal business activities all tend to be of shorter duration.
- Escort, shopping, social/recreation and personal business stops also tend to be somewhat later in the day. These results are very similar to those in the work-based subtour model.

Stops will tend to be shorter when there are more tours to be scheduled in the day, and also when are there more stops to be scheduled on the half tour.

3.2 Commercial Vehicle Travel

The commercial vehicle trip generation and distribution models maintain a standard "four-step" or "trip-based" model system approach. These models create trip matrices in two trip categories: 2 axle commercial vehicle trips, and 3+ axle commercial vehicle trips.

Commercial vehicle trip rates based on surveys of commercial vehicles in the Sacramento region[7], and surveys of commercial vehicle trip generation from the San Francisco Bay Area. Trip rates are shown in Table 3-3. Because of the relatively sparse data available for commercial vehicles, no "production/attraction" distinction is made.

Friction factors for 3-axle commercial vehicle trips were taken from the *Quick Response Freight Manual*[8]. For 2-axle trucks, 3+ commercial vehicle friction factors were derived from the Chicago Area Transportation Study factors, which compared reasonably well with the available local data. Friction factors are shown in Figure 3-7. Trip distribution was calculated using congested midday travel times, using a simple gravity model.

Because no "production/attraction" distinction is made in trip generation, all trip interchanges by time period are forced to be symmetrical in SACSIM, and time-of-travel proportions are applied as flat factors. Table 3-4 shows the time-of-travel factors used.

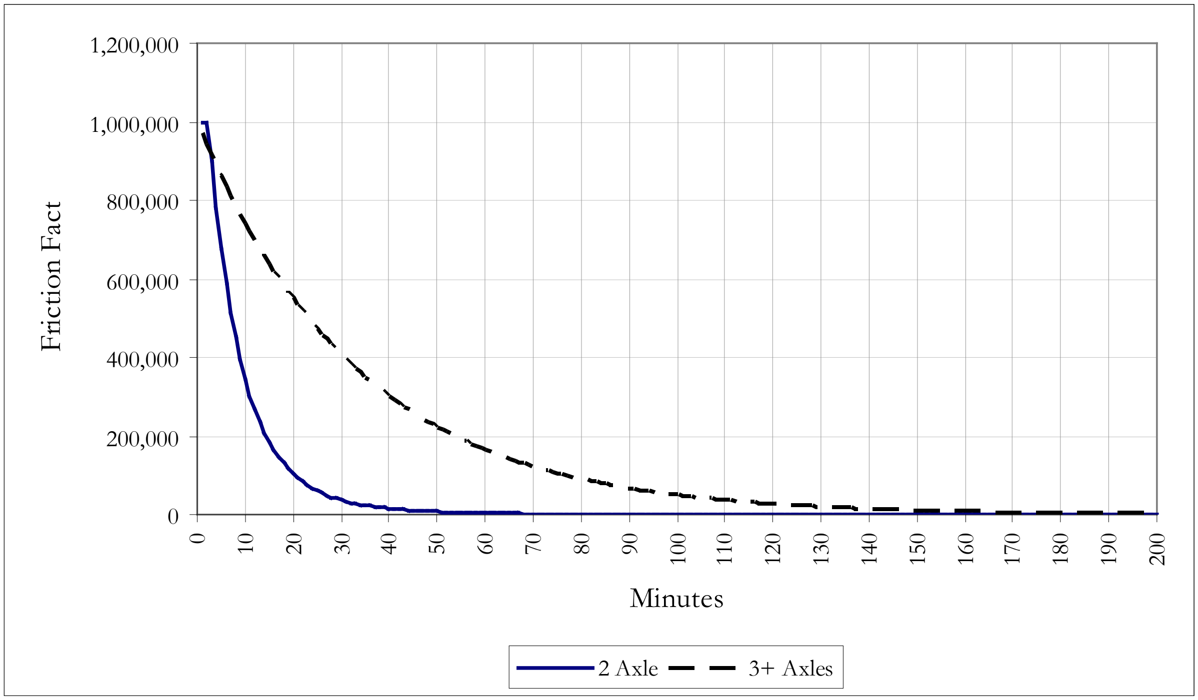
Table 3-3 Commercial Vehicle Trip Rates

Variable	2-Axles	3+ Axles
Household		
Single Family	0.28	0.003
MF 2-4	0.23	0.003
MF 5+	0.17	0.003
Employment		
Retail	0.68	0.045
Office	0.4	0.057
Medical	0.4	0.057
Education	0.4	0.057
Manufacture/Other	0.4	0.11
Source: SACOG 2020.		

[7] SACOG, "Commercial Vehicle Activity Survey Report: Phase One Project Report", July 23, 1998.

[8] FHWA (by Cambridge Systematics), "Quick Response Freight Manual", September 1996.

Figure 3-7 SACSIM Commercial Vehicle Friction Factors



Source: SACOG 2020.

Table 3-4 SACSIM Commercial Vehicle Times-of-Travel

SACSIM Time Period	2 Axle	3+ Axle
AM Hour 7:00-7:59	8%	10%
AM Hour 8:00-8:59	8%	10%
AM Hour 9:00-9:59	4%	3%
Midday (10:00-14:59)	38%	30%
PM Hour (15:00-15:59)	5%	3%
PM Hour (16:00-16:59)	5%	3%
PM Hour (17:00-17:59)	5%	3%
Evening (18:00-19:59)	9%	12%
Night (20:00-6:59)	21%	27%

Source: SACOG 2020.

3.3 External Travel

DAYSIM simulates the activities of households located within the Sacramento region, for their travel ***within the region***. The activities simulated must also be located within the region, since the simulation uses employment and travel data available only within the region. The submodels and processes described here predict the trips entering and exiting the region, which must be included for complete traffic prediction. DAYSIM also uses the predicted external trips to adjust its own predictions to account for external travel, including regional residents who may work or do other activities outside the region, as well as the effect of outside residents who take jobs within the region. These submodels and processes are based on customary aggregate trip generation and distribution models, producing person- and vehicle-trip matrices, at a traffic analysis zone (TAZ) level, not parcel.

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

- *Gateways*--TAZ's representing the areas outside of the SACOG region, connected to highways exiting or entering the region are called "gateways". Typically, each exiting highway is represented as a gateway TAZ, but some groups of highways that converge to practically the same external place share a single TAZ. Table 3-5 lists the SACSIM gateways. Important to note, SACSIM gateways representing roadways outside the region.
- *Gateway Production*--Source of travel demand located outside the SACOG region, but with travel taking it into the region. A household located outside the region, but with household members traveling to the SACOG region to work, shop, etc., would generate some number of gateway productions, which would be located at the gateway zone through which they entered or exited the region.
- *Gateway Attraction*—A location outside the SACOG region, but visited by a SACOG resident for work, shop, etc. would generate some number of gateway attractions, which would be located at the gateway through which the resident exited and re-entered the region.
- *Internal-Internal (I-I)Trips*--Describes trips which have both origin and destination within the region. All household based I-I trips are modeled by DAYSIM (for most normal household activities), and the internal passenger portion of the airport passenger ground access submodel. The commercial vehicle submodel includes the I-I truck trips.
- *Internal-External (I-X) Trips*--Describes a trip which is produced within the region, and attracted to a location outside the region, regardless of the actual direction of travel. A tour (round trip) of an area resident to San Francisco and back is considered two I-X trips. Full understanding of this concept of directionality of trip requires understanding of the difference between a "production" end of a trip, and the "attraction" end of the trip:
    - For all home-based trips, the production end of the trip is the home end. E.g., for a commute trip, the worker's home is the production end.
    - For all home-based trips, the attraction end of the trip is the non-home end. E.g., for a commute trip, the worker's place of work is the attraction end.
    - For non-home-based trips, the difference between production and attraction is somewhat arbitrary, and is assigned by convention. E.g., for work-based trips, the work end of the trip is designated the production, and the other end is the attraction.

- *External-Internal (X-I) Trips--D*escribes a trip produced outside the SACOG region, and attracted within the region, regardless of the actual direction of travel.
- *Through (X-X)Trips*--A trip entering the region through one gateway, passing through the region without stopping, and exiting through another gateway is an X-X trip.
- *Trip Purposes*--External trips are processed in five trip purposes, corresponding to the activities judged most productive of external travel: Work (or worker-flow), personal business, shopping, social-recreational, and airport passenger ground access. Other trip purposes used in DAYSIM (school, escort, and meal activities) are omitted.

All external travel is exogenous (i.e. determined outside the context of the model, and manually set by SACOG as a fixed scenario variable for both the base year and the forecast years) to some degree. I-X and X-I travel is "semi-exogenous", in that the external gateway levels of activity are exogenously set, but the internal levels and locations of activity are modeled to some degree along with other internal activities. X-X travel is exogenous, outside of vehicle trip assignment, where the impact of through trips on capacity affect the level-of-service for internally modeled trips, and I-X and X-I trips.

Table 3-5 SACSIM Gateways

TAZ[1] No.	Gateway Roadway	Segment	Gateway Representation
1	SR-99 N	Sutter-Butte CL	Chico/Butte Co., via SR 99
2	SR-70 N	Yuba-Butte CL	Chico/Butte Co., via SR 70
3	E20/Marysville Rd NE	W. of SR 49/Yuba-Nevada CL	Nevada Co., via Marysville Rd.
4	SR-20 NE	Yuba-Nevada CL	Nevada Co., via SR 20 (from Yuba Co.)
5	SR-49 NE	Placer-Nevada CL	Nevada Co., via SR 49 (from Placer Co.)
6	I-80 NE	E. of Yuba Gap	North Lake Tahoe Basin to east of region, via I-80
7	SR 174 NE	Placer-Nevada CL	Nevada Co., via SR 174 (from Colfax)
8	SR 20 NE	Placer-Nevada CL	Nevada Co., via SR 20 (from Placer Co.)
9	Omo Ranch Road E	N. of SR-88	Amador Co., via Omo Ranch Rd (from S. Central El Dorado Co.)
10	US-50 E	Btwn. Ice House Rd & Echo Lake	South Lake Tahoe Basin, via US50
13	SR 16, 49 East	Sacramento-Amador CL	Amador Co., via SR 16 and 49
15	SR-99 S	Sacramento-San Joaquin CL	San Joaquin Co. and Central Valley, via SR 99
16	Lincoln Road S	Sacramento-San Joaquin CL	San Joaquin Co., via Lincoln Rd.
17	Franklin Road S	Sacramento-San Joaquin CL	San Joaquin Co., via Franklin Rd.
18	I-5 S	Sacramento-San Joaquin CL	San Joaquin Co. and Central Valley, via I-5
19	SR-160 S	S. of SR-12	E.Solano Co., N.Contra Costa Co., N.San Joaquin Co.
20	CR-95A	Yolo-Solano CL	N.Solano Co.
21	CR-104/Mace Blvd. SW	S. of CR-32D/Montgomery	N.Solano Co.
22	I-80 W./I-505 S.	W. of I-505	Solano Co. and Greater SF Bay Area
23	SR-128 W	Yolo-Solano CL	Solano and Napa Counties
24	Putah Creek Rd. W	W. of Winters Rd. Bridge	N.Solano Co.
25	SR-12 SE	E. of SR-160	NW.San Joaquin Co.
26	SR-12 SW	W. of SR-160	E.Solano Co.
27	SR 16	Yolo-Colusa CL	Colusa and Lake Co.
28	I-5 N	Yolo-Colusa CL	Colusa Co. and N.Sacramento Valley, Redding etc. via I-5
29	SR 45	Sutter-Colusa CL	Colusa Co.
30	SR-20 NW	Sutter-Colusa CL	Colusa Co. and N.Sacramento Valley, Redding etc., via SR 20

1. TAZs 11,12,14 are currently left blank and not used.

Source: SACOG 2020.

Trip Generation for I-X and X-I Travel

Trip generation of the gateway TAZs is an exogenous input consisting of person trips for gateway productions (i.e. trips produced outside the region, but traveling to attractions within the region) and for gateway attractions (i.e. trips produced within the region, but attracted to locations outside the region, as represented by the gateway zones). External trip purposes are:

- Work
- Personal Business
- Shopping
- Social-Recreational
- Commercial Vehicle (2 Axle)
- Commercial Vehicle (3+ Axle)
- Airport Passenger

Table 3-6 and Table 3-7 provide the exogenously set worker flow, home-based non-work and commercial vehicle trip ends. The worker flows, home-based non-work and commercial vehicle trips were based off previous version of SACSIM. The file was originated by using Census Journey-to-Work statistics (to set worker flows at each gateway), Caltrans truck volume counts (to set commercial vehicle volumes), with the other trip purposes set as "residuals" which made up the difference between the observed vehicle volumes at each gateway and that portion of the vehicle volume accounted for by worker flows and commercial vehicles. Home-based school trips, escort and meal trips are such a small part of gateway travel that they are omitted in SACSIM.

Table 3-6 SACSIM19 Year 2016 External Gateway Demand (Part 1 of 2)

Gate-way No.	Gateway Desc.	Worker Flows X-I (P's)	Worker Flows I-X (A's)	Pers.Bus. Trip Ends X-I (P's)	Pers.Bus. Trip Ends I-X (A's)	Shop Trip Ends X-I (P's)	Shop Trip Ends I-X (A's)	Soc./Rec. Trip Ends X-I (P's)	Soc./Rec. Trip Ends I-X (A's)
1	SR-99 N	1,792	2,422	2,005	1,337	2,415	1,610	2,415	1,610
2	SR-70 N	1,467	1981	1,632	1,632	1,010	1515	2,070	1,380
3	E20/Marysville Rd NE	0	0	125	125	125	125	125	125
4	SR-20 NE	0	0	1027	1,027	303	708	1,172	502
5	SR-49 NE	4,345	5,992	3,116	3,116	3,116	3,116	3,116	3,116
6	I-80 NE	1380	1,902	1,862	1,862	3,944	1,690	1,602	3,738
7	SR 174 NE	483	666	615	615	615	615	615	615
8	SR 20 NE	0	0	431	431	374	374	492	738
9	Omo Ranch Road E	0	0	255	255	255	255	255	255
10	US-50 E	690	951	1128	1,128	588	1,371	967	2,256
13	SR 16, 49 East	622	1,380	1,262	1,262	1,619	1,619	1,574	1,574
15	SR-99 S	7,200	6,986	5,242	5,242	6,889	10,334	6,028	11,195
16	Lincoln Road S	720	699	677	677	677	677	677	677
17	Franklin Road S	0	0	167	167	167	167	167	167
18	I-5 S	5,039	4,890	5,289	3,526	9,437	4,044	3,526	5,289
19	SR-160 S	1,440	1,397	985	985	985	985	985	985
20	CR-95A	0	0	76	76	58	134	78	78
21	CR-104/Mace Bl. SW	0	0	246	246	246	246	246	246
22	I-80 W	37,649	22,837	12,783	12,783	18,609	18,609	17,152	17,152
23	SR-128 W	0	0	268	268	430	107	368	859
24	Putah Creek Rd. W	0	0	28	28	28	28	43	43
25	SR-12 SE	0	0	313	580	395	734	461	461
26	SR-12 SW	768	466	1271	1271	1230	1230	1554	1554
27	SR 16	0	0	83	45	110	74	78	116
28	I-5 N	1,219	1,352	2,595	1,730	3,285	1408	1,612	1,612
29	SR 45	0	0	119	119	129	129	89	89
30	SR-20 NW	25	28	976	976	1,059	1059	728	728

Source: SACOG 2020.

Table 3-7 SACSIM19 Year 2016 External Gateway (Part 2 of 2)

RAD	Gateway No. / TAZ	Gateway Desc.	Commercial Vehicle Trip Ends	
			2 Axle	3+ Axle
97	1	SR-99 N	194	472
97	2	SR-70 N	214	382
97	3	E20/Marysville Rd NE	50	25
97	4	SR-20 NE	1260	1030
97	5	SR-49 NE	1370	835
97	6	I-80 NE	2,022	2,286
97	7	SR 174 NE	64	182
97	8	SR 20 NE	160	180
97	9	Omo Ranch Road E	168	284
97	10	US-50 E	420	310
97	13	SR 16, 49 East	438	444
97	15	SR-99 S	684	4667
97	16	Lincoln Road S	0	0
97	17	Franklin Road S	0	0
97	18	I-5 S	460	5,005
97	19	SR-160 S	252	476
97	20	CR-95A	0	0
97	21	CR-104/Mace Blvd. SW	0	0
97	22	I-80 W	3,826	2,538
97	23	SR-128 W	100	50
97	24	Putah Creek Rd. W	0	0
97	25	SR-12 SE	356	528
97	26	SR-12 SW	456	478
97	27	SR 16	24	62
97	28	I-5 N	2,688	3,419
97	29	SR 45	26	113
97	30	SR-20 NW	622	311

Source: SACOG 2020.

3.3.1 Internal Trip Generation for External Work Travel Model

The internal productions are employed residents who work outside the region. These are computed from the household marginals database, counting 1 employed resident per 1-worker household, 2 per 2-worker household, and 3.5 per household with 3 or more workers. The internal attractions are jobs held by workers residing outside the region, aggregated into zones (TAZs) from the parcel database. Both internal productions and attractions are scaled in total to balance to the external productions and attractions in the gateway file described above and shown in Table 3-8 and Table 3-9.

3.3.2 Internal Trip Generation for External Non-Work Travel Model

As discussed below, the non-work external trip distribution model only distributes I-X and X-I trips; only the gateways have "trip generation" in the customary sense. But the probability that a gateway trip is distributed to a particular internal zone is based on both its proximity to the gateway, and to a composite measure of the zone's "size". This composite measure of size is the exponentiated "size variables" coefficients, times the size function scale. Since the composite size function is not used as a number of trips or other constraint, its scale is arbitrary. The actual number of external trips distributed to any given zone is not known until external distribution, since that would depend on proximity to gateways.

3.3.3 Internal Trip Generation for Commercial and Airport Passenger Trips

Commercial vehicle trip generation (and distribution) is fundamentally different than home-based travel in SACSIM, since the submodel is entirely independent of DAYSIM. Exogenous gateway trips are appended to the internally generated trip ends, as described in the previous chapter. Airport passenger trips from the external gateways do not require internal attractions, since the airport is the sole generator of the trips.

Table 3-8 Relative Attraction Rates for External Trip Distribution

Size Variable	Measure	Personal Business	Shopping	Social-Recreational
Educational	employment	0.260	0	0.213
Restaurant	employment	0.107	0.136	0.351
Government	employment	0.286	0	0.112
Office	employment	0.324	0.022	0.146
Other	employment	0	0	0.095
Retail	employment	0.244	1.000	0.142
Service	employment	0.538	0.088	1.000
Medical	employment	1.000	0	0.467
Industrial	employment	0.063	0	0
Households	households	0.035	0	0.092
University	enrollment	0	0	0.266
K-12 School	enrollment	0.113	0	0.173

Source: Bowman and Bradley, SACSIM Technical Memo 8, Usual Location and Tour Destination Models, 2005

3.3.4 Trip Distribution for I-X and X-I Travel

SACSIM calculates a doubly-constrained zone-to-zone gravity model of worker flows, including I-I, I-X, and X-I trips (but not through trips). The I-I trips are then disregarded, and the I-X and X-I trips retained. Additionally, the I-X and X-I worker flows deduct from the parcel files (for internal attractions—jobs) and from the representative population file (for internal productions—workers).

Since DAYSIM's non-work destination choice models do not constrain the numbers of trips attracted to activities, a singly-constrained distribution model is applicable for external trips. For I-X trips, the gateway attractions are constrained, since they are derived from gateway traffic counts or forecasts and any available interregional travel surveys. There is no constraint on the amount or percentage of trips produced by internal zones to go to external attractions. For X-I trips, the gateway productions are constrained, and there is no constraint on the internal zones' trips that go external. For each trip purpose, I-X and X-I trips are distributed separately. Attraction rates for this process are shown in Table 3-8.

3.3.5 Friction Factors and Deterrence for Work Trips

The deterrence function for worker flows was estimated by iteratively fitting trip length frequency of observed home-based work trips in the 2000 household survey. After applying the gravity model with a previous estimate of the deterrence function, a new one is first numerically estimated by multiplying values at each trip length increment by the ratio of observed to modeled trip frequency. Then the parameters of a rational function (quotient of two polynomials) are estimated to best fit the numerical function to a log-likelihood objective (analogous to that used to fit logit choice models). After iterating this fitting procedure until reasonable convergence, this function is obtained:

$$f(t) = \exp\left(\frac{-0.00421t^3 - 0.106t^2 + 0.201t}{1 + 0.0425t^2} \right)$$

This function is applied as a lookup table in file “sacfftpp.txt,” rather than coded algebraically.

3.3.6 Friction Factors and Deterrence for Non-Work Purposes

The deterrence function for non-work trips is a composite from parameters in the tour-destination and mode choice models, as listed below in Table 3-9 and Table 3-10.

The deterrence function is the exponential of a parameter times the travel time, in the manner of a logit choice model. The composite parameters are calculated from the above parameters (and an assumption of 50 mph speed). The deterrence function is shown in Table 3-10.

Table 3-9 DAYSIM Factors Utilized for External Trip Deterrence

Parameter	Personal Business	Shop	Social-Recreation
Non-Work Non-School Tour Destination			
Mode Choice Logsum	1	1	1
1-way drive distance, 10+ miles (10s of mi)	-0.7635	-0.8238	-0.4468
Aggregate mode-dest. LogSum at dest.	0.0206	0.1892	n/a
Home-Based Other Tour Mode Choice			
In-vehicle time (min)	-0.025	-0.025	-0.025
Mode nesting parameter	0.73	0.73	0.73
Simplified Mode Choice for Calculating Aggregate Logsums			
In-vehicle time (min)	-0.02	-0.025	n/a

Source: SACOG 2020.
Based on Bowman, John L. and Bradley, Mark A. "Technical Memorandum Number 8: Usual Location and Tour Destination Models", October 28, 2005, and on draft documentation provided by DKS Associates.

Table 3-10 Computation of External Deterrence Factors

Personal Business: -0.0823 = -0.025*0.73 + -0.7635/10mi * 50mi/60min + -0.020*0.0206
Shop -0.0916 = -0.025*0.73 + -0.8238/10mi * 50mi/60min + -0.025*0.1892
Social-Recreational -0.0555 = -0.025*0.73 + -0.4468/10mi * 50mi/60min
Source: SACOG 2020. Based on draft documentation provided by DKS Associates.

3.3.7 Trip Distribution for I-X and X-I Commercial Vehicle and Airport Trips

Commercial vehicle trips are generated and distributed independent of DAYSIM. Trip distribution for all trips is treated through a gravity model as described in the previous chapter. Airport trip distribution is trivial, because of all external airport passenger trips that are to or from the airport.

3.3.8 Mode Split and Time-of-Travel for I-X and X-I Travel

External trips are allocated to vehicle trip modes using flat person-to-vehicle trip factors. The factors are shown in Table 3-11.

Time-of-travel for I-X and X-I trips were also allocated to the nice time periods using fixed factors. Table 3-12 shows the factors used.

Table 3-11 Mode Split Factors for I-X and X-I Travel

Purpose	Mode			
Household-Generated Travel[1]				
	Drive Alone	2 Person Carpool	3+ Person Carpool	Total
Work	89.0%	8.5%	2.5%	100.0%
Personal Business	54.0%	29.0%	17.0%	100.0%
Shop	45.0%	40.0%	15.0%	100.0%
Social Recreational	29.0%	31.0%	40.0%	100.0%
Airport Passenger Ground Access[2]				
	Drive/Park	Drop Off	Van/Shuttle	Total
Airport	50.3%	43.9%	5.8%	100.0%

Source: SACOG 2020.

[1] Based on 2000 SACOG Household Survey data, adapted to SACSIM11 external trip purposed by DKS Associates.

[2] Based on 2002 airport passenger survey, adapted to external passengers by SACOG.

Table 3-12 Time-of-Travel for I-X and X-I Travel

	Purpose									
	Production > Attraction					Attraction > Production				
Demand Time Period	Pers. Bus.	Shopping	Soc./ Rec.	Work	Airport	Pers. Bus.	Shopping	Soc./ Rec.	Work	Airport
AM 7-8	4.2%	2.0%	2.8%	13.8%	3.0%	0.2%	0.1%	0.2%	0.2%	0.3%
AM 8-9	6.6%	2.0%	3.3%	7.8%	2.7%	0.1%	0.3%	0.1%	0.3%	2.0%
AM 9-10	7.8%	4.0%	2.5%	2.9%	4.7%	0.7%	0.3%	0.6%	0.3%	3.0%
MD 10-15	24.6%	19.5%	14.0%	3.7%	15.6%	12.9%	12.4%	6.1%	2.8%	16.1%
PM 15-16	2.3%	3.7%	2.9%	0.4%	2.7%	3.5%	7.9%	2.2%	3.3%	2.7%
PM 16-17	2.3%	3.6%	3.0%	0.5%	3.0%	5.0%	7.2%	3.7%	5.9%	2.7%
PM 17-18	2.7%	3.6%	5.4%	0.5%	2.4%	5.5%	8.2%	4.2%	12.9%	3.4%
EV 18-20	2.0%	2.0%	10.3%	0.4%	5.1%	7.8%	12.5%	7.8%	19.4%	6.0%
NI 20-6	3.9%	2.6%	5.4%	18.3%	10.9%	7.9%	8.0%	25.6%	6.5%	14.0%

Source: SACOG 2020.

3.3.9 Through Trips for X-X Travel

Through trips are a completely exogenous model input, which are read in directly from a prepared through trips file. A portion of gateway trips are assigned to though travel, meaning vehicles that start from and end outside of the SACOG region (XX). Caltrans 2016 3+ Axle and 2+ Axle truck volumes, total vehicle traffic counts at each gateway, and CTPP county to county worker flows are all used to estimate both the passenger vehicle and commercial vehicle through travel model input file.

3.4 Airport Passenger Ground Access Model

3.4.1 Introduction

The airport passenger ground access model is actually a system of models of trip generation, trip distribution, and mode choice, which forecasts auto, transit, taxi, and shuttle van travel of air travel passengers using Sacramento International Airport, as well as return trips for picked-up and dropped-off passengers. The model also includes as an exogenous input estimates of passengers traveling to the airport from origins outside the SACOG region. The model does not include travel by employees of the airport, or airport-using or airport-serving businesses, which are represented by DAYSIM and commercial vehicle models.

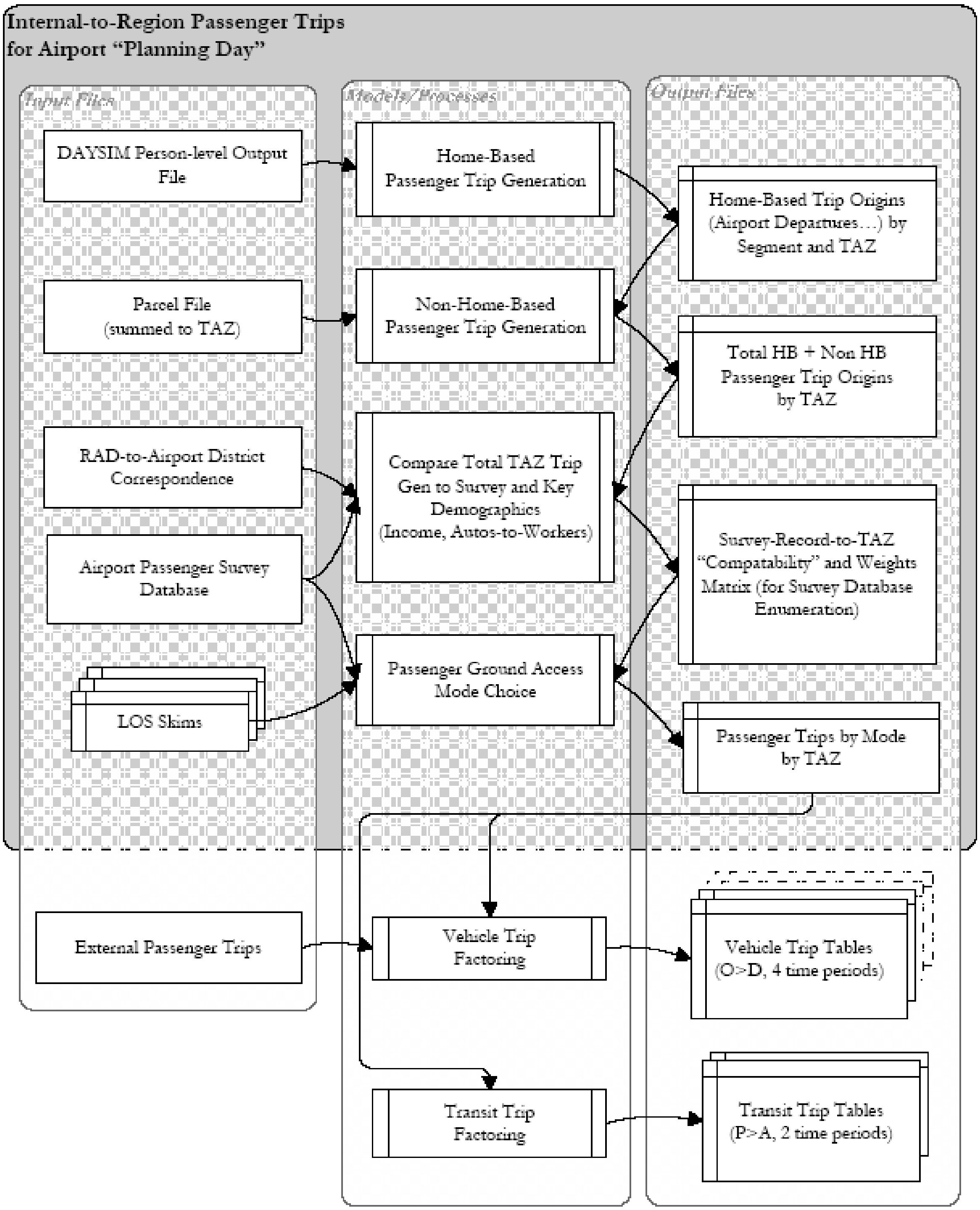
This airport trip model application consists of five main components:

- Trip generation for SACOG (internal) passengers;
- Association of generated trips to representative survey trips, for use in computing survey expansion factors for internal passengers;
- Mode choice for internal passengers;
- Direct estimate of external (i.e. outside SACOG) passengers;
- Time-of-travel and vehicle trip factoring for auto mode trips; and
- Time-of-travel and person trip factoring for transit trips.

The airport passenger ground access model is calibrated to represent activity for a “planning day” at the airport, which is defined as an average day from the peak month of passenger activity at the airport[9]. Figure 3-8 illustrates the major model components and flow.

[9] PB Aviation, “Sacramento International Airport Master Plan Study”, March 8, 2001.

Figure 3-8 Airport Passenger Ground Access Model



Source: SACOG 2020, based on work by DKS Associates (2008).

3.4.2 Trip Generation for Internal Passengers

SACSIM airport internal passenger trip generation was initially built from findings from the Downtown-Natomas Airport Study, 2003 (DNA). The DNA corridor analysis did not directly use trip generation by each model zone (TAZ). Instead, it used survey observation data, with each record's weight factor "grown" proportionally to the aggregate trip generation in its RAD (Regional Analysis District, of which there are approximately 58 in the Sacramento region). This approach was modified for use in SACSIM, to allow for "on-the-fly" enumeration of the survey based on the population and employment in each TAZ.

This application uses the same trip generation factors for non-home-based trips: 0.006 per non-retail employee, except the Downtown Sacramento RAD, with 0.010 per non-retail employee.

But for home-based trips, trip generation factors are applied to household segmentations by income as shown in Table 3-13:

Table 3-13 Home-Based Airport Trip Generation based on Household Income (Enplaning Airport Passengers)

Household Income (c.2000 dollars)	Estimated Enplaning Passengers per Household
Under $15k	0.0060
$15k to 35k	0.0068
$35k to 50k	0.0133
$50k to 75k	0.0156
$75k or more	0.0269

Source: SACOG 2020.

Home-based trip generation rates apply to five household income strata as described above. These generated trips are then saved in four household categories used by the mode choice model, which can be considered a two-dimensional array of (1) whether the household income is over $50,000, and (2) whether there are as many autos available as persons in the household.

A concurrent process adjusts the survey records' expansion factors factored to match the respective grand totals of home-based and non-home-based trips. The Tripgen program is ideally suited to do this concurrently, treating each survey record's expansion factors as "attractions" flagged into either "purpose 1" or "purpose 2," respectively. Normally the "control totals" of these two purposes are determined by zonal trip generation, and naturally grow when forecasting with regional growth.

3.4.3 External Passenger Generation Rates from Population

To forecast SMF passenger demand outside the SACOG region within the SACSIM models, the full demographic detail used within the region is neither necessary nor appropriate. It would be appropriate and pragmatic to have simpler and more readily-forecast independent variables than income-stratified households and non-retail employment.

County populations were checked and found to be reasonably proportional to the preceding passenger demand estimates from detailed demographics. Non-retail employment is likewise reasonably proportional to county population. Proportionalities with respect to county population are significantly closer than to total households in county. Consequently, only one independent variable, population, is chosen for application of external airport passenger demand.

Table 3-14 shows airport passenger generation rates for external (non-SACOG) areas. Table 3-14's rates count both arrivals and departures, unlike above tables that count departures only. Table 3-14 shows passenger generation rates split into the demographic strata needed by the airport access mode choice model, obtained by dividing the generation calculated for each particular stratum, by population.

Table 3-14 Two-Way SMF External Passenger Generation Rates

Trip Category	Income	Cars per Person	2-Way Rate per Population
Home-Based	Less than $50k	As many or more	0.00090
Home-Based	Less than $50k	Fewer	0.00039
Home-Based	More than $50k	As many or more	0.00179
Home-Based	More than $50k	Fewer	0.00022
Non Home-Based			0.00095

Source: SACOG 2020. For External Areas Only

3.4.4 Enumeration of Passenger Survey Database

This model application phase calculates appropriate weights for passenger survey observations to represent a given zone's generated trips for the sake of mode choice, so that the mode choice model can be applied as a modified sample enumeration procedure. Conversely, this phase can be considered to split or spread each survey record across several zones, instead of its one observed zone. (This phase is analogous to trip distribution, although, strictly speaking, the airport trip generation described above is also trip distribution, since the trips are attracted to one zone, the airport.) The general objective is that each zone's generated trips would be represented by "compatible" survey records, that is, compatible in demographics and geography, as well as matching in being home-based or non-home-based. (This phase was not needed in the DNA Corridor Study, in which survey records "stayed in their zones" and were growth-factored for forecasting.)

This association is represented as two matrices, one for home-based and the other for non-home-based trips; rows represent actual TAZs and columns represent survey records. The cells are zero if not "compatible," and have a spread weight value otherwise. The row-sums for home-based trips must match the zonal home-based trip generation, and likewise the row-sums for non-home-based trips must match non-home-based trip generation. Column-sums are proportional to the base year expansion factor of the respective survey observation, but are scaled to the same grand total as the trip generation.

Ideally there would be several survey observations, of each demographic cross-classified category (persons by income by autos), that could be associated with each demographic category in each RAD. But there aren't enough survey cases to do this. Instead, we must combine RADs into yet larger districts just to provide home-based and non-home-based survey observations to all zones. Some cross-classified cells have few or no cases at all in the survey. Therefore, the more demographic variables of the modeled households we wish to match to representative survey records, the larger the districts must be for the computation to be possible.

For home-based trips, the present application chooses survey records for each trip in the same one of 8 regional districts, matching whether household income is less than $50,000 (a mode choice dummy variable), and whether there is a shortage of autos per person (as defined for another mode choice dummy variable). This could be conversely be thought of as spreading each survey record across all zones in the same of 8 districts, proportionally to the airport trip generation by households of the same of two income classes and two autos-per-person classes. This particular compatibility scheme is subject to change as validation and forecasting issues are considered.

For non-home-based trips, this application chooses all survey records in the same one of the 8 regional districts.

The actual mechanism to achieve these associations or spreads, subject to row and column constraints, is iterative proportional factoring, implemented in the TP+ Fratar program. The constraint vectors are the trip generation results (home-based and non-home-based zonal demand as productions, factored survey weights as attractions). The input matrix to the home-based process is the compatible-class trip generation of the zone; the input matrix for the non-home-based process is simply a 1 if in the same of 8 districts, and a 0 otherwise. The result matrices are the number of trips generated by the *i* zone, associated with survey record number *j* (or conversely, the number of trips of survey record *j* spread to zone *i*.)

3.4.5 Ground Access Mode Choice for Internal Passengers

The mode choice model used a two-by-two segmentation of air passengers: resident vs. non-resident, and business vs. other. The model was based on highway and transit network level-of-service measures obtained from a regional travel demand model. The model is applied by enumerating (i.e. expanding) the airport survey dataset according to residential growth (for home- or residence- based trips) or non-retail employment (for non-home-based trips).

The mode choice model is taken directly from an application spreadsheet used in the DNA Corridor Study. It is multinomial logit, with these seven alternatives:

- Auto Drop-Off
- Drive-and-park at airport (for residents)
- Return rental car at airport (for visitors)
- Taxi
- Van
- Transit Walk-Access
- Transit Drive-Access
- Transit Drop-Off Access

Table 3-15 shows the coefficients of this logit model. This paper does not report the numerous details in the definitions of the variables. Demographic variables only apply to home-based trips by residents.

This model is applied to the matrix of weighted trips computed in the preceding phase, in which the *i* zone is the zone of trip generation, and the *j* zone is the survey record number. It is thus a modified form of sample enumeration, with the survey records "spread" among numerous zones, instead of kept in their original zones. The actual output result of this application is the row sums of the seven modal matrices, that is, the aggregation of them by zone, collapsing all survey records. Reports aggregating modal trips by the segment (travelers, resident business, resident leisure, visitor business, and visitor leisure) are also provided; reports aggregating by any survey data variable can be generated.

Table 3-15 Airport Ground Access Mode Choice Logit Model Coefficients

Coeff No.	Variable	Passenger Market Segment 1 Resident/ Business	2 Resident/ Leisure	3 Visitor/ Business	4 Visitor Leisure
Mode Constants					
1	Auto Drop-Off	0	0	0	0
2	Auto-Park(Res)/Return Rental(Vis)	0.5303	0.5303	0.106	-1.1104
3	Taxi	-1.5858	-2.1639	-0.3116	-1.8789
4	Van	-1.0737	-0.5921	-0.4271	-1.2767
5	Transit-Walk Access	0.5281	0.5281	0.705	0.705
6	Transit-Drive Access	0.1097	0.1097	-0.5949	-0.5949
7	Transit-Drop-Off Access	-0.2191	-0.2191	0.3275	0.3275
Demographic Variables					
8	Autos<Persons	-0.2494	-0.2494	0	0
12	1 Persons	-0.3995	0	0	0
13	3+ Persons	0	0.6422	0	0
14	Income<$50K	0	0.7416	0	0
Cost Variables					
15	Parking Cost	-0.0155	-0.0155	0	0
16	Van/Taxi Cost	-0.0191	-0.0003	-0.0191	-0.0003
17	Transit Cost	-0.0422	-0.0422	-0.0422	-0.0422
Travel Time/Level-of-Service Variables					
18	Main Mode Time	-0.0095	-0.0095	-0.0095	-0.0095
19	Walk and Transfer Time	-0.0518	-0.0518	-0.0518	-0.0518
20	Drive Access Time	-0.0079	-0.0079	-0.0079	-0.0079
21	Chauffer Time	-0.0055	-0.0003	-0.0055	-0.0003
22	First Transfer	0	0	0	0
23	Second+ Transfer	-0.845	-0.845	-0.845	-0.845
Airport Egress Variables					
24	Walk Egress Time	-0.0183	-0.0183	-0.0183	-0.0183
25	Walk Egress Dummy	-0.0916	-0.0916	-0.0916	-0.0916
26	Shuttle Egress Time	-0.0053	-0.0053	-0.0053	-0.0053
27	Shuttle Egress Dummy	-0.0526	-0.0526	-0.0526	-0.0526
Other Variables					
28	Scale Factor for Utility	1.865	1.865	3.0869	3.0869

Source: SACOG 2020. Using values from November 2008.
Based on technical memorandum by Bowman, John L., Bradley, Mark A., and Griesenbeck, Bruce “Sacramento RT DNA Transit Access Mode Choice Model”, July 3, 2002.

3.4.6 Updated Time-of-Day Distribution of Airport Access

No surveys or counts of trips entering or exiting the airport have been available that would yield time-of-day distributions of airport passenger arrivals or departures, either at the flight gate or on the road. An alternative basis is the time of day of aircraft arrivals and departures, assuming most flights are nearly full, and different-sized aircraft are scheduled consistently across the day.

Table 3-16 presents the approximate (shifted) distribution of passenger ground travel, in the nine time periods used in the updated SACSIM model system. (Arriving and departing percentages are both normalized to 50%.)

Table 3-16 Estimated Time-of-Day Distribution of Ground Access of SMF Airport Passengers

SACSIM Time Period	Percent Departing	Percent Arriving
AM Hour 7:00-7:59	3.0%	0.3%
AM Hour 8:00-8:59	2.7%	2.0%
AM Hour 9:00-9:59	4.7%	3.0%
Midday (10:00-14:59)	15.6%	16.1%
PM Hour (15:00-15:59)	2.7%	2.7%
PM Hour (16:00-16:59)	3.0%	2.7%
PM Hour (17:00-17:59)	2.4%	3.4%
Evening (18:00-19:59)	5.1%	6.0%
Night (20:00-6:59)	10.9%	14.0%

Source: SACOG 2020.

3.5 Vehicle Trip Table

3.5.1 Vehicle Trip Table Preparation and Assignment

This chapter documents the process of taking the various estimates of person trips and vehicle in different formats, creating origin-to-destination vehicle or passenger trip tables, and assigning those tables to highway or transit networks. The generic estimates of trips are:

- DAYSIM person trip segments, which includes person trip segments in origin-to-destination format, with one record per person trip, with mode and time of travel information on each trip record.
- Commercial vehicle trips which are daily, total flow of vehicle trips, split into number-of-axle classifications (2 axle and 3+ axle vehicles). The trips are in origin-to-destination form, with assumed symmetry of flows to and from origins and destinations.
- Airport passenger person trips, which are predicted as “half-round-trips” in production-to-attraction format, with the airport end being the attraction. The half-round-trip, P-to-A matrix is converted to a daily, both direction flow by transposing the P-to-A half-round trips, with symmetry of round trips assumed.
- IX and XI daily person trips, in production-to-attraction format.
- XX vehicle trips, in daily, both-direction, origin-destination format, with three tables: private autos and commercial vehicles (2 axle and 3+ axle combined).

Trip assignment to highway networks is made for nine demand periods using a conventional, TAZ-to-TAZ, origin-destination, static equilibrium assignment using Citilabs® TP+/HWYLOAD software.:

- 7-8 AM,
- 8-9 AM,
- 9-10 AM,
- Midday 10 AM-3 PM,
- 3-4 PM,
- 4-5PM,
- 5-6PM,
- Evening 6-8PM,
- Night Time 8PM-7AM

Transit passenger trips are assigned using Citilabs® Public Transport software, with trips in origin-to-destination format. Five demand periods are assigned:

- Period 1, spanning from 5:00am until 9:00am
- Period 2, from 9:00am until 3:00pm
- Period 3, from 3:00pm until 6:00pm
- Period 4, from 6:00pm until 8:00pm
- Period 5, from 8:00pm until 11:00pm

3.5.2 Trip Table Preparation

This process combines trips from DAYSIM, and the models of external, airport, and commercial vehicle trips into time periods for assignment to highway and transit networks. SACSIM19 is broken into nine time periods, for simplicity, performance, and establish unit-hour period durations for the entire day. Previous version of SACSIM broke out the two peak periods each cover three-hour periods. SACSIM19 separates these out into individual hours for a total of six separate trip tables during the peak periods. The midday period is five hours, Evening is two hours, and Night time (late evening/early morning) period is eleven hours.

Table 3-17 SACSIM Demand Period Definition

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

3.5.2.1 DAYSIM Person Trip Segments

For highway assignable trip tables, DAYSIM auto person-trips are aggregated into TAZ-to-TAZ flows, stratified by mode, 3 person values-of-time (VOT) bins, and time period. This file is generated in O-to-D format, with arrival and departure time on each trip record, so none of the ordinary directionality conversion from P-to-A, or from daily to the demand period, is required.

Auto person-trips are already stratified by occupancy (drive alone, 2 person shared ride, and 3+ person shared ride) and VOT bins (high, medium, low), and each record is converted to a vehicle trip equivalent using the inverse of the average occupancy (i.e. 1.0 for drive alone, 0.5 for 2 person shared ride, and 0.3 for 3+ person shared ride). The values of time bins were updated to reflect latest traveler preference survey in the SACOG region conducted by RSG consultants. More information on actual threshold price points, distribution curves, and data collection can be found in *Appendix B, RSG Travel Demand Model Toll Enhancement Technical Memorandum, September 2018*.

In the DAYSIM trip output file, transit person-trips are distinguished by walk-access and drive-access, and the drive-access trips are distinguished by direction (drive-transit-walk versus walk-transit-drive). The transit drive-access trips from DAYSIM are generated in O-to-D format, without explicit reference to the location of the transition the between transit and auto. The Origin-to-Destination

(O-D) person trips were split and converted to Production-to-Attraction (P-A) format, then split into the two transit service periods.

A simple park-and-ride (also including kiss-and-ride) lot choice model in SACSIM19 splits these trips into separate auto and transit segments. The auto portion of the trip (e.g. from home to the park-and-ride lot, or from the park-and-ride lot home) is included with other vehicle trips in the highway assignment; the transit and walk from the last transit stop to the final destination (e.g. at the work end of a work tour), or the walk from the primary tour destination to the first transit stop on the return half-tour, is assigned as a passenger trip in the transit assignment. This process for transit drive-access trips will be discussed in greater detail below.

3.5.2.2 External Trips

The external models create partial matrices of daily person-trips between the gateways and the internal zones in P-to-A format. These are converted to vehicle trips split by occupancy and time of day to be included in the vehicle trip assignments. The auto mode split, directionality, and time-of-travel factors were presented earlier. No external transit, walk, or bike trips are predicted. Conversion of auto person-trips to vehicle trips is made using the same vehicle trip equivalent factors discussed above.

3.5.2.3 Commercial Vehicle Trips

Commercial vehicle, and exogenous through-trip matrices are also split by time of day for the vehicle trip assignments using the time-of-travel factors presented in Section 3.2. Commercial vehicle and through trips do not have any orientation of production and attraction defined, so they are split equally in both directions and split by time of day using the non-directional factors in presented in Section 3.2.

3.5.2.4 Airport Ground-Access Trips

Airport passenger trips are converted to vehicle trips, including the extra "return" trip required for pick-ups and drop-offs, within the airport mode choice computation module, because the traveling party-size is available then as a survey variable. Assumptions used in this process include the following rules:

- *Auto Drop*--One vehicle trip for pick-up or drop-off, plus the vehicle trip of the air traveler. If the air travel party size is 1 or 2, then it is assumed that 80% of such travelers are picked up or dropped off by one person, and 20% are by two persons. For larger air travel party sizes, this changes to 90% by one person, 10% by two. These assumptions are judgments, for lack of survey data. The pick-up or drop-off vehicle trip is stratified by occupancy (number of meeting persons), and the air-travelers' vehicle trip is stratified by its occupancy (number of meeting persons plus air travel party size).
- *Auto Park*--One vehicle trip per traveler, stratified by party size.

- *Taxi*--One and a half vehicle trips per traveler, one with the traveler, plus a judgmental assumption that half of such trips involve a "deadhead" taxi trip without a passenger. The "deadhead" trip is assumed single-occupant (the driver alone), and the regular trip's occupancy is the party size plus the driver.
- *Van*--One tenth of a vehicle trip per traveler.
- *Transit Drive and Transit Drop*--The same auto trip making and occupancy assumptions apply as with Auto Park and Auto Drop, including pick-up and drop-off trips. These trips are saved stratified into three matrices of daily auto trips as if to the airport, to be later "relocated" to a park-and-ride lot, and split by time and directionality. The transit part of each trip is also relocated to travel from the park-and-ride lot to the airport.

Time-of-travel factors presented in Section 3.5 were used to split the vehicle trips into the four demand periods for highway assignment. Transit passenger trips were converted to P-to-A format and split into the two transit demand periods (peak and off-peak) for assignment with the other transit passenger trips. Transit-drive access airport passenger trips are split into the drive portion (e.g. from home to park-and-ride, or from park-and-ride to home), and the transit portion in the same manner as non-airport transit-drive access trips, which will be discussed in greater detail below.

3.5.3 Vehicle Trip Assignment

Vehicle trip assignment in this model system uses a standard deterministic user equilibrium algorithm which iterates the Dijkstra tree-building "shortest paths" algorithm and a form of Frank-Wolfe or "conditional gradient" direction step size choice to blend the iteration volumes progressively closer to equilibrium. Ideal equilibrium achieves Wardrop's criterion, that no traveler can reduce travel time by shifting to another route. Each vehicle trip assignment solves the conditional equilibrium *for the given trips* during any iteration of the SACSIM19 system-equilibrium solution.

This application is a simultaneous multi-class assignment like past versions of SACSIM. However, SACSIM19 differs from past versions by expanding assignment routing classifications by path impedances by vehicle type/occupancy and VOT to determine preferences of path choice by class. A total of 15 combinations of VOT, vehicle type, and vehicle occupancy are grouped into the following 12 classes:

- Class 1: "LOW" VOT Single Occupancy Vehicle (SOV) & "LOW" VOT 2 Axle Commercial Vehicles (CV2)
- Class 2: "LOW" VOT 3+ Axle Commercial Vehicles (CV3+)
- Class 3: "LOW" VOT 2 Passenger Shared Occupancy Vehicle (S2)
- Class 4: "LOW" VOT 3+ Passenger Shared Occupancy Vehicle (S3+)
- Class 5: "MEDIUM" VOT Single Occupancy Vehicle (SOV) & "MEDIUM" VOT 2 Axle Commercial Vehicles (CV2)
- Class 6: "MEDIUM" VOT 3+ Axle Commercial Vehicles (CV3+)
- Class 7: "MEDIUM" VOT 2 Passenger Shared Occupancy Vehicle (S2)
- Class 8: "MEDIUM" VOT 3+ Passenger Shared Occupancy Vehicle (S3+)

- Class 9: "HIGH" VOT Single Occupancy Vehicle (SOV) & "HIGH" VOT 2 Axle Commercial Vehicles (CV2)
- Class 10: "HIGH" VOT 3+ Axle Commercial Vehicles (CV3+)
- Class 11: "HIGH" VOT 2 Passenger Shared Occupancy Vehicle (S2)
- Class 12: "HIGH" VOT 3+ Passenger Shared Occupancy Vehicle (S3+)

Previous SACSIM iterations also included a percentage of "Violators" and exempt SOV vehicles to use HOV lanes and a percentage of HOV prefer general purpose lanes. Since implementing the VOT bins already increases the class, thus significant assignment runtime, and is required for implanting roadway and mileage-based pricing functionality; violator HOV choice classifications were removed from SACSIM19 vehicle path choice.

Controls for the equilibrium assignment are set to and increasing number of maximum assignment iterations, and a decreasing relative gap. The "maximum assignment iterations" are a limit placed on the vehicle/highway assignment process for each time period assignment. "Relative gap" is a measure of the degree of closure or the decreasing difference in target measures for additional assignment iterations. In combination, maximum assignment iterations and relative gap function as an "either/or" criteria for ending a given time period assignment. The assignment ends if either the relative gap closure criteria is met (i.e. if the difference between the current assignment iteration and the last iteration is less than the relative gap criteria), or if the number of iterations reaches the maximum. "System iterations" are iterations of the entire model system, also known as "feedback loops"—system iteration and convergence is discussed in the following chapter. The settings for the equilibrium assignment criteria are shown in Table 3-18

Table 3-18 Equilibrium Assignment Closure Criteria

System Iteration	Maximum Assignment Iterations	Relative Gap
1	300	0.0006
2	300	0.0003
3	300	0.0002

Source: SACOG 2020.

3.5.3.1 Congestion Delay Functions

3.5.3.1.1 Conical Delay

SACSIM19 uses computed speed-flow curves, which are based on the conical delay function. Conical delay function has the form:

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

Where:

- VC = V/C ratio on a link;
- A = a user-specified coefficient; and
- B = (2A -1)/(2A -2)
- E = 2 - B

The attributes of this function which make it desirable for applications in travel demand model assignments are:

- *f*(x) is strictly increasing. This is necessary for convergence to a unique solution;
- *f*(0) = 1 and f(1) = 2. This ensures that free-flow travel times are uncongested, and congestion at capacity (i.e. V/C ratio = 1) doubles travel time for the link.
- The function does not require exponentiation, which results in computation time savings.

A modified form of the conical delay function was used for SACSIM:

$$T_C = T_O * \min\{E - A(1-Lx) + (A^2(1-Lx)^{2} + B^2)^{0.5}, \max(T_C)\}$$

The variables are the same as for the basic conical delay function, except:

- T_C =congested travel time
- T_O =”free flow” travel time
- L= VC ratio factor, adjusted so that TC=+/- 1.5 when VC=1.0
- $Max(T_C)$=M + N(VC)

3.5.3.1.2 Passenger Car Equivalents Conversion

Commercial vehicles are converted into passenger equivalent vehicles by for the delay function to more accurately reflect vehicle size impacts on congestion and delay estimations. Vehicles are used for the to calculate volume to capacity ration by:

- Passenger vehicles = 1

- Smaller commercial vehicles = 1.5
- Larger or 3+ axle commercial vehicles = 2.0

For this reason, V_1 or V_1T are considered passenger equivalent total volume and not recommend to be used to report total vehicle volumes. The subtotals volume classes after the assignment has been completed should be used to report to total vehicle volumes totals.

3.5.3.1.3 SACSIM Delay Formula Variables

Table 3-19 reports the variable values utilized for SACSIM. The A and B values were calibrated to allow for "softening" of the basic form. As mentioned above, the function itself was created to return a congestion factor of 2 when VC ratios equal 1. In test assignments, this resulted in erratic assignments with high link error. The optimal results were achieved when congestion factors were about 1.5 when VC ratios equal 1. A "soft ceiling" maximum was included in the function, to reasonably constrain the time factors, while still providing some positive slope to the curve. Table 3-20 provides a comparison of the current speed-flow functions

Table 3-19 Congestion Factor Variables and Values

	Variable					
	A	B	E	L	M	N
Class of Roadway	User Specified Conical Delay Coeff.	User Specified Conical Delay Coeff.	User Specified Conical Delay Coeff.	VC factor	Maximum constant at 2.2 V/C	Maximum coeff.
Freeway	6	1.1	0.9	0.88	9.1	0.5
Highway	5	1.125	0.875	0.86	8.3	0.0002
Arterial	4	1.167	0.833	0.83	6.4	0.0002

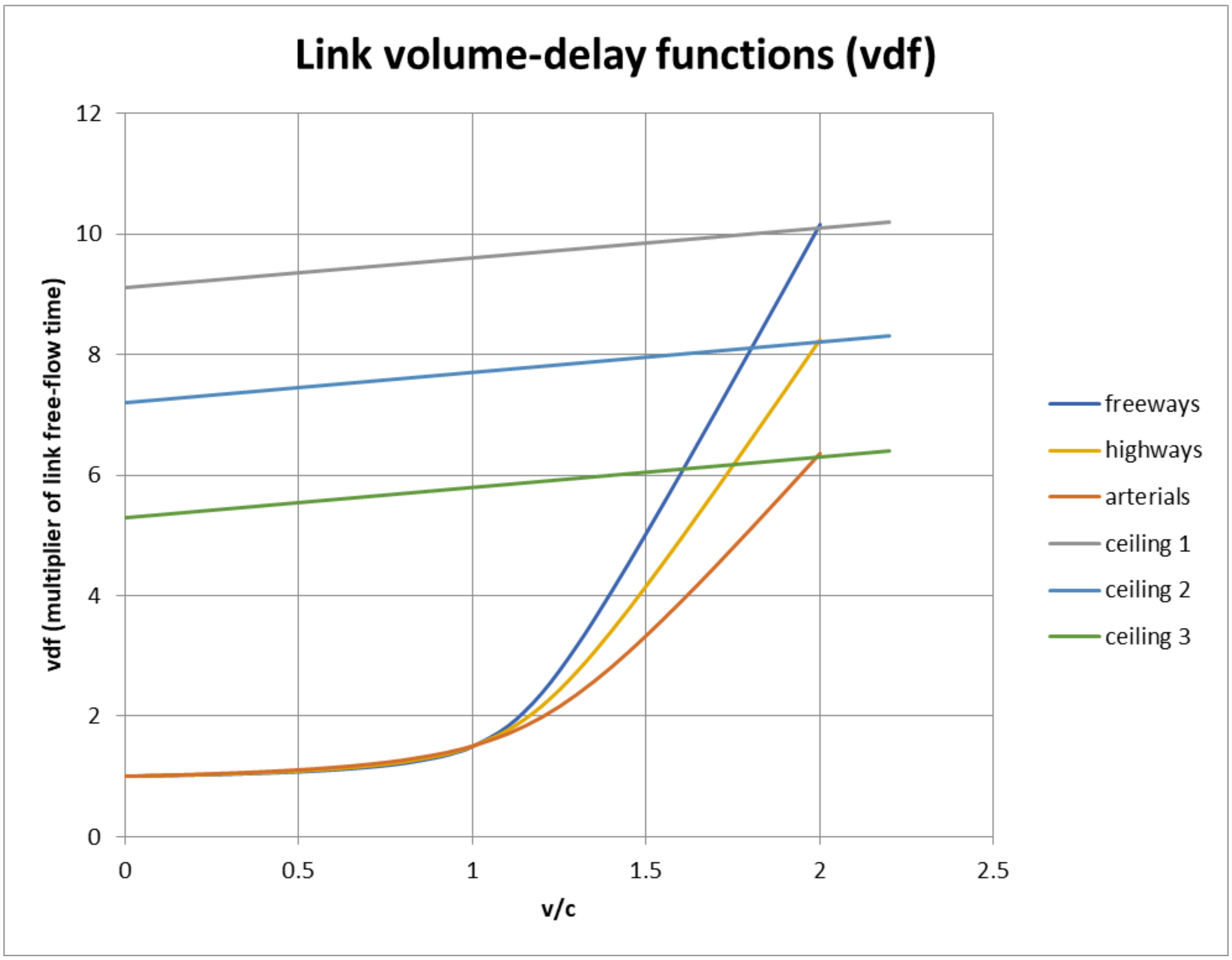
Source: SACOG 2020.

Table 3-20 Range of Congestion Factor Calculations

	Congestion Factor at VC =…					
Class of Roadway	**0.00**	**0.80**	**1.00**	**2.00**	**Max TF**	**Max. @ VC=…**
Freeway	1.00	1.21	1.49	10.15	11+	2.20
Highway	1.00	1.24	1.50	8.25	11+	2.20
Arterial	1.00	1.27	1.50	6.36	7+	2.20

Source: SACOG 2020.

Figure 3-9 SACSIM19 Link volume delay function



Source: SACOG 2020.

3.5.3.2 Traffic Flow Intensity Factors

The time periods of traffic assignment depend on vehicle trip tables factored by the directional time-of-day factors. Also needed is a factor, for each assignment period, relating the volume of traffic in that period, to the average flow rate in vehicles per hour. The "time-mean" definition of such an average is simply one divided by the number of hours. Instead of that, however, an average was preferred that represents the average intensity of traffic as experienced by the drivers, what may be termed a "vehicle-mean." Vehicle-mean traffic intensity rates were calculated using a summary, from the household travel survey, of vehicle-miles traveled grouped by 15-minute increments of the whole day. This formula estimated the "vehicle-mean" traffic intensity for AM and PM 3-hour periods and the off-peak period, summing for all 15-minute periods within the 3-hour periods:

$$\frac{\sum_1^n VMT^2}{(\sum_1^n VMT)^2}$$

Where *n* is the number of 15-minute periods within the multi-hour AM/PM peaks.

3.5.3.3 Metered On-Ramps

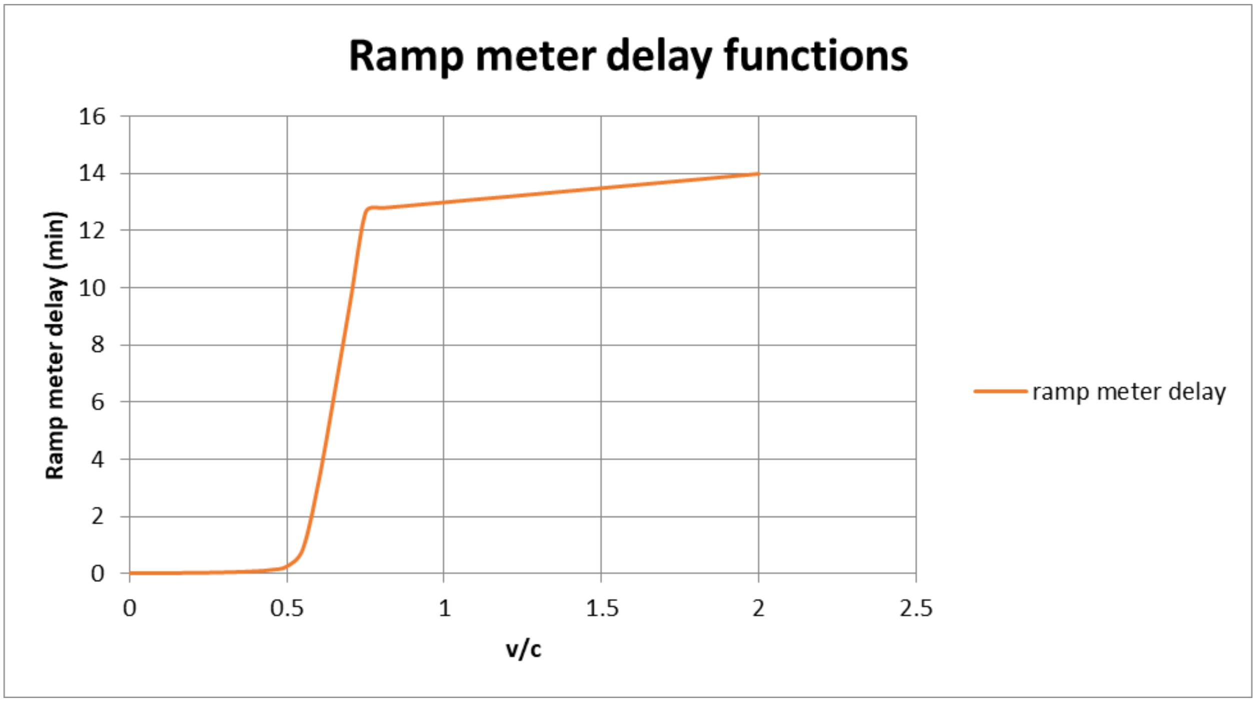
Migrating the traffic assignments to TP+ required a new way to operationalize HOV lanes and metered on-ramps. In the highway network, DELCURV identifies on-ramp links that restrict or "meter" flow entering a freeway at certain times of the day using special traffic signal systems at the on-ramp. Values of this code are:

- 0 = not a metered on-ramp (most links in the network)
- 1 = metered in the AM peak period (3 hours)
- 2 = metered in the PM peak period (3 hours)
- 3 = metered in both AM ad PM peak period (6 hours)
- 4 = metered in AM, Mid-Day, PM
- 5 = metered all 24 hours

The presence of ramp metering on freeway entrance ramps can significantly add to vehicular travel time for trips which utilize metered ramps, particularly when demand is near or exceeds ramp capacity. Therefore, a delay function was developed which estimates vehicular delay at metered ramps as a function of the volume-to-capacity (v/c) ratio.

The two key input factors are the distribution of demand over time and the vehicle discharge rate. For the assignment periods during the three hour peak AM and PM periods modeled, the relative distribution of demand was initially derived from the Caltrans/SACOG household travel surveys and travel time testing. The vehicle discharge rate was assumed to be 900 vehicles per lane per hour. By proportionally changing the three-hour demand, total delay over a three hour period was calculated as a function of three-hour v/c ratio. The delay curve was represented as a piecewise linear equation. Overriding this derived curve was a “soft ceiling” delay of 15 minutes, and a constantly increasing delay with respect to v/c ratio. Figure 3-10 shows the meter delay curve.

Figure 3-10 Ramp Meter Delay



3.5.3.4 Bypass Lanes for HOVs at Metered On-Ramps

At some metered on-ramps in the Sacramento region, special lanes for high-occupancy vehicles have been designated. These lanes are not controlled or otherwise delayed by the ramp-meter signal. The model network representation of these lanes consists of longitudinally-connected pairs of links parallel to the metered on-ramp link. (Two links instead of one are required because the network software permits only one link in a direction between the same pair of nodes.) The effect is that HOVs (and any other eligible vehicles) are not delayed by the ramp meter delays. The following codes are required on HOV links that bypass metered on-ramps:

- DELCURV = 0 (0 for all links except metered on-ramps)
- USECLASS 2 or 3 (for ramp meter bypass links, specify minimum occupancy requirement to use bypass)

3.6 Transit Assignment

3.6.1 Transit Path Building and Assignment

Transit path-building and assignment is performed in five time periods:

- Morning peak (start of service to 10:00AM)
- Midday period (10:00AM to 3:00PM)
- Afternoon peak (3:00PM to 6:00PM)
- Early Evening (6:00PM to 8:00PM)
- Night period (8:00PM to end of service)

Additionally, transit path-building and assignment is done in an origin-to-destination, direction format. SACSIM19 accomplishes this O-D assignment format by splitting the drive portion of drive access trips from the transit assignment, and assigning all trips as "walk-transit-walk". The drive portion of path-building and assignment, between home and the park-and-ride lot, is accomplished through HWYLOAD and matrix processing, outside of PT.

3.6.2 Transit Background Network

The SACSIM19 PT implementation builds routes using transit lines and walk access links connecting them to each other and zone centroids. A background network is created on which transit lines run, and walk access is found. The background network is created from:

- Loaded highway networks corresponding to the five transit service periods, including centroid connectors, minus any dummy placeholder links used in different scenarios. This is the source of walking distance and traffic speeds.
- Reverse directions of one-way links in the highway network, for (1) walk access, and (2) enable two-way transit lines to use one-way streets without run failure.
- Exclusive transit links, given in a file manually prepared transit links file ("transit_links.csv"), for light rail and other transit-only links.
- Walk access links connecting the highway network to light rail stops (and other services on exclusive ROW), given in in a manually-prepared station links file ("station_links.csv").
- A manually prepared park-and-ride file ("_pnr.dbf") with lot sizes and connections to transit stops from, to provide a shorter walk distance from park-and-ride zone than the centroid connector.

Before PT builds complete routes via transit, it prepares walk access links using the shortest path between nodes on the compiled background network. In output files, however, these links appear as direct connections between nodes, skipping the intermediate nodes.

3.6.3 Transit System Coding Structure

The SACSIM19 PT implementation uses three “system” files:

- A fare file (“PTfare.txt”) which specifies initial boarding fares, and operator-to-operator transfer fares.
- A system file (“PTsystem.txt”) which specifies transit modes, operators, and various wait time curves.
- A factor file (“PTfactor.txt”) which specifies parameters affecting path-building.

The PT system file declares the coding conventions for transit lines, transit access links, and operators. It also declares a set of wait curves (discussed later). Each transit line has a mode and an operator. PT generates additional links for access, egress, and transfer, with their own modes. Modes are shown in Table 3-21. Operators and fare groups area shown in Table 3-22.

Table 3-21 SACSIM19 Transit Modes

Mode	Description
1	Light rail (and other local guideway)
2	Commuter bus and rail
3	Local bus
12	Transfer links generated by PT
13	Access and egress links generated by PT
14 (not used)	(reserved for separate egress links, if needed)
15 (not used)	(reserved for separate park-and-ride access links, if needed)

Source: SACOG 2020.

Table 3-22 SACSIM19 Transit Operators

Operator / Fare Group Number	Description
1	RT light rail lines
2	RT fixed-route bus lines
3	Yolobus commuter/express lines
4	Yolobus local fixed route bus lines
5	Roseville commuter bus lines
6	Roseville local fixed route bus lines
7	Yuba-Sutter Transit commuter lines
8	Yuba-Sutter local fixed route bus lines
9	El Dorado Transit commuter bus lines
10	El Dorado Transit local fixed route bus lines
11	Placer County Transit commuter lines
12	Placer County Transit local fixed route bus lines
13	Unitrans local fixed route bus lines; CSUS Hornet shuttle lines
14	Heavy rail (currently Sacramento region stops for Capitol Corridor)
15	South County Transit (SCT Link)
16	E-Tran commuter lines
17	E-Tran local bus lines
18	Future Neighborhood Shuttle
19	Future Streetcar
20	Folsom Stage Line

Source: SACOG 2020.

The PT factors file declares:

- Parameters for path building
    - Maxima on numbers of boardings, etc.
    - Relative weights for costs and out-of-vehicle times compared to in-vehicle, in determining generalized cost of paths
    - Multi-path choice parameters
- Additional coding convention information
- Associates fare-systems with operators
- Time-transfer nodes declaring special wait curves for particular nodes.

3.6.4 Transit network

Details of transit network coding are provided in Chapter 7. For purposes of path building and assignment, travel speeds of buses on highway links are related to the background traffic speeds in the respective period of the day, multiplied by a time factor that represents delays from stopping, loading and unloading, acceleration and deceleration. Time factors are specified for each line but can vary along different segments of the same line. Each operator has an initial boarding fare, and transfer fares from an operator-to-operator matrix. There are no zone- or distance-based fares in the model.

Timed-transfer stations are coded with alternatives to the global or default maxima on wait time specified in the PT factors file. These alternatives are specified by station or stop node. Each refers to an “xwaitcurve” code which must be present in PT system file. Code 105 represents a 5-minute maximum wait (or “pulse” period), 107 is a 7-minute maximum wait, and 110 a 10-minute maximum wait.

3.6.5 Routing

For drive-access transit travel, the PT application processes only the walk-transit-walk portion. Park-and-ride lot choice is a separate model applied outside of PT, using auto and transit skims, and the auto and transit trip-legs separated for assignment. The auto portion uses the highway network to or from any zone having capacity in the “_pnr.dbf” file, and the transit portion uses the transit network to or from the respective park-and-ride zone.

Generalized time (or “perceived time” used to evaluate routes) derives from times, distances, and costs according to parameters specified in the PT factors file. Perception of first-wait time is a piecewise-linear function fitted to the logarithm of randomly-distributed exponentiated utility, coded as the “wait curve” in the Factors file. This gives a high sensitivity to short headways, and a lesser sensitivity to long headways (infrequent service) without the total loss of sensitivity that a truncation would impose.

PT applies a multi-path routing model. Waiting at a stop, travelers are routed among all acceptable lines with probability proportional to frequency, from the premise that a traveler will board whichever service arrives there first among those that efficiently reach his/her destination. PT also provides a multinomial logit choice at decision points to wait at one node or another. Its parameters are the “spread” parameters in the “PTfactors.txt” file, specified close to the program defaults.

3.6.5.1 Skimming

DAYSIM uses TAZ-to-TAZ skim components rather than total perceived time. DAYSIM does not use the skimmed walk time, but instead estimates it parcel-to-parcel. (Composite time among walk branches is available but not used, although multiple used lines picking up at a node get the combined frequencies. For future improvement, consider adding "value of choice" to utility)

3.6.6 Transit Assignment

Transit assignment is performed at the end of the model, since it is not needed in feedback. It uses the same routing criteria as skimming.

Within SACSIM19, DAYSIM uses 5 discrete period skims, but outputs trips in continuous time, therefore it is not always certain by which skim period SACSIM19 created a transit trip prior to settling the person's full itinerary. As a result, some trips are placed into a period having no transit service, so they are unassignable. Many of the unassignable trips occur in the evening period. To minimize unassignable trips, special rules are applied for transit trips in their placement into periods of the day for assignment.

- All trips earlier than the normal AM 4-hour period are placed in AM,
- If a trip begins in one period and ends in another, but one of these periods lacks transit service (as evident from lacking a transit skim), it is placed into the period that has service,
- If a trip occurs in the evening period, but has no service, it is placed into the PM period if it has service.

3.6.7 Drive Access to Transit

Park-and-ride travel is modeled in much the same way as described in *Sacramento Activity-Based Travel Simulation Model (SACSIM11): Model Reference Report* (SACOG, Feb 2012). For each individual park-and-ride trip pair (drive-transit-walk and walk-transit-drive), the park-and-ride lot of minimum generalized time is chosen, among those not already full at the time of the trip's outbound departure (beginning of the drive-transit-walk leg). Skims are a probability-weighted average across the period, of the time-dependent best choice.

To provide a more realistically short walk access between the park-and-ride zone and light rail stops, the model script was changed so the short link between them connects directly to the light rail stop, instead of a nearby node on the highway network.

PT, and this model's park-and-ride model, allow but do not require the "funnel link" system at light rail stops as in the SACSIM11/TRNBUILD model. It is sufficient to provide one link (or a few as needed) connecting an adjacent node in the highway network to each light-rail stop node. Conversion to PT retained all the funnel links from the SACSIM11/TRNBUILD model, in the interest of preserving access that was provided before, and to expedite conversion.

3.6.8 Park-and-Ride Lot Assignment

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

- Multinomial logit with shadow cost solution;
- All-or-nothing choice of the least generalized cost;
- All-or-nothing least generalized cost choice, but with maximum drive times solved for each full lot so that demand does not exceed capacity. (A maximum drive time can be considered a catchment area radius, but with catchment areas of different lots freely overlapping; and
- Simulate filling of parking lots over time, making each lot that fills up unavailable to later trips.

The first approach, (multi-nomial logit + shadow cost) was not explored due to lack of data, and budget and time constraints. The second approach (AON assignment based on generalized least cost) was rejected, simply because it lacked any capacity constraint. The third approach (varying drive-to-park-and-ride-lot sheds to match observed loadings) was rejected, because any correlation between drive shed size and lot capacity was weak, and lacked any behavioral relationship. The fourth approach (simulated lot filling, based on generalized least cost), which simulated lot choice, was tested and implemented.

The selected approach has appeal as a simple simulation of a familiar process of parking lots available to those who arrive before they fill up and closed to those who come late. Such a mechanism is reasonable since transit park-and-ride lots mostly serve commuters to work in the morning, and most vehicles stay parked through the day until the evening commute period. Its run-time is quite fast when applied to disaggregate trips such as from DAYSIM.

3.6.8.1 Implementation

There are two interrelated parts to the implementation of the park-and-ride lot choice model: the actual parking lot choice for each trip, and level of service (skim) measurement of the auto-access transit mode for each origin-destination pair.

The park-and-ride lot choice model is applied to each disaggregate trip record predicted by DAYSIM with the auto-transit-walk mode (mode 1). For each, this model selects one zone for this trip to park. Only zones having available parking capacity are allowed. With this selection, the trip is split into an auto trip from the origin to the parking zone, and a transit trip from the parking zone to the destination.

Each trip is linked to the same person's return trip (mode 2), and the return trip is split into a transit and an auto trip through the same parking zone. (The return trip may have a different origin than the original d-t-w trip's destination, and/or a different destination than the original trip's origin.)

The resulting auto and transit trips are then aggregated into trip matrices by time period for inclusion in the auto and transit assignments. This trip processing model is applied after DAYSIM (since DAYSIM trip predictions are input), and before auto assignment (since the auto portions of trips are included in the assignments).

The parking lot choice model makes a single choice for each d-t-w trip of the parking zone, among those available for parking and not filled up, having the least generalized cost combined from the auto and transit portions of travel parking at that zone. The generalized costs are as follows, for origin zone *i* and parking zone *k*:

$GC(auto)_{ik}$ = {3*Auto $Time_{ik}$ + 2*(TermTime $_i$+ TermTime $_k$) + 2*(AutoDist $_{ik}$ * 12 cents/mile + $ParkCost_k$ /2) * 0.0558 minutes equivalent/cent } / 1.28 persons per vehicle

Where:

- GC(auto) = generalized cost for auto portion of transit-drive access trip, per person trip
- Auto $Time_{ik}$ = auto travel time from i-zone to park-and-ride lot k-zone (minutes)
- TermTime = terminal travel time at i-zone and k-zone (minutes)
- AutoDist = i-to-k zone auto driving distance (miles)

$GC(transit)_{kj}$= InVehTime + 2*WalkTime + 1.5*InitWaitTime + 2*TransfTime + (2*Fare * 0.0558 minutes equivalent/cent)

Costs are in year 2000 cents, consistent with SACSIM. The factors on costs are taken from the SACSIM model's middle stratum of cost factors for work trips. Parking cost is specific to park-and-ride activity, being taken from the park-and-ride capacity database file, not the zonal land use or parcel data.

Ideally, the park-and-ride zones would be special zones coded at the actual locations of the parking lots. However, presently they are in ordinary zones, and some of their centroids are some distance away from the parking and the transit station. The ordinary walk-access transit skims would include walk time from the parking zone centroid to the transit stops, which is excessive in some zones. TP+ is not able to isolate or exclude walk time from the origin to the first boarding, which would solve this problem. The current solution to transit skimming for park-and-ride is to actually run customary drive-to-transit skimming, with the requirement that all park-and-ride zones be coded in their own catchment areas. This approach does not appear to introduce conflicts, because the parking lot choice calculations ignore all the transit skims except those beginning at the parking lot zones (i.e. the zones with parking capacities).

This model processes AM trips in chronological order, according to the predicted time-of-day of each trip. Because the trip start-times from DAYSIM occur at a limited number of unique times, a random number breaks ties to settle the order in which trips are processed and given priority at parking lots. One parking zone is chosen for each DAYSIM drive-transit trip, which has the least total generalized cost from its auto and transit legs. The remaining capacity of the chosen zone is decreased by 1 vehicle; if that was the zone's last available parking space, then the zone is unavailable to all later trips.

In addition to the trip pairs labeled with the parking lot choice, the AM drive-transit trip processor also outputs the schedule of when each parking zone fills up, expressed as a fractional number from 0 to 1, representing the cumulative fraction of AM period trips that have been processed.

For the midday period, all lots that fill up in the AM period are unavailable. For PM and evening, all lots are available for drive-to-transit trips. Airport transit-drive trips are not disaggregate and are few in number, so all parking lots are considered available to them.

4 Land Use Data

4.1 Land Use for SACSIM Introduction

For its transportation planning functions as a Metropolitan Planning Organization, SACOG's jurisdiction covers part of all of the six county Sacramento region. This area includes Sacramento, Sutter, Yolo and Yuba counties in their entirety, and the portions of Placer and El Dorado counties below the Sierra Nevada ridge line. The extreme eastern portion of Solano County falls in the Sacramento air basin for some emissions, but is within the jurisdiction of the Metropolitan Transportation Commission for federal transportation planning purposes; for this reason the Commission provides emissions estimates to SACOG for air quality regulatory purposes.

This chapter presents the process for assembling SACSIM parcel-point data files. This discussion focuses mostly on building the SACSIM file from land use datasets and other data sources. Land use dataset is the primary data source for households and jobs on each parcel. School employment and enrollments, street pattern, off-street parking supply and cost, and transit proximity come from various other data sources, described below. It is helpful to have clear definitions of some terms and processes:

4.1.1 Terminology

- *Parcels* are pieces of land with area, shape, and location defined by assessor's maps and records. In general, this definition applies to SACSIM, with a couple of caveats:
    - SACSIM parcellation was initially created on best assessors records available to SACOG . Every four years during the MTP/SCS, this parcel data is updated with most recent data from available sources.
    - Large parcels with significant growth from the base year to the planning horizon year (2040) were manually split down to "false" or "pseudo" parcels, which have no bearing to assessor's records.
- *A Parcel-point* is a dimensionless point located roughly at the geographic center of a parcel, and used to represent the location of that parcel for SACSIM. The points have unique identifiers which allow for parcel data (e.g. dwellings or jobs estimates from land use model) to be matched or aggregated to the parcel-points.
- *Base year inventories* are datasets of land use features which are not directly represented in land use model, and maintained as separate datasets. Generally, these are GIS point files, which are matched or aggregated to parcels (and later, parcel-points) based on their location.
- *Base-to-future changes* are land use or transportation system changes which are flagged by comparing a future year scenario file (typically, a land use parcel data file) with a comparable base year file. Changes are flagged based on change in use (place type), or a change in the intensity of development (dwellings and jobs), comparing the future year scenario to the base year data at parcel level.
- *Base-plus-future-change datasets* are assembled by using the base year data for parcels with little or no change, and a future year estimate of use if a change has been flagged. This basic

approach for creating future year datasets is used for SACSIM school enrollment, school employment, street pattern, transit station or stop, and off-street parking facility uses.

4.2 Land Use Data Files

The land use model provides the land use input data file for use in creating the SACSIM parcel-point data file. Estimates of dwelling units and employment by sector are developed at parcel level in land use model. SACSIM utilizes geographic information system (GIS) outputs from Land use modeling and augments the dwelling and employment estimates with other information, which is described in greater detail below. There are several key concepts and terms which are useful in understanding the capabilities of land use model:

- *Landuse Type* is the fundamental description of the existing or future land use of a parcel. This roughly corresponds to general plan land use types commonly used by jurisdictions for describing land use policy; however, Land use model allows for more standardized land use types to be utilized across the region. Along with other variables described below, dwelling unit and employment rates per acre are associated with place types, and are utilized as one component of an estimate of the quantity of dwellings or jobs on a parcel.
- *Percent developed or percent covered* is the percentage of a parcel which is developed per the coded place type.
- *Gross-to-net acreage percentage* is the percentage of the parcel area which could be developed, net of setbacks, sidewalks, streets, and other dedications.
- *Constraints* are geographic (e.g. slope) or policy (e.g. flood zone) variables which generally reduce the development potential of a particular parcel.
- *Redevelopment potential* is coded to parcels through various fields in Land use model, to represent the likelihood of a given existing, developed parcel changing its use (place type) or development intensity.

Using all these available concepts and data layers, land use modeling generates estimates or yields of dwellings and jobs for each parcel Base year (2016) inventory, estimates are gathered by control totals at the census block level and paired with parcel database inventory to determine the land use with number of dwelling units. Employment categories also collected at the census block level or smallest geography available, are then proportionally distributed or “painted” onto the parcel level into sub-employment categories based on the land use types.

Future scenarios are developed by changing place type, coverage, constraints or redevelopment potential at parcel level, and re-estimating the yields of dwelling and jobs for each parcel. The MTP/SCS must address state and federal requirements Table 4-1 illustrates all the regulatory, policy, and market based factors considered in considering the MTP/SCS land use forecasts.

Table 4-1 Land Use Forecast Consideration Factors

Draft February 2018

Factors Considered in Updating the MTP/SCS Land Use Forecast

	Regulatory/Policy and Market Factors	Description of projects assumed to have the highest likelihood to build within 20 years	Middle range of conditions	Description of projects assumed to have the lowest likelihood to build within 20 years
REGULATORY	Local Entitlements	Specific Plan approved, Annexation complete (if required), Tentative Map(s) in process	Range of conditions includes: projects that are approved but still need annexation; projects approved but no tentative maps submitted; projects approved but have unsettled lawsuit; projects currently in process; projects in pre-application	No current entitlement activity; identified by general plan or SOI as future growth area
	State/Federal Entitlements	Approved	Range of conditions includes: projects that are not yet approved but in process; projects participating in an HCP or NCCP; projects with no significant resource issues	Significant, unresolved resource issues
POLICY	Air Quality	In SCS with lower VMT than average for Developing Communities	Range of conditions includes: projects that are in the SCS with average VMT; projects in the SCS with higher than average VMT; projects not in the SCS with lower than average VMT; projects not in the SCS with average VMT	Not in SCS with above average VMT for Developing Communites
	Regional Plans and Policies	Consistent with 2012 MTP/SCS and Blueprint	Range of conditions includes: projects in MTP/SCS and partially consistent with Blueprint; projects in MTP/SCS and not consistent with Blueprint; projects consistent with Blueprint and not MTP/SCS; projects partially consistent with Blueprint and not in MTP/SCS	Not consistent with 2012 MTP/SCS or Blueprint
MARKET	Proximity to Job Centers	Close proximity to a regional jobs center	Range of conditions includes: projects partially within 4 miles of a regional job center; projects within 4 miles of a secondary job center; partially within 4 miles of a secondary job center	Significant distance from any job center(s)
	Housing Mix	Mix of housing types including mostly small-lot and attached	Range of conditions includes: projects that have a mix of housing types including small-lot and attached housing at varying amounts; projects that are primarily large-lot residential because they are in more rural areas	All large-lot single-family where higher densities could be supported (i.e more urban or suburban locations)
	Market Area Saturation	Historically high market demand and limited number of approved or pending projects in market area	Range of conditions includes: projects in areas with high market demand and high number of approved or pending projects in market area; projects in areas with average market demand and a high number of approved or pending projects in market area; projects in area with lower market demand and a high number of approved or pending projects in market area, but have a unique factor that could significantly change the market demand for the area	Historically low market demand and a high number of approved or pending projects in market area
	Adjacency	Adjacent to existing urban development or has significant borders with a city boundary or areas designated for future urban development	Range of conditions includes: projects that are adjacent to existing development at varying rates	Less than 10% adjacent with existing urban development,a city boundary or areas designated for future urban development
	Developer Activity	Very active, single ownership or experienced ownership partnerships, multiple completed projects in region	Range of conditions includes: very active to active, single or multiple ownerships with no development history; single or mulitple ownerships with varying levels of activity and some projects completed in the region; single or mulitple ownerships with varying levels of activity and no history of completed projects in or outside the region	Not active, single or multiple ownership, no completed projects in the region
	Transportation Infrastructure	No major or regional infrastructure needed or infrastructure is fully funded	Range of conditions includes: projects that have some infrastructure, but need more; projects that can build some before significant infrastructure investment is needed; projects that need significant infrastructure and have funding	Significant infrastructure needed and not funded or not yet defined
	Other Infrastructure (sewer, water, flood control, etc)	No major or regional infrastructure needed of infrastructure is fully funded	Range of conditions includes: projects that have some infrastructure, but need more; projects that can build some before significant infrastructure investment is needed; projects that need significant infrastructure and have funding	Significant infrastructure needed and not funded or not yet defined

Source: SACOG 2020.

4.3 SACSIM Parcel-Point Structure and Variables

The SACSIM parcel file is the key land use input for the SACSIM model. Each record in this file represents an individual parcel. The only spatial information contained in the file is the X and Y coordinates of a point (preferably the centroid) within the parcel. Table 4-5 presents the variable names and descriptions included in the initial parcel point file. While the majority of the parcel data is built in GIS, the SACSIM input is written to an ASCII delimited (tab, space or comma as delimiter specified in the DAYSIM configuration files) text file format. Additional buffering information will be added to the Parcel-Point file for the SACSIM final input format described later in this chapter. Below are further descriptions of the parcel-point initial variables.

4.4 Parcel Variables

The parcel point file is used as the DAYSIM "microzone" file containing the parcel id, geographic coordinates, and land use variables including land use type, number of households, employee total and sub employee categories, public off street parking spaces and pricing. The sections that follow provide a brief description of the parcel variables and Table 4-3 lists out the field names as they appear in the parcel file.

4.4.1 Parcel Identification

The PARCELID filed is required as the unique identify for every individual parcel This must be a unique, ascending, positive integer identification number. PARCELID is required to associate back to the trip and household tables DAYSIM table outputs. SACSIM only used Parcel's with households, employment, students, and/or parking. All other areas such as forests or vacant parcels are not included. For this reason, PACELID may have gaps provided in ascending order to remove these parcels from the complete SACOG regional parcel land use file.

4.4.2 Coordinates

The XCOORD_P and YCOORD_P fields store the X and Y State plane coordinates of each parcel's location. The location is a point within the parcel area and closest to the centroid as possible. The precision of the coordinates is to the nearest foot and therefore these fields store the data as Long Integers.

4.4.3 Area

The SQFT_P field stores the area of the parcel in square feet. This is usually calculated from the geometric area of the parcel polygon feature. Some parcels may have a geometry that could be corrupt which could result in zero square feet.

4.4.4 Traffic Analysis Zone

The TAZ_P field is used to link the DAYSIM "Zone" data to the "Microzone" data. SACSIM links ~1500 Traffic Analysis Zones (TAZ) to ~800,000 parcels. TAZ are later Used for SACSIM trip aggregation and assignment.

4.4.5 Households

Households on each parcel are estimated by occupancy rate and the number of dwelling units (DU's) from land use dataset. Occupancy rate is sourced from ACS sample data and adjusted by regional control of the number of households. More information on households is in chapter 5, Representative Population Data.

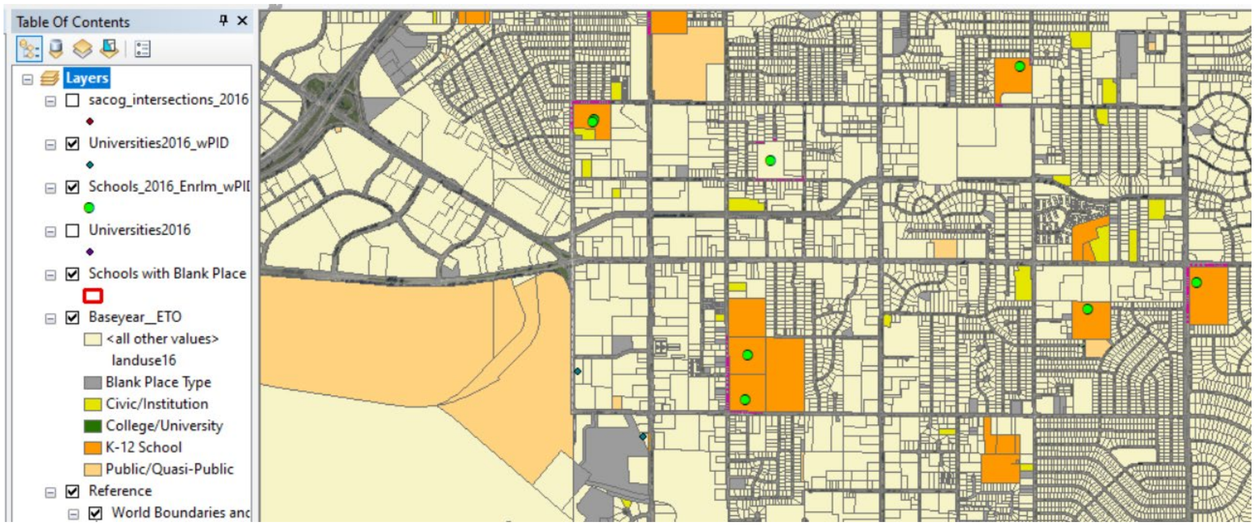
4.4.6 K-12 Student Enrollment

The STUGRAD and STUHGH field stores the number of students on parcels that have elementary, middle and high schools. SACOG collected student enrollment data for the base year inventory (2016), and forecasts future enrollment based on land use forecasting data. Populating student enrollment fields involves constructing a shapefile or table of existing or forecasted school locations with enrollment numbers and moving these numbers.

4.4.6.1 Base Inventory

The STUDUNI field stores the number of students on parcels that are part of major universities and community colleges. As with K-12 enrollment, university enrollment inventory, involves constructing a shapefile or table of existing and projected university/college locations with student enrollment. Figure 4-1 illustrates an example of K-12 and University enrollment inventory spatially associated to corresponding parcel land use types.

Figure 4-1 K-12 and University Student Inventory Collection for Parcel File Development



4.4.6.2 College and University Student Enrollment

Universities with a student body largely in person are counted in full. Universities or colleges with enrollment but have a larger amount of online classes and are not likely to travel daily to campuses to attend courses are weighted by reducing the overall student enrollment. Full or primarily online programs with student enrollment that do not travel to campus are not included in STUDUNI number of students.

4.4.7 Employment

Employment variables are:

- Education (empedu);
- Food service (empfoo);
- Government (empgov);
- Industrial (empind);
- Medical (empmed);
- Office (empofc);
- Retail (empret);
- Service (empsvc);
- Other (empoth); and
- Total employment (emptot).

SACSIM employment types are based on land use model employment types, which in turn are based on a simplified scheme of industrial sector categories. That is, they are based on the industrial sector which describes the use on a given parcel, and not the classification of the job in occupational terms (e.g. laborer, clerical, administrative, technical, professional, managerial, etc.). Table 4-2 shows SACSIM defined employment categories based on the North American Industry Classification System (NAICS) codes. These definitions were applied and used by SACOG in establishing its land use scenario analysis system.

4.4.7.1 Processing of Medical Employment

Medical employment is defined differently between land use model and SACSIM. Medical employment is generated in land use model by one place type: Medical Facility, which is defined as hospitals and major medical centers, with 400 or more employees. SACSIM requires a more expansive definition of medical employment, which includes both hospitals/major medical centers, plus medical employment in smaller offices, clinics, etc. Most of this medical sector employment is dispersed and mixed in office and business park areas, with higher concentrations located around hospitals and major medical centers. In order to resolve this inconsistency in definition, a portion of the employment in office and service areas is “converted” to medical; additionally, the portion of the total employment which is so converted varies directly with proximity to hospitals/major medical centers. That is, the closer an office- or service- employment generating use is to a hospital/major medical center, the greater the proportion of total employment which is likely to be medical

Table 4-2 NAICS Code and SACSIM Sectors

SACSIM sectors	SACSIM name	NAICS codes	Subcodes / Description
Education	EMPEDU	61	Educational Services *(exclude 6115-6117 trade school, education support, include in service)*
Food service	EMPFOOD	722	7221-7225 (restaurants and bars)
Government	EMPGOV	92	Public Administration *(exclude 9281 security and information, include in Other)*
Industrial	EMPIND	11	Agriculture, Forestry, Fishing and Hunting
		21	Mining, Quarrying, and Oil and Gas Extraction
		22	Utilities
		23	Construction
		31-33	Manufacturing
		42	Wholesale Trade
		48-49	Transportation and Warehousing *(exclude 4911 post office, include in service)*
		562	562 - (5621 - 5629) included in industrial because uses are administrative for waste, utilities and construction uses.
Medical	EMPMED	62	Health Care and Social Assistance *(exclude 623-624 nursing and residential care, social service, include in service)*
Office	EMPOFC	51	Information
		52	Finance and Insurance
		53	Real Estate and Rental and Leasing
		54	Professional, Scientific, and Technical Services
		55	Management of Companies and Enterprises
		56	Administrative and Support and Waste Management and Remediation Services (exclude 562, construction, include in industry)

SACSIM sectors	SACSIM name	NAICS codes	Subcodes / Description
		813	8131 - 8139 included in Office (Office) because uses are larger civic and charitable organizations.
Other	EMPOTH	9281	9281 (military) included in Military/Other
Retail	EMPRET	44-45	Retail Trade
Service	EMPSER	4911	4911 post office
		6115-6117	6115-6117 (trade and technical schools) included in Retail(Service) because I-PLACE3S Education is K12 and college related
		623	623 - Nursing and Residential Care Facilities
		624	624 - Social Assistance
		71	Arts, Entertainment, and Recreation
		721	Accommodation and Food Services (exclude 722, include in Food)
		81	Other Services *(except Public Administration, exclude 813 (8131-8139), include in office)*

Source: SACOG 2020.

4.4.8 Parking

Parking is included in SACSIM for off-street, paid parking only. The number of daily spaces (parkdy), hourly spaces (parkhr), daily parking cost (ppricdy), and hourly parking cost (pprichr) variables are included. Base year parking inventory was gathered by using parking inventory data from previous iterations of SACSIM, aerial imagery, and ParkMe spaces and prices. Currently, the supply variables are not distinguished; i.e. for paid off-street facilities, all spaces are assumed to be available for either hourly or daily use, and the supply variables are equal.

Table 4-3 SACSIM Unbuffered Parcel File Variables

Header label	Valid values	Description, comments
parcelid	1 – 9999999	The parcel ID number. Values must be unique positive integers, in ascending order. (Gaps are allowed, but not efficient for memory.)
xcoord_p	1-999999999	The x coordinate of the parcel centroid, in integer length units (typically SPF).
ycoord_p	1-999999999	The y coordinate of the parcel centroid, in integer length units (typically SPF).
sqft_p	0-999999999	The area of the parcel, in thousands of square length units (typically sqf, does not need to be an integer)
taz_p	1-9999999	The zone that the parcel is in. Must be a valid zone_id in the "zone" file
lutype_p	0-9999999	A land use type value. This variable currently has no mandatory use in the DAYSIM code, so is available for region-specific usage.
hh_p	Real >=0	The number of households residing on a parcel.
stugrad_p	Real >=0	The number of grade school (K-8) students enrolled in schools on a parcel
stuhgh_p	Real >=0	The number of high school (9-12) students enrolled in schools on a parcel. If this is not available separately, then set to 0 & put the number of K-12 students in stugrd_p
stuuni_p	Real >=0	The number of university/college students enrolled in schools on a parcel.
empedu_p	Real >=0	The number of educational employees working on a parcel
empfoo_p	Real >=0	The number of food service employees working on a parcel
empgov_p	Real >=0	The number of government employees working on a parcel
empind_p	Real >=0	The number of industrial employees working on a parcel
empmed_p	Real >=0	The number of medical employees working on a parcel

Header label	Valid values	Description, comments
empofc_p	Real >=0	The number of (other) office employees working on a parcel
empret_p	Real >=0	The number of retail employees working on a parcel
empsvc_p	Real >=0	The number of (other) service employees working on a parcel
empoth_p	Real >=0	The number of other sector employees working on a parcel. Typically contains construction, agriculture, mining.
emptot_p	Real >=0	The total number of employees working on a parcel. Should equal the sum of the 9 previous fields.
parkdy_p	Real >=0	The number of paid public off-street parking spaces on a parcel with per day pricing. (May overlap with parkhr_p if have both types of pricing.)
parkhr_p	Real >=0	The number of paid public off-street parking spaces on a parcel with per hour pricing. (May overlap with parkdy_p if have both types of pricing.)
ppricdyp	Real >=0	The average price of public off-street parking spaces on a parcel with per day pricing. (In cents per day)
pprichrp	Real >=0	The average price of public off-street parking spaces on a parcel with per hour pricing. (In cents per hour)

Source: SACOG 2020. Downloaded from RSG *DAYSIM Input Data File Documentation* GitHub RSGInc/DAYSIM

4.5 SACSIM Land Use Spatial Association

4.5.1 Circuity Buffer Introduction

The Parcel-Point DAYSIM file not only includes the parcel level variables described above, but also requires relative distance information to calculate attractiveness between land use data. Previous versions of SACSIM utilized a Euclidean distance parcel point to parcel point approach which is common in buffering analysis. SACSIM19 parcel point files uses a hybrid approach between shortest orthogonal path, and node to node path distances call “circuity-based measures for each parcel”. This method creates a “circuity surface” using 24 radially distributed points to represent the path distances from a walkable streets network based on XY coordinates; 8 directions at 3 distinct distance bands (0.5 mile, 1 mile and 1.5 mile) and the parcel-point location. Each point is then mapped to the closest network node. For a parcel, a circuity factor or ratio is calculated based on the shortest path distance and straight line distance for all 24 radial points. To measure the distance from a parcel to another parcel, the distance is interpolated based on the circuity factors surrounding the destination parcel. Figure 4-2 illustrates the circuity path distance calculation conceptually. Figure 4-3 shows how the decay function adjusts the radial point distances per parcel. Figure 4-4 compares the relationship of parcels distance to employment centers using the “Circuity buffering” process compared to a Euclidean distance.

Figure 4-2 Parcel Circuity Ratio Diagram

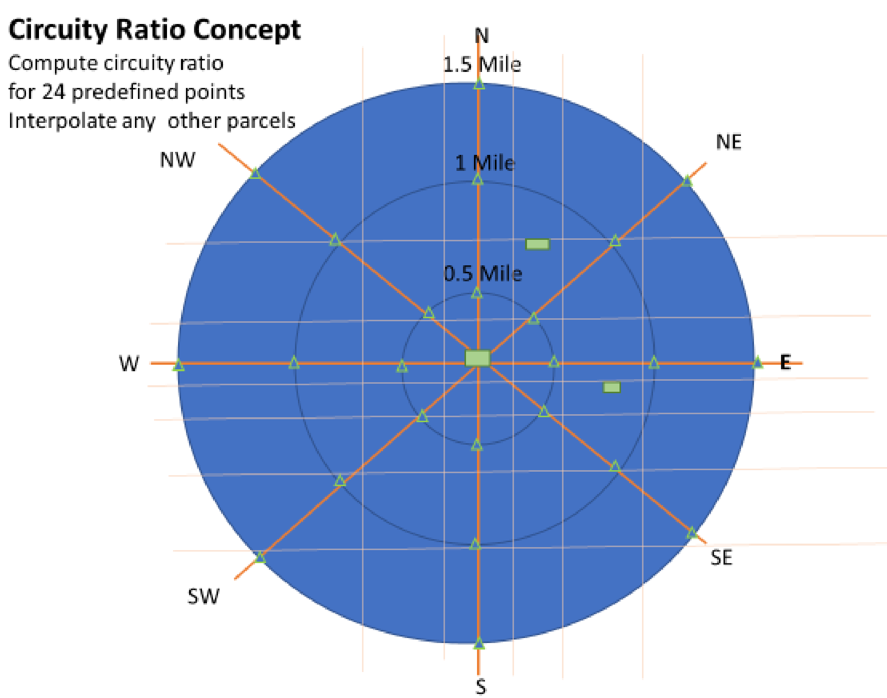
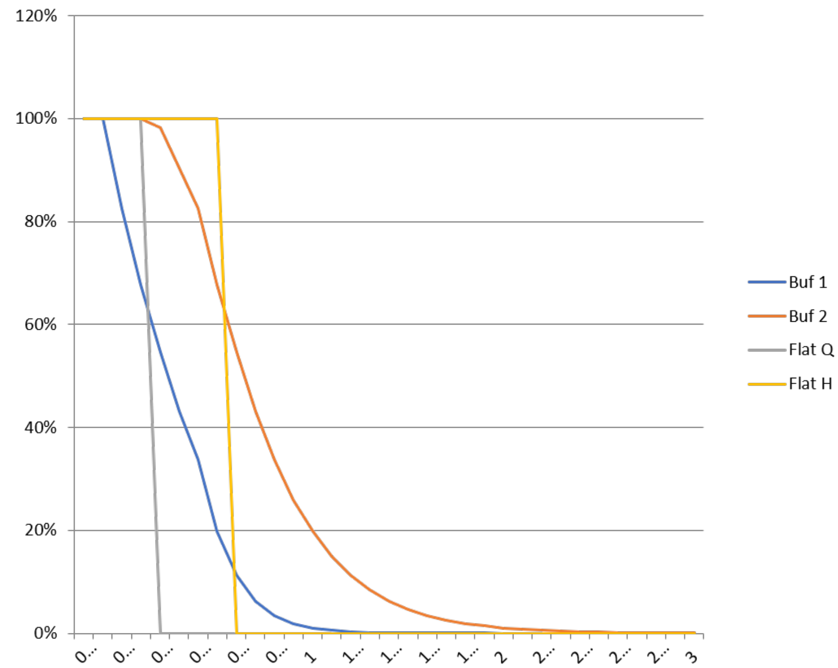


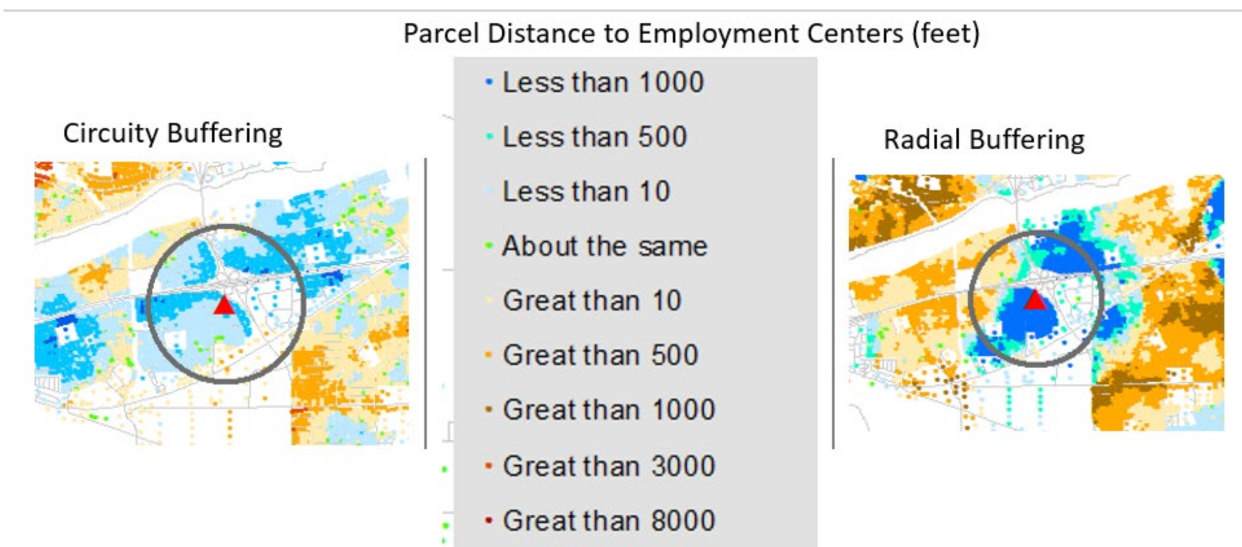
Figure 4-3 Decay Function Compared to Flat Buffering Relationship

Mile	Feet	Buf 1	Buf 2	Flat Q	Flat H
0.1	528	100%	100%	100%	100%
0.125	660	100%	100%	100%	100%
0.2	1056	83%	100%	100%	100%
0.25	1320	68%	100%	100%	100%
0.3	1584	55%	98%	100%	100%
0.35	1848	43%	90%	100%	100%
0.4	2112	34%	83%	0%	100%
0.5	2640	20%	68%	0%	100%
0.6	3168	11%	55%	0%	100%
0.7	3696	6%	43%	0%	100%
0.8	4224	3%	34%	0%	0%
0.9	4752	2%	26%	0%	0%
1	5280	1%	20%	0%	0%
1.1	5808	1%	15%	0%	0%
1.2	6336	0%	11%	0%	0%
1.3	6864	0%	8%	0%	0%
1.4	7392	0%	6%	0%	0%
1.5	7920	0%	5%	0%	0%
1.6	8448	0%	3%	0%	0%
1.7	8976	0%	3%	0%	0%
1.8	9504	0%	2%	0%	0%
1.9	10032	0%	1%	0%	0%
2	10560	0%	1%	0%	0%
2.1	11088	0%	1%	0%	0%
2.2	11616	0%	1%	0%	0%
2.3	12144	0%	0%	0%	0%
2.4	12672	0%	0%	0%	0%
2.5	13200	0%	0%	0%	0%
2.6	13728	0%	0%	0%	0%
2.7	14256	0%	0%	0%	0%
2.8	14784	0%	0%	0%	0%
2.9	15312	0%	0%	0%	0%
3	15840	0%	0%	0%	0%



Source: SACOG 2020.

Figure 4-4 Circuity vs Radial Buffering Comparison



Source: SACOG 2020.

4.5.2 Files Required for Circuity Buffer Process

Circuity Factor File: a parcel list with circuity factors or ratios of 24 points describe above.

Parcel Base: a parcel list with all variables is specified in Table 4-5.

Intersections: A list of intersections, with node ID, XY coordinates, and number of links terminating at the node. (This can be the same file as the node list used above, but it should contain all intersections, regardless of whether or not it is a nearest node to any parcel, and it contains the extra information on number of links ending at the node.)

Transit stops: A list of transit stops, with stop ID, XY coordinates, and the type of transit serving the stop. SACSIM19 currently uses local bus and LRT stops are used for parcel to parcel buffering.

Open space areas: A list of parks, sports fields and other public recreational areas, with an ID and the size, in square feet. If this file is not provided, the buffered variables for open space will be 0.

4.5.3 Development of Circuity Buffering Inputs

This section describes the process of how to create the necessary input variables to calculate the parcel circuity buffering process.

4.5.3.1 Circuity Factor File Creation

Parcel and network information are read in and 24 fictitious points around the parcel are created (from the X and Y coordinates of the parcels). The 24 points correspond to 8 directions (East, Northeast, North, Northwest, West, Southwest, South, and Southeast) and 3 distance bands (0.5, 1.0, and 1.5 miles) around each parcel. Each of the 25 points (including the parcel itself) is then mapped to its closest node on the network. The process and tools needed are described in Appendix F, Circuity Surface Data Preparation Memo.

Regional circuity factor regional averages by base year land use type inventories were used to forecast scenario parcels in new development areas.

Further process, description and tools needed are described in Appendix F Circuity Surface Data Preparation Memo.

Intersection File Process

Each parcel record in the SACSIM table must have information about the surrounding walkable street network pattern. This information is stored in the following fields: NODES1Q, NODES1H, NODES3Q, NODES3H, NODES4Q and NODES4H. NODES1 indicates the number of nearby cul-de-sacs and dead-ends. NODES3 indicates the number of nearby "T" or three-way intersections and NODES4 indicates the number of nearby 4-way (or more) intersections. These fields affect the walkability of the street network surrounding a parcel.

4.5.3.1.1 Street Intersection Base Layer

To populate the node fields, spatial buffer operations must be performed against a layer of street intersections. Generally, this layer can be created from a street centerline layer use a line to point style node_builder script. These street intersections do not include nodes along freeways and other facilities that are closed-off to pedestrians.

The node_builder script will identify the number of links attached to the nodes (valence) so that they can be separated into 1-link, 3-link and 4+-link layers.

Figure 4-5 Street Intersection (NODE) Layer

Source: SACOG 2020.

Figure 4-6 Node Typology

Source: SACOG 2020.

4.5.3.1.2 Intersections for Future Streets

Street centerline data do not exist for future development areas. SACOG implemented an estimation of 1-link, 3-link and 4+-link nodes per acre based on the place type of a future-development area. These estimations were applied to a grid of synthetic nodes of fixed area, and nodes/acre values to them. For example, for a newly developed greenfield area typical rates of 1-link, 3-link and 4+-link intersections were applied to each grid point, based on the development type. These node densities are listed below in Table 4-4 for each place type.

Table 4-4 Node Density by Place Type

Place Type	1-Leg Intersections per acre	3-Leg Intersections per acre	4-Leg Intersections per acre
1. Rural Residential	0.026	0.020	0.039
2. Very Low Density Residential	0.026	0.065	0.052
3. Low Density Residential	0.065	0.260	0.104
4. Medium Density Residential	0.130	0.390	0.260
5. Medium-High Density Residential	0.130	0.390	0.260
6. High Density Residential	0.013	0.390	0.455
7. Urban Residential	0.013	0.390	0.455
8. High-Intensity Office	0.013	0.390	0.455
9. Moderate-Intensity Office	0.130	0.195	0.390
10. Community/Neighborhood Retail	0.000	0.104	0.039
11. Regional Retail	0.013	0.104	0.013
12. Light Industrial - Office	0.013	0.104	0.013
13. Light Industrial	0.013	0.104	0.013
14. Heavy Industrial	0.013	0.104	0.013
15. Public/Quasi-Public	0.013	0.026	0.013
16. Community/Neighborhood Commercial/Office	0.000	0.104	0.039
17. Regional Commercial/Office	0.013	0.104	0.013
18. Mixed Use Employment Focus	0.130	0.390	0.260
19. Mixed Use Residential Focus	0.130	0.390	0.260
24. Low Density Mixed Residential	0.065	0.260	0.104
25. Medium Density Mixed Residential	0.130	0.390	0.260
26. High Density Mixed Residential	0.013	0.390	0.455
27. Low Density Mixed Use Center or Corridor	0.065	0.260	0.130
28. Medium Density Mixed Use Center or Corridor	0.130	0.325	0.195
29. High Density Mixed Use Center or Corridor	0.013	0.325	0.390
31. Suburban Center/Corridor	0.065	0.260	0.130
40. Sac CBD High Intensity Mixed Use Office	0.020	0.260	0.590
45. Intense Urban Residential	0.100	0.260	0.260
47. Agricultural Residential	0.020	0.010	0.050
47. Medical Facility	0.010	0.070	0.010
48. Airport	0.010	0.010	0.010
50. K-12 Schools	0.010	0.030	0.010
51. Colleges and Universities	0.050	0.070	0.130
52. Civic/Institution	0.100	0.260	0.130

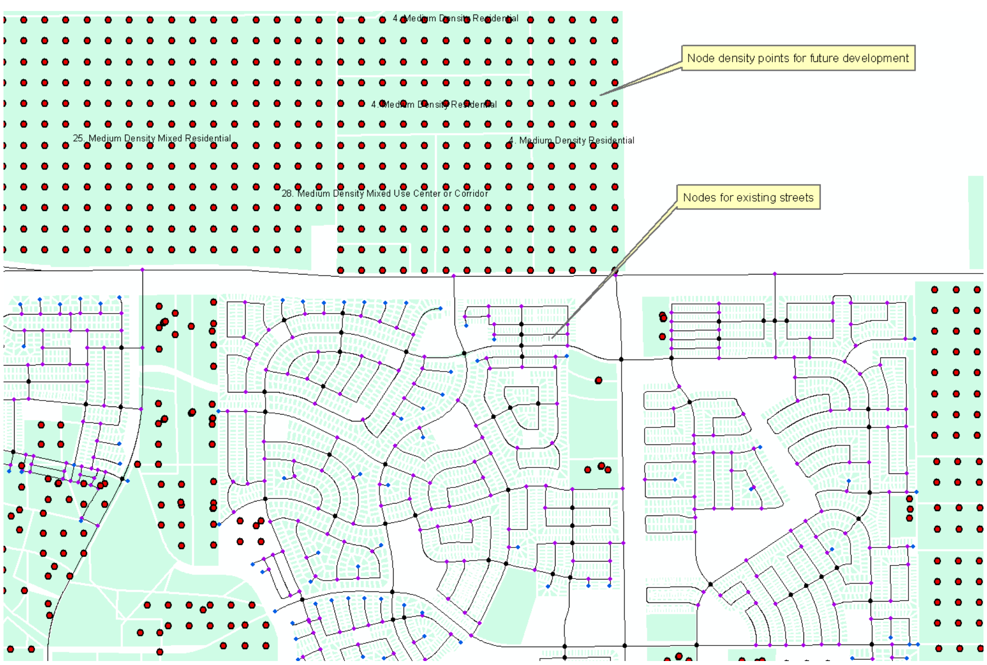
Source: SACOG 2020.

The first step in determining where to generate the grids of synthetic nodes is to identify those areas where future greenfield development will occur. Figure 4-7 shows a portion of the region where development exists with streets and areas slated for future development. In these areas of future development are synthetic nodes to represent a street pattern based on development type.

Once node rates have been set, the synthetic nodes may be combined with real nodes so that the node proximity variables (NODES1Q, NODES1H, NODES3Q, NODES3H, NODES4Q and NODES4H) can be computed. An example is shown below of combining the node sets to create a point layer of 1-link nodes.

A final forecasting step takes into consideration new development areas within SACOG designated Complete Street project areas. Within 500 feet of the complete street identified segments, a 20 percent increase in unit value was added to 3- or 4-way intersections and a 20 percent decrease for one-way (cul-de-sac) intersections. These factors are applied as a factor to better represent complete street design infrastructure and safety characteristics.

Figure 4-7 Synthetic Nodes for Future Development Street Pattern

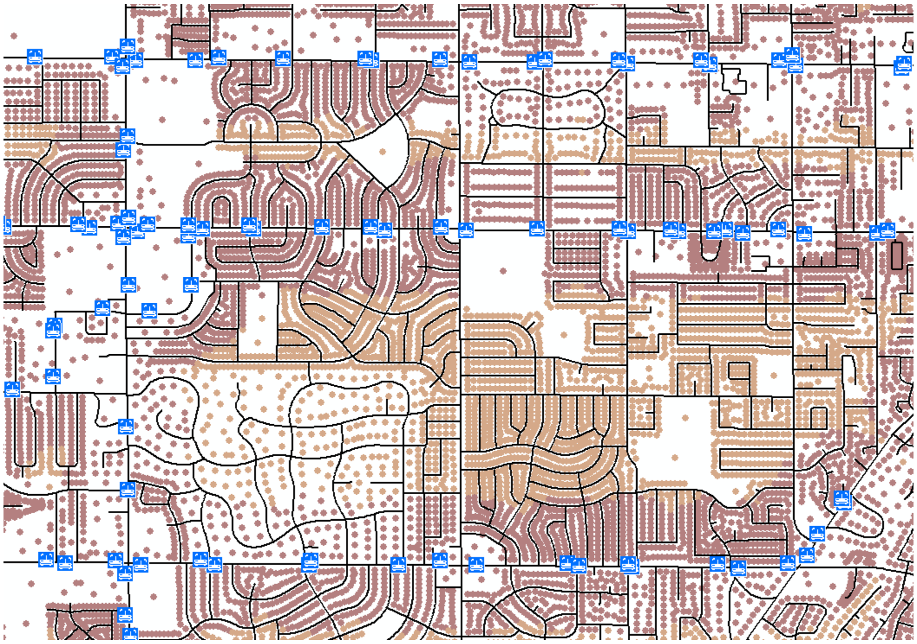


Source: SACOG 2020.

4.5.3.2 Transit Stops File Process

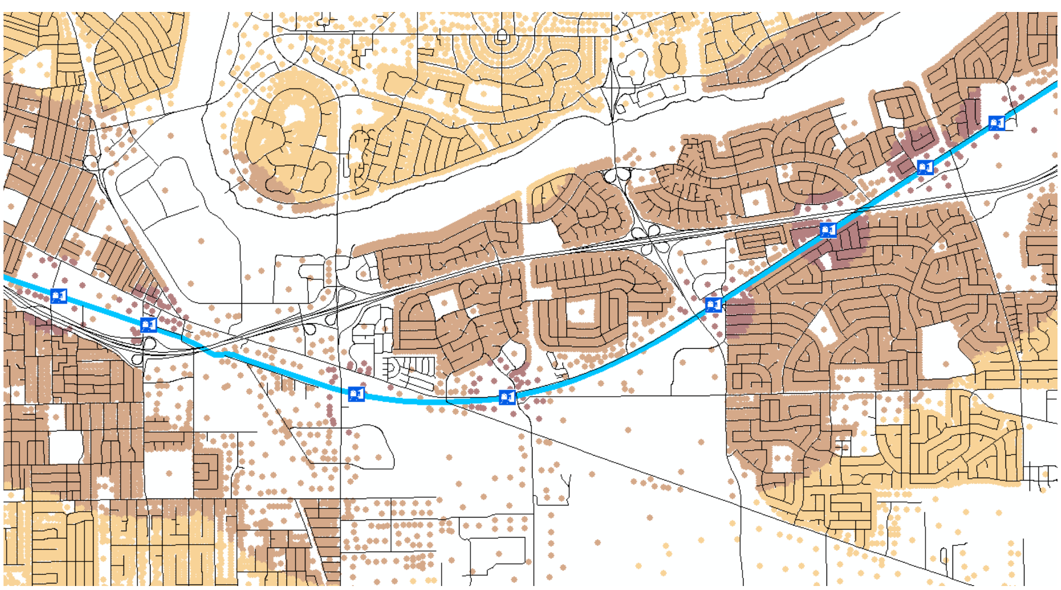
Transit proximity is represented at parcel level as the distance to the nearest transit station or stop. Two variables are computed for each parcel: the distance to the nearest LRT (or more generally, rail) station (DIST_LRT), and distance to the nearest bus (or more generally, rubber-tired) stop. The distance is computed as the straight-line distance from the parcel point and the nearest station or stop. Figure 4-8 and Figure 4-9 show the relationship between Bus and Light Rail Stops to parcel-points.

Figure 4-8 Bus Stops and Parcel Centroids



Source: SACOG 2020.

Figure 4-9 LRT Stations and Parcel Centroids



Source: SACOG 2020.

4.5.3.3 Open Space File Process

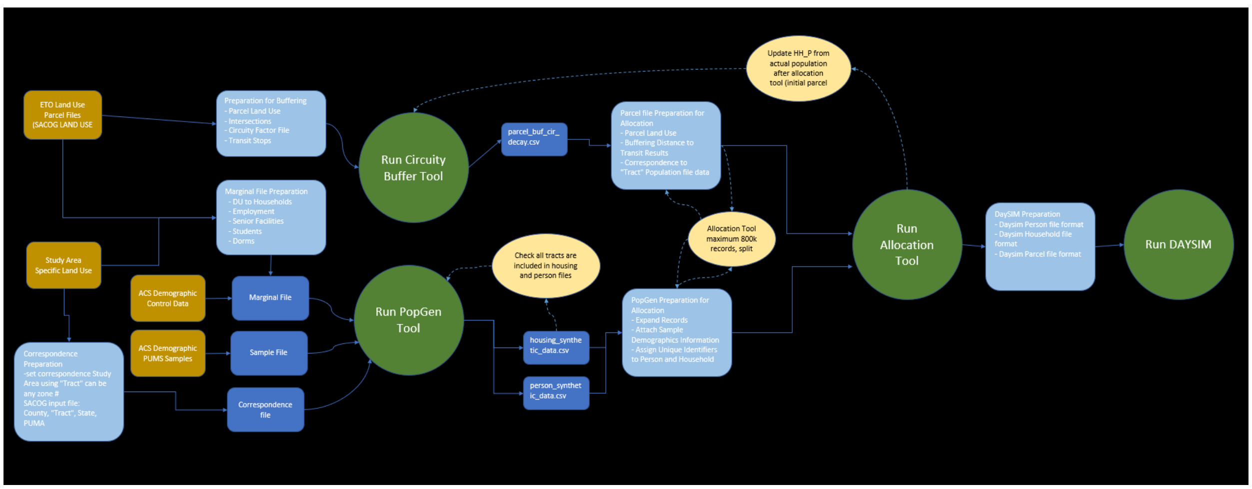
Open space file includes open space areas with public recreation access. This includes parks and sporting fields. Large open spaces with restricted access were removed from file. Open spaces are represented by a centroid location and area.

4.6 SACSIM Parcel Land Use User Guide

4.6.1 Introduction

SACSIM19 requires detailed parcel, household, and population data inputs to run DAYSIM at a parcel zone level. Preparing these files is not part of SACSIM itself, but a necessary preparatory step to create and format the inputs needed to model a scenario. These three files are interdependent; they require specific relationship identification fields to link between data such as parcel point locations, household and person characteristics. More information on these files and relationships can be found in *Appendix B SACSIM19 Data Dictionary.xlsx.* Steps described in this section are how SACOG staff developed these files for scenarios during the 2020 MTP/SC with the data and processing available at this time. Steps below layout how to create the initial parcel file, spatial land use attributes, and tools to join parcel, household, and population files together. Chapter 5 describes how to create the household and population files and will need to be used concurrently to develop the three inputs. Figure 4-10 illustrates the flow and sometimes iterative nature used to prepare the preprocessing land use, demographic, and population files used to build the SACSIM19 *<scenario>_raw_parcel.txt*, *<scenario>_raw_household.txt*, *<scenario>_raw_person.txt* required inputs.

Figure 4-10 Flow Chart of Land Use and Demographic File Development Process



4.6.2 Step 1: Create Scenario Parcel Base File

Create Parcel file containing all parcel variables described in Section 4.4 above and formatted in Table 4-3. Since XY coordinates, TAZ relationships, and parcel area are required, starting with a GIS boundary field is helpful.

Households and Employment totals must be defined for each SACSIM scenario. Households on each parcel are estimated by occupancy rate and the number of dwelling units (DU's) from land use dataset. Dwelling units are developed as part of our 2020 MTP/SCS. Then occupancy rate is sourced from ACS sample data and adjusted by regional control to determine the initial estimate of number of households per parcel. Employment totals and sub totals are also forecasted as part of the MTP/SCS process.

For project-level analysis, more disaggregated land use information may be readily available and should be formatted into the SACSIM parcel categories and formatting.

K-12 and University parcels will need to be identified with the number of students enrolled. This data is then assigned a corresponding PARCELID based on land use and proximity and combined into the scenario parcel file. See section Parcel Variables K-12 Student Enrollment on details for enrollment inventory and forecasting.

Parking inventory and pricing is joined to the parcel similar to student enrollment by assigning a corresponding PARCELID based on land use and proximity. SACSIM19 cost functions operates using 2000 dollars. Daily and hourly parking price data must be converted to 2000 dollars using an appropriate Consumer Price Index (CPI) conversion rate. SACOG uses the Western Regional CPI. See section Parcel Variables Parking on details for enrollment inventory and forecasting.

4.6.3 Step 2: Prepare Inputs for Parcel Buffering

Once the base scenario parcel file is created. The following Circuity Buffering process inputs must be prepared:

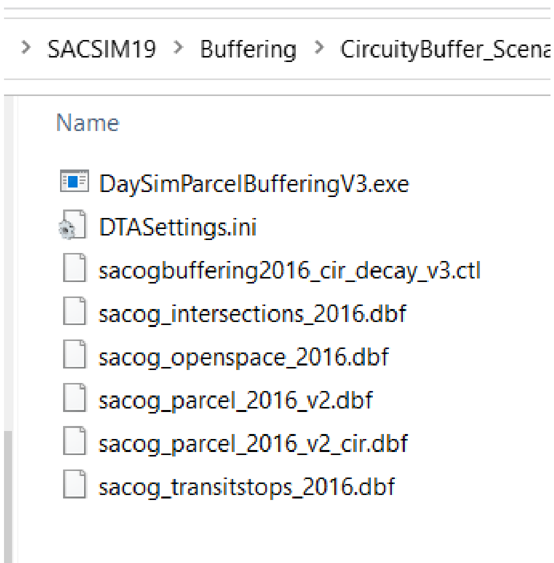
- Intersections
- Transit Stops
- Open Space
- Circuity Points

Descriptions and formatting for these files can be found under Section 4.5.3 "Developing of Circuity Buffering Inputs." and Appendix F. As part of the MTP/SCS, SACOG staff developed a circuity files for each scenario year that can be requested. This process uses the base year circuity file described in appendix F and uses the base inventory averages by land use type file *CircuityFactor_by_landuse.csv* for forecasting parcels with new development areas.

4.6.4 Step 3: Run Circuity Buffering Tool

1. Set up scenario folder with buffering executable DaySimParcelBufferingV3.exe, control file sacogbuffering_.ctl, and parcel buffering inputs.

Figure 4-11 Circuity Buffer Tool Input Folder Example



2. Set up control file inputs.
    a. Output file name and directory, this will be the be the parcel input for DAYSIM.
    b. Parcel Buffering inputs and file types created in step 1.
    c. Buffering Parameters
        i. Logistic decay parameters:
            1. Limited 3 miles
            2. Buffer Band 1 Distance 0.125 miles
            3. Buffer Band 2: Distance 0.25 miles
            4. Offsets 0.5 miles

Figure 4-12 Circuity Buffering Tool Configuration File Example

sacogbuffering2016_cir_decay_v3.ctl

```
RUNLAB sacog 2008 decay buffering with circuity adjustment
PRNTFN sacog_2016_decay_and_circ.prn                         print file name

OUTDIR .\                                            output directory pathname
OUTFNM parcel_16_buf_cir_decay_may19.txt                     output parcel buffer file name (file type always ascii)
OUTDLM 3                                             outfile file delimiter (1=space, 2=tab, 3=comma)
INPDIR .\                                            input directory pathname
PARCFT 1                                             input parcel file type (1=dbf, 2=ascii - space or tab delimited)
PARCFN sacog_parcel_2016_v2.dbf                       input parcel base data file name
INTSFT 1                                             input intersection file type (0=none, 1=dbf, 2=ascii - space or tab delimited)
INTSFN sacog_intersections_2016.dbf                  input intersection data file name
TRSTFT 1                                             input transit stop file type (0=none, 1=dbf, 2=ascii - space or tab delimited)
TRSTFN sacog_transitstops_2016.dbf                   input transit stop data file name
OPSPFT 1                                             input open space file type (0=none, 1=dbf, 2=ascii - space or tab delimited)
OPSPFN sacog_openspace_2016.dbf                      input open space data file name
CIRCFT 1                                             input circuity file type (0=none, 1=dbf, 2=ascii - space or tab delimited)
CIRCFN sacog_parcel_2016_v2_cir.dbf               input circuity data file name
CIRCDF 0                                             >0 if circuity data file is for different set of points

DLIMIT 15840.0          orthogonal distance limit (feet) above which parcels are not considered for buffering

BTYPE1 2                type for buffer 1 (1 = flat, 2 = logistic decay, 3 = exponential decay)
BDIST1 660.0            buffer 1 inflection distance (feet) - used in different way depending on buffer type
BOFFS1 2640.0           buffer1 offset distance (feet) (used for logistic decay type)
DECAY1 0.76             buffer 1 decay slope parameter (used for logistic decay type)

BTYPE2 2                type for buffer 2 (1 = flat, 2 = logistic decay, 3 = exponential decay)
BDIST2 1320.0           buffer 2 inflecton distance (feet) - used in different way depending on buffer type
BOFFS2 2640.0           buffer2 offset distance (feet) (used for logistic decay type)
DECAY2 0.76             buffer 2 decay slope parameter (used for logistic decay type)
```

3. Run executable from Command Prompt.
    a. Point to directory example: *cd Q:\SACSIM19\Buffering\Circuity\circuity_buffer_2016*
    b. Run executable with control file: DaySimParcelBufferingV3.exe sacogbuffering_.ctl

Figure 4-13 Run Circuity Buffer From Command Prompt

Command Prompt

```
Microsoft Windows [Version 10.0.18363.720]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\Windows\system32>Q:

Q:\>cd Q:\SACSIM19\2020MTP\data release\Mirror of FTP site\SACSIM19\Buffering\CircuityBuffer_Scenarios\CircuityBuffer_Sc
enarios\circuity_buffer_2016

Q:\SACSIM19\2020MTP\data release\Mirror of FTP site\SACSIM19\Buffering\CircuityBuffer_Scenarios\CircuityBuffer_Scenarios
\circuity_buffer_2016>DaySimParcelBufferingV3.exe sacogbuffering2016_cir_decay_v3.ctl
```

    c. Confirm Buffer scripts begins running through zones.

Figure 4-14 Run Circuity Buffer From Command Prompt 2

```
Command Prompt - DaySimParcelBufferingV3.exe  sacogbuffering2016_cir_decay_v3.ctl
BOFFS2 2640.0            buffer2 offset distance (feet) (used for logistic decay type)
DECAY2 0.76              buffer 2 decay slope parameter (used for logistic decay type)
Opened DBase file .\sacog_parcel_2016_v2.dbf for input
dBase file last updated: 6/5/119
File has 24 data fields  and 751364 records of 403 bytes
Field 1: PARCELID   N10.0
Field 2: X_COORD   N10.0
Field 3: Y_COORD   N10.0
Field 4: AREA_SQF   N10.0
Field 5: TAZ   N10.0
Field 6: LUSECODE   N10.0
Field 7: HH_P   F19.11
Field 8: STUGRD_P   F19.11
Field 9: STUHGH_P   F19.11
Field 10: STUUNI_P   F19.11
Field 11: EMPEDU_P   F19.11
Field 12: EMPFOO_P   F19.11
Field 13: EMPGOV_P   F19.11
Field 14: EMPIND_P   F19.11
Field 15: EMPMED_P   F19.11
Field 16: EMPOFC_P   F19.11
Field 17: EMPRET_P   F19.11
Field 18: EMPSVC_P   F19.11
Field 19: EMPOTH_P   F19.11
Field 20: EMPTOT_P   F19.11
Field 21: PARKDY_P   F19.11
Field 22: PARKHR_P   F19.11
Field 23: PPRICDYP   F19.11
Field 24: PPRICHRP   F19.11
   10000   20000   30000   40000   50000   60000   70000
```

d. Buffer Complete

4.6.5 Step 4: Prepare Population file for Allocation

See Chapter 5 for more detailed instructions on preparing the household and population files.

4.6.6 Step 5: Prepare Parcel Buffer Outputs for Allocation Process

Once the synthetic population and households have been developed (Step 4) and the parcel buffering is complete. The parcel file must be prepared for the population and households to be associated back with the parcel file. SACOG uses an executable allocation process developed by RSG to perform this process. This includes assigning the correct number of dorm students, and senior facilities to the proper TAZ and Census Tracts.

To prepare the parcel file for the allocation process, the land use parcel input must be combined with the circuity buffering project outputs.

Distance fields must also be updated. The Circuity file produces 999 distance placeholders for far away distance that must be replaced with -1. All other distance formats must be converted by multiplying the distance 100 and converting to an integer.

The household count field (hh_p) from the circuity script must also be multiplied by 100 and converted to a whole integer.

Since senior facilities household demographics characteristics are controlled to only parcels where senior living facilities exists, senior facilities are added to a separate category and treated the same way Dorm students are for the Allocation process. Once these are separated into a separate 'dome' sub category, be sure to not double count senior facility households in the parcel file. Figure 4-15 shows example code of this process.

Figure 4-15 Senior Facility and Dorm Preparation Example

```
#Tracts & Dorms - Joined by parcel id by orginal parcel file
if key in parcel_dtt_dict:
    row[fieldlist.index('DORM')] = parcel_dtt_dict[key]['DORM']

    #Remove double counting of senior facilities households
    newHP = (HSP - parcel_dtt_dict[key]['DORM'])*100 if HSP > 0 else 0
    if newHP < 0:
        newHP = 0
    row[fieldlist.index('HOUSESP')] = newHP
if key in DormsForecastDict:
    DORM_senfac = row[fieldlist.index('DORM')] if row[fieldlist.index('DORM')] is not None else 0
    DORM_v = DormsForecastDict[key] + DORM_senfac
    row[fieldlist.index('DORM')] = DORM_v
```

The Allocation tool requires parcel unique identifier to be sorted in ascending order and must not be greater than 800,000 records. For this reason, we split the parcel and population files in half and run the allocation tool twice. Figure 4-16 shows example python code on how to order and split the parcel file for allocation preparation.

Figure 4-16 Format Parcel File for Allocation Example

```
arcpy.Sort_management(parcelTemp,parcelTemp + "_sort",[["PARCELID","ASCENDING"]])
print("Sorted by ParcelID")
print("Create DBF Outputs: " + outfolder)
maketable(parcelTemp + "_sort",parcelout + ".dbf","",OrderedOutFields)

# This step is due to a maximum amount of records hard coded
#  in the Allocation executable
print("Create partial Pop files for Allocation Tool")
parcel_dbfh1 = os.path.join(parcelTemp,parcelout+'h1.dbf')
parcel_dbfh2 = os.path.join(parcelTemp,parcelout+'h2.dbf')
wc_p_h1 = ''' "TRACT" < 9105 '''
wc_p_h2 = ''' "TRACT" >= 9105 '''
maketable(parcelTemp + "_sort",parcel_dbfh1,wc_p_h1,OrderedOutFields)
maketable(parcelTemp + "_sort",parcel_dbfh2,wc_p_h2,OrderedOutFields)
```

4.6.7 Step 6: Run Allocation Tool

1. Once both Population (Step 4) and parcel file (Step 5) have been prepared for allocation tool, scenario folder set is required with Allocation executable parcelAllocationModel1.exe, control file parcelallocation1.ctl, print file, dpr, and parcel and population inputs as shown in Figure 4-17.

Figure 4-17 Allocation Inputs

Name

parcelAllocationModel1.exe
schema.ini
parcelallocation1.ctl
parcel16h1.dbf
pp_popgen_expandh1.dbf
parcelAllocationModel1.dpr
parcelallocation.prt

2. Set up control file inputs and directory paths.
    a. Print file (*parcelallocation.prt*)
    b. Parcel file
    c. Population file

Figure 4-18 Parcel Allocation Configuration File Example

parcelallocation1.ctl

```
RUNLAB  SACOG Synthetic Population Parcel Allocation within Tract

RUNDIR Q:\SACSIM19\2020MTP\popgen\2016\03_2016_Base\03_PostProcess\02_Allocation\02_Split\
PRNTFN parcelallocation.prt

PCLDIR Q:\SACSIM19\2020MTP\popgen\2016\03_2016_Base\03_PostProcess\02_Allocation\02_Split\
PARCFN parcel16h2.dbf

SAMDIR Q:\SACSIM19\2020MTP\popgen\2016\03_2016_Base\03_PostProcess\02_Allocation\02_Split\
SAMPFN pp_popgen_expandh2.dbf

USEMOD 1
RNSEED 54321
```

3. Run executable parcelAllocationModel1.exe from Command Prompt.
   a. Point to directory example: *cd Q:\SACSIM19\2020MTP\popgen\\01_2016_Base\03_PostProcess\02_Allocation\01_Split*
   b. Run executable with control file: arcelAllocationModel1.exe parcelallocation1.ctl
4. Check for Parcel Allocation Errors in print file.
   a. During allocation process, print stamen keeps track of parcel allocated to zones. This step may break if number of population per zone or group quarter per zone between the parcel and population files do not match.

Figure 4-19 Review Allocation Print File for Errors

parcelallocation.prt

```


Reading sample households ....  Percent completed ...
0...10...20...30...40...50...60...70...80...90...100
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
Finished at  5/7/2019 10:20:11 AM
1244673 records read from pp_popgen_expandh2.dbf

SEQ TRACT NPCLS NDORM NDREC NHHLDS NHHREC  D/PCL  SLACK    Before Adjustment
  1 30602  2195    24    24   2446   2446  0.000      0
  2 30603  1077     0     0   1163   1163  0.000      0
  3 30601  1786     0     0   1921   1921  0.000      0
  4 31900    31     0     0     31     31  0.000      0
  5 30901  1041     0     0   1161   1161  0.000      0
  6 31302  1276     0     0   1828   1828  0.000      0
  7 31000  1673     0     0   2453   2453  0.000      0
  8 31100  1665     0     0   2221   2221  0.000      0
  9 31301  1101     1     1   1258   1258  0.000      0
 10 30801  1282     1     1   1341   1341  0.000      0
 11 30701  1945     0     0   2170   2170  0.000      0
 12 31406  1899     0     0   1971   1971  0.000      0
 13 30902  1543     1     1   1577   1577  0.000      0
 14 31405   845     0     0    876    876  0.000      0
 15 31200  1656    96    96   1934   1934  0.000      0
```

5. Review Allocation tool run is complete, review result outputs and summary in print statement.

Figure 4-20 Review Allocation Print Summary Example

parcelallocation.prt

```

Reading sample households ....  Percent completed ...
0...10...20...30...40...50...60...70...80...90...100
>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
Finished at  5/7/2019 10:20:58 AM
1244673 records read from pp_popgen_expandh2.dbf

      High  Mod.High   Mod.Low       Low  Very Low Urban/Mix Segment
      5896     17530     14066     32081     18584       611 Income  0- 20
      3963     14757     13295     38500     22513       433 Income 20 -40
      1940      9412      9990     36297     20447       199 Income 40 -60
      1991     10567     11264     42943     28619       189 Income 60-100
      1050      5602      7329     35976     26829       122 Income > 100
      8299     40727     41163    151906     95238       847 2+ pers hhld
      6541     17141     14781     33891     21754       707 1 pers hhld
     11900     50091     45636    162076    106288      1299 Family hhld
      2940      7777     10308     23721     10704       255 Non-family hhd
     12616     47096     42670    130012     85465      1281 No school kids
      2224     10772     13274     55785     31527       273 1+ school kids
      9722     43285     45055    161074     99112       895 Not all senior
      5118     14583     10889     24723     17880       659 All seniors
     14488     56237     55225    182678    114205      1507 Not single prt
       352      1631       719      3119      2787        47 Single parent

```

4.6.8 Step 7: Rerun buffering analysis

The initial buffer tool was calculated based off estimated households (ACS occupancy rates * dwelling units). Because of this, after the representative population and household allocation have been completed, the circuity buffer tool should be rerun to make sure all households proximity to transit are accurate. Important: If split for allocation, both results must be merged back using PARCELID before running Circuity Buffering and Step 8.

4.6.9 Step 8: Format Parcel File for DAYSIM

Rename and format results of final circuity buffering results into DAYSIM parcel input format: ASCII delimited, with header. The delimiter can be specified in the configuration file. Table 4-5 lists the order and description of all required fields.

Table 4-5 Parcel Input File Fields for SACSIM19

Field	Description
parcelid	The parcel ID number
xcoord_p	The X coordinate (SPF) of the parcel centroid
ycoord_p	The Y coordinate (SPF) of the parcel centroid
sqft_p	The square footage area of the parcel
taz_p	The zone_ID associated with the parcel
lutype_p	The land use type code (housing density class)
hh_p	The number of households residing on the parcel
stugrd_p	The number of grade school (K-8) students enrolled at the parcel
stuhgh_p	The number of high school students enrolled at the parcel
stuuni_p	The number of college students enrolled at the parcel
empedu_p	The number of educational employees working at the parcel
empfoo_p	The number of food service employees working at the parcel
empgov_p	The number of government employees working at the parcel
empind_p	The number of industrial employees working at the parcel
empmed_p	The number of medical employees working at the parcel
empofc_p	The number of (other) office employees working at the parcel
empret_p	The number of retail employees working at the parcel
empsvc_p	The number of (other) service employees working at the parcel
empoth_p	The number of other sector employees working at the parcel (typically agriculture, mining - not used for SACOG)
emptot_p	The total number of employees working at the parcel (equals the sum of the previous 9 values)
parkdy_p	The number of paid off street parking spaces on the parcel with per day pricing
parkhr_p	The number of paid off street parking spaces on the parcel with per hour pricing
ppricdyp	The average price per day for paid off street parking spaces on the parcel

Field	Description
pprichrp	The average price per hour for paid off street parking spaces on the parcel
hh_1	The number of households residing in Buffer 1
stugrd_1	The number of grade school (K-8) students enrolled in Buffer 1
stuhgh_1	The number of high school students enrolled in Buffer 1
stuuni_1	The number of college students enrolled in Buffer 1
empedu_1	The number of educational employees working in Buffer 1
empfoo_1	The number of food service employees working in Buffer 1
empgov_1	The number of government employees working in Buffer 1
empind_1	The number of industrial employees working in Buffer 1
empmed_1	The number of medical employees working in Buffer 1
empofc_1	The number of (other) office employees working in Buffer 1
empret_1	The number of retail employees working in Buffer 1
empsvc_1	The number of (other) service employees working in Buffer 1
empoth_1	The number of other sector employees working in Buffer 1 (typically agriculture, mining - not used for SACOG)
emptot_1	The total number of employees working in Buffer 1 (equals the sum of the previous 9 values)
parkdy_1	The number of paid off street parking spaces in Buffer 1 with per day pricing
parkhr_1	The number of paid off street parking spaces in Buffer 1 with per hour pricing
ppricdy1	The average price per day for paid off street parking spaces in Buffer 1
pprichr1	The average price per hour for paid off street parking spaces in Buffer 1
nodes1_1	The number of 1-node intersections (dead-ends, cul-de-sacs) in Buffer 1
nodes3_1	The number of 3-node intersections (T junctions) in Buffer 1
nodes4_1	The number of 4+ node intersections in Buffer 1

Field	Description
tstops_1	The number of transit stops (of all types) in Buffer 1
nparks_1	The number of publicly accessible open space areas in Buffer 1
aparks_1	The average area (sq feet) of publicly accessible open space areas in Buffer 1
hh_2	The number of households residing in Buffer 2
stugrd_2	The number of grade school (K-8) students enrolled in Buffer 2
stuhgh_2	The number of high school students enrolled in Buffer 2
stuuni_2	The number of college students enrolled in Buffer 2
empedu_2	The number of educational employees working in Buffer 2
empfoo_2	The number of food service employees working in Buffer 2
empgov_2	The number of government employees working in Buffer 2
empind_2	The number of industrial employees working in Buffer 2
empmed_2	The number of medical employees working in Buffer 2
empofc_2	The number of (other) office employees working in Buffer 2
empret_2	The number of retail employees working in Buffer 2
empsvc_2	The number of (other) service employees working in Buffer 2
empoth_2	The number of other sector employees working in Buffer 2 (typically agriculture, mining - not used for SACOG)
emptot_2	The total number of employees working in Buffer 2 (equals the sum of the previous 9 values)
parkdy_2	The number of paid off street parking spaces in Buffer 2 with per day pricing
parkhr_2	The number of paid off street parking spaces in Buffer 2 with per hour pricing
ppricdy2	The average price per day for paid off street parking spaces in Buffer 2
pprichr2	The average price per hour for paid off street parking spaces in Buffer 2
nodes1_2	The number of 1-node intersections (dead-ends, cul-de-sacs) in Buffer 2

Field	Description
nodes3_2	The number of 3-node intersections (T junctions) in Buffer 2
nodes4_2	The number of 4+ node intersections in Buffer 2
tstops_2	The number of transit stops (of all types) in Buffer 2
nparks_2	The number of publicly accessible open space areas in Buffer 2
aparks_2	The average area (sq feet) of publicly accessible open space areas in Buffer 2
dist_lbus	The distance (miles) to the nearest local bus stop (999 if beyond 3 miles)
dist_ebus	The distance (miles) to the nearest premium bus stop (999 if beyond 3 miles)
dist_crt	The distance (miles) to the nearest commuter rail stop/station (999 if beyond 3 miles)
dist_fry	The distance (miles) to the nearest passenger ferry terminal (999 if beyond 3 miles)
dist_lrt	The distance (miles) to the nearest light rail stop/station (999 if beyond 3 miles)
dist_park	The distance (miles) to the edge of the nearest publicly accessible open space area (999 if beyond 3 miles)
Circ_E1	The short-distance circuity factor for direction E, distance 0.5 miles
Circ_E2	The short-distance circuity factor for direction E, distance 1.0 miles
Circ_E3	The short-distance circuity factor for direction E, distance 1.5 miles
Circ_NE1	The short-distance circuity factor for direction NE, distance 0.5 miles
Circ_NE2	The short-distance circuity factor for direction NE, distance 1.0 miles
Circ_NE3	The short-distance circuity factor for direction NE, distance 1.5 miles
Circ_N1	The short-distance circuity factor for direction N, distance 0.5 miles
Circ_N2	The short-distance circuity factor for direction N, distance 1.0 miles
Circ_N3	The short-distance circuity factor for direction N, distance 1.5 miles
Circ_NW1	The short-distance circuity factor for direction NW, distance 0.5 miles
Circ_NW2	The short-distance circuity factor for direction NW, distance 1.0 miles
Circ_NW3	The short-distance circuity factor for direction NW, distance 1.5 miles

Field	Description
Circ_W1	The short-distance circuity factor for direction W, distance 0.5 miles
Circ_W2	The short-distance circuity factor for direction W, distance 1.0 miles
Circ_W3	The short-distance circuity factor for direction W, distance 1.5 miles
Circ_SW1	The short-distance circuity factor for direction SW, distance 0.5 miles
Circ_SW2	The short-distance circuity factor for direction SW, distance 1.0 miles
Circ_SW3	The short-distance circuity factor for direction SW, distance 1.5 miles
Circ_S1	The short-distance circuity factor for direction S, distance 0.5 miles
Circ_S2	The short-distance circuity factor for direction S, distance 1.0 miles
Circ_S3	The short-distance circuity factor for direction S, distance 1.5 miles
Circ_SE1	The short-distance circuity factor for direction SE, distance 0.5 miles
Circ_SE2	The short-distance circuity factor for direction SE, distance 1.0 miles
Circ_SE3	The short-distance circuity factor for direction SE, distance 1.5 miles

5 Representative Population Data

The SACSIM model requires a detailed population file with representation of key demographics, such as household size, income and age of the population. SACOG uses the following process to generate the representative population file. The key software used in the process is known as “PopGen”, developed by the School of Sustainable Engineering and the Built Environment at Arizona State University along with additional research institutions and metropolitan planning organizations. The current PopGen version is maintained and hosted by the Mobility Analysis Research Group. The program generates synthetic populations whereby both household-level and person-level characteristics of interest can be matched. Moreover, PopGen facilitates the use of Census data. This chapter describes the various aspects involved in the process of generating the representative population for transportation demand forecasting.

5.1 Land Use Scenarios

Parcel-based dwelling units maintained in the land use scenario model is the base for generating representative population. Land use scenarios include “yield” estimates of a range of land use variables at parcel level. Two variables are used directly in SACSIM: dwelling units and jobs by sector. The yield estimates are based on the “place type” (generalized land use) of the parcel, the parcel area, and a number of physical, environmental, or policy constraints. Yield estimates are calibrated to match small area inventories of dwellings and jobs for the base year. Yield estimates are made for future year growth based on the future year place type and development status of each parcel in the future year scenario, and constraints expected to be in place at each parcel in the future year.

5.2 Household/Population Demographics

Travel demand forecasting models like SACSIM have always relied heavily on representations of key demographic characteristics in the population input file used for modeling. The most common demographic variables included in travel demand models are:

- Household size—the number of persons in the household
- Number of workers—the number of working adults in the household
- Household income—usually classified by three or more income categories.

Increasingly, ***age*** has become a variable of interest for travel demand modeling. In part, the increase in interest is related to the so-called "graying" of the population in the United States and elsewhere. Most of older/state-of-practice travel demand models do not account for age in the population demographics. SACSIM is the first of a new generation of "activity-based" travel demand models which allow for more realistic and thorough accounting of demographic variables like age.

The following variables and categories, at census tract level, are used for the household controls in the current process:

- Household size (4 categories: 1, 2, 3, and 4-or-more persons per household)
- Workers per household (4 categories: 0, 1, 2 and 3-or-more workers per household)
- Household Income in 2016 dollars (5 categories: less-than-$20,000; $20,000 to $39,999; $40,000 to $59,999; $60,000 to $99,999; and $100,000-or-more)
- Age of householder, or head-of-household (3 categories: <35 years; 35 to 64 years; and 65-or-more years)
- Ethnicity: (4 categories: 1. White Non-Hispanic, 2. Black Non-Hispanic, 3. Hispanic, and 4. Asian, Pacific Islander, or Other; including people who identify with two ethnic groups and Native Americans and Pacific Islanders. Note SACOG only controlled ethnicity for base year demographic population using 5 year ACS data, but did not use ethnicity as a control for any future year forecasting.

In addition to these household-level variables, the number of university student "households" clustered near to colleges or universities are controlled. As well as the number of senior "households" at senior living facilities. Dorm students and senior living persons are accounted for as Group Quarter population throughout the development of the representative population process. Senior households are still included in general household and population summaries. Person-level controls on age are also included. There are four categories of age controls: 14 years and younger, 15 to 34 years, 35 to 64 years and 65 years and older.

5.3 Base Year household/population demographics

The base year for SACSIM19 is 2016. The ACS data, tract level 5-year sample 2012-2016, provides a comprehensive demographic portrait of the region's population. Based on these ACS tract level totals and ACS Public Use Microdata Sample (PUMS) data, SACOG uses a software tool PopGEN to develop a representative, or synthetic, population to use to model travel within the region using SACSIM.

Table 5-1 through Table 5-5 provide demographic distributions of the five main control variables at county-level in 2016 representative population file. Although reported here at county level, these control variables were established at census tract level.

Table 5-1 Household Size Distribution

SACSIM19 Representative Sample Data

County	1 person	2 persons	3 persons	4+ persons
El Dorado*	21%	40%	17%	22%
Placer*	24%	36%	15%	24%
Sacramento	27%	31%	16%	27%
Sutter	22%	30%	17%	31%
Yolo	24%	32%	18%	27%
Yuba	20%	32%	17%	31%
Total	25%	33%	16%	26%

Source: SACOG 2020.
Based on American Community Survey 2012 5-year Sample data, excludes Tahoe Basin.

Table 5-2 Workers per Household Distribution

SACSIM19 Representative Sample Data

County	0 worker	1 workers	2 workers	3+ persons
El Dorado*	32%	37%	28%	4%
Placer*	30%	35%	29%	6%
Sacramento	27%	40%	27%	6%
Sutter	29%	38%	26%	7%
Yolo	26%	36%	31%	7%
Yuba	32%	40%	24%	5%
Total	28%	38%	28%	6%

Source: SACOG 2020.
Based on American Community Survey 2012 5-year Sample data, excludes Tahoe Basin.

Table 5-3 Household Income Distribution

SACSIM19 Representative Sample Data

County	< $20K	$20K - $40K	$40K - $60K	$60K - $100K	$100K+
El Dorado*	11%	16%	13%	22%	39%
Placer*	11%	14%	13%	23%	39%
Sacramento	17%	19%	16%	23%	26%
Sutter	18%	20%	16%	23%	22%
Yolo	19%	17%	15%	20%	28%
Yuba	18%	24%	18%	23%	16%
Total	16%	18%	15%	23%	28%

Source: SACOG 2020.
Based on American Community Survey 2012 5-year Sample data, excludes Tahoe Basin.

Table 5-4 Year 2020 Age of Householder Distribution

SACSIM19 Representative Sample Data

County	< 35 Years	35 - 64 years	>= 65 Years
El Dorado*	9%	60%	31%
Placer*	14%	57%	29%
Sacramento	21%	57%	21%
Sutter	20%	56%	24%
Yolo	28%	52%	20%
Yuba	27%	53%	20%
Total	20%	57%	23%

Source: SACOG 2020.
Based on American Community Survey 2012 5-year Sample data, excludes Tahoe Basin.

Table 5-5 Year 2016 Household Population Age Distribution

County	<= 14 years	15 - 34 years	35 - 64 years	>= 65 years	Population
El Dorado*	18%	21%	43%	19%	147,202
Placer*	20%	23%	39%	18%	363,896
Sacramento	21%	29%	37%	13%	1,476,573
Sutter	22%	28%	36%	14%	96,392
Yolo	18%	38%	33%	11%	214,784
Yuba	24%	31%	34%	11%	77,464
Total	20%	28%	37%	14%	2,376,311

Source: SACOG 2020.
Based on American Community Survey 2012 5-year Sample data, excludes Tahoe Basin.

5.4 Future Year household/population demographics

SACOG has relied on the Center for Continuing Study of the California Economy (CCSCE) to prepare the long range, region-level projections of population, housing and jobs. These projections were adopted by the SACOG Board of Directors, for use in development and analysis of the MTP/SCS scenarios. The Board-adopted region-level projections serve as control totals and guidance for development of spatially detailed, small area projections.

When establishing marginal controls for future years, a new process is implemented. For the residential areas already developed in 2016 base year, average demographics from 2016 representative population by generalized place type (see Table 5-11 for descriptions), community type and census tract are applied. For the future developing residential areas, regional average demographics by community type and generalized place type from base year 2016 (see Table 5-12 through Table 5-14) is used. Then, the regional demographic projections from CCSCE and expected demographic changes are factored into the base year controls, to ensure that expected/predicted changes in total population, household size, workers, household income, and age are reflected in the future year population files. Table 5-6 through Table 5-10 show the regional demographic 2016 base year and 2040 projections for the control variables used to generate future year representative population. Finally, Table 5-15 through Table 5-18 show the final MTP/SCS future year preferred land use scenario (2040) demographic tables by land use type.

Table 5-6 Age of Householder Distribution of Year

Year	< 35 Years	35 - 64 years	>= 65 Years
2020	21%	56%	24%
2036	17%	50%	33%

Source: SACOG 2020.

Table 5-7 Population Age Distribution of Year 2016/2040

Year	<= 14 years	15 - 34 years	35 - 64 years	>= 65 years
2016	20%	28%	38%	14%
2040	16%	25%	37%	22%

Source: SACOG 2020

Table 5-8 Regional Household Size Distribution of Year 2016/2040

Year	1 person	2 persons	3 persons	4+ persons
2016	25%	33%	16%	26%
2040	27%	32%	16%	25%

Source: SACOG 2020.

Table 5-9 Workers per Household Distribution of Year 2016/2040

Year	0 worker	1 workers	2 workers	3+ workers
2016	28%	38%	28%	6%
2040	30%	37%	27%	5%

Source: SACOG 2020.

Table 5-10 Household Income Distribution of Year 2016/2040

Year	< $20K	$20K - $40K	$40K - $60K	$60K - $100K	>= $100K
2016	16%	18%	15%	23%	28%
2040	16%	18%	16%	22%	28%

Source: SACOG 2020. Income breaks are in year 2016 dollars.

Table 5-11 Description of Generalized Place Types

Place Type #	Description	Examples of Place Types from Land use Model
1	High density	High density attached residential/Very high density attached residential
2	Medium-High density	Medium-High density attached/detached residential
3	Medium density	Medium density attached/detached residential, mobile home
4	Low density	Low density detached residential
5	Very low density	Farm home/Rural residential/Very low density detached residential
6	Mixed/Urban	Residential/Retail Mixed Use Low/High, Urban Attached Residential

Source: SACOG 2020.

Table 5-12 Typical Household Demographics by Community Type and Place Type: Household Size & Workers

Community Type	Place Type	Household Size				Worker per Household			
		HH size 1	HH size 2	HH size 3	HH size 4+	0 worker HH	1 worker HH	2 worker HH	3+ worker HH
Center / Corridor	High Density	45%	18%	11%	26%	51%	32%	11%	6%
	Medium High Density	33%	29%	20%	19%	44%	37%	15%	4%
	Medium Density	36%	37%	12%	15%	45%	35%	17%	3%
	Low Desnity	24%	38%	14%	24%	30%	37%	27%	6%
	Very Low Density	21%	41%	16%	22%	29%	37%	29%	5%
	Mixed Use / Urban	33%	7%	20%	40%	47%	33%	20%	0%
Developing / Established	High Density	56%	24%	9%	12%	41%	41%	15%	3%
	Medium High Density	35%	33%	14%	19%	37%	41%	18%	4%
	Medium Density	36%	33%	12%	18%	41%	33%	21%	4%
	Low Desnity	23%	32%	17%	27%	21%	41%	31%	6%
	Very Low Density	18%	30%	21%	32%	21%	43%	30%	6%
	Mixed Use / Urban	66%	23%	6%	6%	38%	46%	14%	2%
Agricultural / Rural Residential	High Density	47%	24%	11%	18%	48%	34%	14%	4%
	Medium High Density	32%	32%	14%	21%	39%	39%	18%	5%
	Medium Density	30%	32%	13%	25%	36%	34%	24%	6%
	Low Desnity	20%	32%	18%	30%	22%	38%	33%	7%
	Very Low Density	17%	36%	19%	28%	21%	39%	35%	6%
	Mixed Use / Urban	48%	23%	9%	20%	56%	29%	12%	4%

Source: SACOG 2020.

Table 5-13 Typical Household Demographics by Community Type and Place Type: Household Income & Age

Community Type	Place Type	Household Income					Householder's Age		
		< 15K	15K-30K	30K-50K	50K-75K	>=75K	Age < 35	Age 35-64	Age >= 65
Center / Corridor	High Density	20%	21%	12%	23%	25%	5%	18%	77%
	Medium High Density	22%	21%	16%	23%	19%	6%	31%	62%
	Medium Density	22%	20%	16%	23%	20%	9%	47%	44%
	Low Desnity	14%	20%	19%	26%	21%	14%	60%	26%
	Very Low Density	11%	16%	13%	24%	36%	12%	64%	24%
	Mixed Use / Urban	13%	13%	27%	13%	33%	7%	0%	93%
Developing / Established	High Density	31%	22%	16%	16%	15%	30%	38%	32%
	Medium High Density	26%	24%	17%	18%	15%	24%	44%	33%
	Medium Density	23%	24%	16%	19%	18%	23%	45%	32%
	Low Desnity	18%	20%	17%	23%	23%	30%	60%	10%
	Very Low Density	18%	23%	16%	21%	23%	29%	64%	7%
	Mixed Use / Urban	31%	20%	14%	15%	21%	36%	40%	25%
Agricultural / Rural Residential	High Density	28%	22%	17%	18%	15%	18%	35%	48%
	Medium High Density	21%	22%	17%	20%	20%	17%	42%	41%
	Medium Density	18%	19%	16%	23%	24%	19%	51%	31%
	Low Desnity	12%	16%	15%	25%	32%	21%	64%	15%
	Very Low Density	9%	13%	13%	22%	42%	17%	69%	14%
	Mixed Use / Urban	27%	26%	16%	18%	14%	12%	30%	57%

Source: SACOG 2020.

Table 5-14 Typical Person Age & Ethnicity Group Demographics by Community Type and Place Type

Community Type	Place Type	Person's Age				Person's General Ethnicity Group			
		<= 14 year	15 - 34 yea	35 - 64 yea	>= 65 year	White, Non-Hispanic	Black, Non-Hispanic	Hispanic	Asian and Other
Center / Corridor	High Density	12%	16%	34%	38%	55%	41%	0%	5%
	Medium High Density	11%	21%	31%	36%	65%	23%	1%	11%
	Medium Density	12%	20%	38%	29%	71%	19%	1%	8%
	Low Desnity	18%	25%	42%	16%	65%	20%	2%	13%
	Very Low Density	19%	22%	43%	16%	76%	13%	1%	10%
	Mixed Use / Urban	14%	14%	31%	41%	65%	35%	0%	0%
Developing / Established	High Density	13%	34%	32%	22%	50%	26%	7%	17%
	Medium High Density	16%	31%	33%	20%	42%	29%	8%	21%
	Medium Density	18%	29%	33%	20%	48%	26%	7%	19%
	Low Desnity	22%	34%	37%	7%	42%	27%	8%	23%
	Very Low Density	27%	31%	37%	5%	44%	28%	6%	22%
	Mixed Use / Urban	8%	38%	35%	19%	56%	21%	7%	17%
Agricultural / Rural Residential	High Density	15%	28%	29%	29%	43%	30%	7%	20%
	Medium High Density	16%	27%	32%	25%	49%	25%	6%	20%
	Medium Density	19%	28%	35%	18%	50%	23%	6%	22%
	Low Desnity	23%	29%	40%	9%	51%	21%	5%	23%
	Very Low Density	23%	25%	43%	9%	66%	15%	3%	17%
	Mixed Use / Urban	16%	25%	25%	34%	49%	37%	2%	11%

Source: SACOG 2020.

Table 5-15 SACSIM19 forecasted Demographic Distributions (2040): Household Size

Landuse Type	HH size 1	HH size 2	HH size 3	HH size 4+
Agriculture	17%	38%	17%	28%
College/University	100%	0%	0%	0%
High Density Residential	45%	24%	12%	19%
Low Density Residential	19%	33%	17%	30%
Medium Density Residential	26%	32%	15%	27%
Medium-High Density Residential	31%	34%	15%	20%
Mixed Use	49%	23%	11%	17%
Rural Residential	18%	40%	17%	25%
Very High Density Residential	55%	24%	9%	12%
Very Low Density Residential	16%	37%	18%	28%
Regional	27%	32%	16%	25%

Source: SACOG 2020.

Table 5-16 SACSIM19 forecasted Demographic Distributions (2040): Household Workers

Landuse Type	0 worker HH	1 worker HH	2 worker HH	3+ worker HH
Agriculture	20%	44%	32%	4%
College/University	84%	16%	0%	0%
High Density Residential	47%	35%	15%	3%
Low Density Residential	22%	37%	35%	6%
Medium Density Residential	29%	38%	28%	6%
Medium-High Density Residential	39%	39%	18%	4%
Mixed Use	46%	37%	14%	3%
Rural Residential	27%	37%	32%	5%
Very High Density Residential	43%	41%	14%	2%
Very Low Density Residential	21%	37%	37%	5%
Regional	30%	37%	27%	5%

Source: SACOG 2020.

Table 5-17 SACSIM19 forecasted Demographic Distributions (2040): Household Income

Landuse Type	HH Income < 15K	HH Income 15K-30K	HH Income 30K-50K	HH Income 50K-75K	HH Income >=75K
Agriculture	13%	18%	22%	20%	27%
College/University	100%	0%	0%	0%	0%
High Density Residential	28%	22%	20%	14%	16%
Low Density Residential	13%	17%	20%	20%	29%
Medium Density Residential	18%	20%	21%	18%	23%
Medium-High Density Residential	23%	23%	22%	16%	16%
Mixed Use	27%	21%	20%	14%	18%
Rural Residential	11%	16%	19%	20%	34%
Very High Density Residential	32%	22%	18%	13%	16%
Very Low Density Residential	10%	14%	18%	20%	39%
Regional	18%	19%	20%	18%	25%

Source: SACOG 2020. Income breaks are in year 2000 dollars.

Table 5-18 SACSIM19 forecasted Demographic Distributions (2040): Householder Age

Landuse Type	HH Holder Age < 35	HH Holder Age 35-64	HH Holder Age >= 65
Agriculture	16%	68%	16%
College/University	95%	3%	3%
High Density Residential	14%	28%	58%
Low Density Residential	19%	61%	20%
Medium Density Residential	18%	51%	30%
Medium-High Density Residential	13%	34%	53%
Mixed Use	14%	30%	56%
Rural Residential	11%	60%	29%
Very High Density Residential	22%	33%	44%
Very Low Density Residential	14%	65%	21%
Regional	17%	50%	33%

Source: SACOG 2020.

5.4.1 Representative Population Generation Process

A representative population file includes one data record per person in the base year or future year to be analyzed. This section describes the steps SACOG uses to generate a representative population.

5.4.1.1 Prepare Input files for PopGen

As described above, SACOG uses an open source synthetic population software called, PopGen, which requires three sets of input files:

Marginal control files for the control variables, micro-samples collected by the Census Bureau, and geographic corresponding file describing relationships among levels of geographic areas. To prepare household marginal control file, dwelling units from land use model are aggregated to census tracts and are converted to households by applying adjusted occupancy rates based on ACS 5-year sample data at census tract level. Then the households are split by predefined categories of control variable using ACS 5-year demographic profiles for the base year or adjusted base year demographics with factors of expected/projected future demographics for the future year. The population control totals for each tract are estimated using the number of households by household size controls. Then the age demographic profile from ACS 5-year sample from base year is applied to create population controls by age for the base year, while adjusted age demographics by regional projected factors is applied to create future year population controls. The population file also includes persons ethnic categories based on ACS 5-year sample, however, this ethnic category information is not used in the at all by SACSIM19 therefore does not have an effect in any forecasting. The Group Quarter marginal control file is created with two categories,

1. Representing dorm students in UC Davis and California State University Sacramento,
2. Representing seniors living in senior living facilities.

Sample Files are used to create this micro-sample file for PopGen, Public Use Micro-sample (PUMS) files from Census are modified by recoding control variables to the defined categories. 2012-2016 5-year PUMS survey was used and joined into the 2010 iPUMS GIS files to build the relationships. The following households are identified as clustered university student households, or seniors in senior living facilities: any one- or two- person households in which all members are students or seniors.

Correspondence file is used to connect the Sample and Marginal files.

5.4.1.2 Run PopGen

Based on marginal control files, PopGen estimates household and person type constraints using the Iterative Proportional Fitting procedure. Then it estimates sample household weights that satisfy both household and person type constraints using the Iterative Proportional Updating (IPU) algorithm. The resulting outputs from PopGen are synthetic household and population files. Below are the table structures used by SACOG staff; PopGen requires some of these inputs but not all inputs. For more information on how to download, install and run PopGen, go to the Mobility Analytics PopGen webpage: *https://www.mobilityanalytics.org/popgen.html. Appendix G Run PopGen provides screenshots of the steps SACOG staff uses to run a PopGen scenario to generate a* *synthetic population. Appendix G also includes brief tips for troubleshooting installation using the Population installation instructions on the PopGen webpage.*

5.4.1.2.1 PopGen SACOG Input File Descriptions

Table 5-19 Marginal File Population File Field Descriptions

Columns for Popgen	Type	Description
state	bigint	State # ID, California is 6
county	bigint	County # ID
tract	bigint	Census Tract ID
bg	bigint	Block Group ID, Left as 0 for SACOG (controlled at Tract Level)
pop0	bigint	# of Persons Age Group: <= 14 years
pop15	bigint	# of Persons Age Group: 15 - 34 years
pop35	bigint	# of Persons Age Group: 35 - 64 years
pop65	bigint	# of Persons Age Group: >= 65 years
eth_w_nh	bigint	# of Persons General Ethnicity Group: White, Non-Hispanic
eth_b_nh	bigint	# of Persons General Ethnicity Group: Black, Non-Hispanic
eth_h	bigint	# of Persons General Ethnicity Group: Hispanic
eth_a_o	bigint	# of Persons General Ethnicity Group: Asian and Other

Source: SACOG 2020.

Table 5-20 Marginal File Household File Field Descriptions

Columns for Popgen	Type	Description
state	bigint	State # ID, California is 6
county	bigint	County # ID
tract	bigint	Census Tract ID
bg	bigint	Block Group ID, Left as 0 for SACOG (controlled at Tract Level)
hhsize1	bigint	# of Households Group: 1 Person Households
hhsize2	bigint	# of Households Group: 2 Person Households
hhsize3	bigint	# of Households Group: 3 Person Households
hhsize4	bigint	# of Households Group: 4+ Person Households
worker0	bigint	# of Households Group: 0 Worker Households
worker1	bigint	# of Households Group: 1 Worker Households
worker2	bigint	# of Households Group: 2 Worker households
worker3	bigint	# of Households Group: 3+ Worker Households
hh_inc_1	bigint	# of Households Group: Household with Annual Income <15k
hh_inc_2	bigint	# of Households Group: Household with Annual Income >=15k and <30k
hh_inc_3	bigint	# of Households Group: Household with Annual Income >=30k and <50k
hh_inc_4	bigint	# of Households Group: Household with Annual Income >=50k and <75k
hh_inc_5	bigint	# of Households Group: Household with Annual Income >=75k
hh_hd_1	bigint	# of Households Group: Householder Age < 35
hh_hd_2	bigint	# of Households Group: Householder Age 35 - 64
hh_hd_3	bigint	# of Households Group: Householder Age >=65
univ1	bigint	# of Households Group: Students in Dorm Living Facilities
univ2	bigint	# of Households Group: Seniors in Senior Living Facilities

Source: SACOG 2020.

Table 5-21 Marginal File Group Quarter File Field Descriptions

Columns for Popgen	Type	Description
state	bigint	State # ID, California is 6
county	bigint	County # ID
tract	bigint	Census Tract ID
bg	bigint	Block Group ID, Left as 0 for SACOG (controlled at Tract Level)
type1	bigint	# of College/University Students
type2	bigint	# of Seniors in Senior or Assisted Living Facilities

Source: SACOG 2020.

Table 5-22 Correspondence File Group Quarter File Field Descriptions

Columns for Popgen	Type	Description
county	bigint	State # ID, California is 6
tract	bigint	County # ID
bg	bigint	Census Tract ID
state	bigint	Block Group ID, Left as 0 for SACOG (controlled at Tract Level)
pumano	bigint	Public Use Micro-sample ID
stateabb	bigint	State Abbreviation, "CA"
countyname	text	County Name

Source: SACOG 2020.

The Sample file used is the Public Use Microdata Sample (PUMS) data 2012-2016 5-year average sample for PUMA within the SACOG region, available to download from the Census webpage.

5.4.1.3 Post-processing PopGen Outputs

The synthetic population file generated from PopGen lists the frequencies of micro-sample in each census tract, and only include control variables in categories. The population file used in SACSIM requires per-person per record and actual values instead categories for the variables. Also the SACSIM input file requires some additional variables such as gender, student status etc. Therefore, the output from PogPen is post-processed to meet SACSIM’s requirements.

5.4.1.4 Allocate Household/population to Parcels

Finally, a separate, customized program is used to allocate the representative population households to parcels within tracts considering characteristics of the parcel such as land use type, distance to transit, distance to schools etc. See Chapter 4 for more information on how to setup and run the household and population to parcel allocation process.

6 Highway Networks

The travel model uses coded representations of the Sacramento region's highway network, which provides the basis of estimating zone-to-zone travel times and costs for the trip distribution and mode choice models and for trip routing in the vehicle assignments. The highway network serves not only as the basis of highway travel times and traffic assignments, but also as the basis of bus running times and zonal walk- and drive-access for transit travel time and assignment. This section provides an overview of the coding of the highway network.

6.1 Opening and Editing the Highway Network

SACSIM's highway network is a Cube NET file. To open and edit the file, use Cube Base modeling software.

Table 6-1 lists the network variables used in the SACSIM highway base network. Most link attributes are intuitive and modelers can use Table 6-1 as a reference for coding updates to the highway network. However, the conventions for coding the CAPCLASS values are more nuanced and we recommend users refer to the sections below on Capacity Class and Other Highway Network Characteristics.

Table 6-1 SACSIM Highway Network Variables

Property (SACSIM variable name)	Convention
SPEED (Free Flow Speed)	"Free-flow" speed, or average travel speed with no congestion.
DISTANCE	Link distance (miles).
CAPCLASS (Capacity Class Code)	Points to a lookup table of capacity values, in vehicles per hour per lane.
USECLASS	0 = General-purpose lane 2 = Restricted to vehicles with 2+ occupants 3 = Restricted to vehicles with 3+ occupants
LANES	Number of through-lanes in the link's direction
SPDCURV (Speed-flow Curve Selector)	1 = Freeway 2 = Two-Lane Transitional Roadway 3 = Urban/Suburban Arterial
DELCURV (Ramp Meter Indicator)[1]	0 = Not Metered 1 = AM 3 hours only 2 = PM 3 hours only 3 = AM and PM periods (6 hours) 4 = AM, Midday, and PM periods (12 hours) 5 = Metered 24 hours
HOVLINK (Access Codes for Path Building and Assignment)	0 = All trips permitted 1 = Walk and bicycle trips only 2 = HOV-only facility in freeway[2] 3 = HOV-only bypass lane at metered on-ramp
BIKE (Type of bicycle route or facility present on link)	0 = No bike lane 1 = Class 1 bike route 2 = Class 2 bike route 3 = Class 3 bike route 8 = Surface street over- or under- crossing of a freeway, with ramps present, and NO bike lane 9 = Same as type 8, but WITH Class 2 bike lane

Notes:

1 – Only DELCURV values 0, 1, and 2 were used in 2020 MTP-SCS submission

2 – HOVs, or high-occupancy vehicles are vehicles with two or more occupants.

6.2 Capacity Class

The capacity class, or CAPCLASS, attribute determines the capacity of a link in the model network. Capacity classes should not be treated as black-or-white categories. While the definitions of some categories are relatively clear (e.g. “freeway”), most roadways are not “textbook” examples and exhibit some, but not all, characteristics of a specific capacity class. Users must exercise professional judgment to classify a specific existing roadway, based on its observed characteristics, or future roadway, based on the best planning information available. Note that SACSIM capacity classes have no intentional relation to Federal Aid functional classifications.

The definitions below should provide background for the categories used in SACSIM, and guidance to modelers who are using SACSIM networks. Following the definitions is Table 6-3, summarizing basic operating characteristics for each capacity class.

6.2.1 Freeways

A ***freeway*** is a restricted access roadway facility, with all access mediated by ramps. Freeways are intended primarily for longer trips, including: through trips to a region; longer inter-regional trips which begin or end outside the region; and longer regional trips, such as commute trips. There are several “sub-classes” within the general capacity classification:

- General-purpose lanes allow access to any vehicle at any time of day, regardless of occupancy within the vehicle.
- Auxiliary lanes are freeway lanes which connect from an on-ramp to the next downstream off-ramp. They operationally serve as extensions of the subject on-ramp and off-ramp, providing more distance to complete merges and weaves entering or leaving the freeway between the subject ramps. Additionally, auxiliary lanes provide lanes for shorter, ramp-to-ramp trips to use.

  Auxiliary lanes are further split into two types:

  - Lanes of one-mile-or-greater length, which are coded to full freeway capacity, but with free-flow speed 5 mph less than the “through” lanes.
  - Lanes of less-than-one-mile length, which are coded to 1500 vplph, and with free-flow speed 5 mph less than the “through” lanes.

High-occupancy vehicle lanes*,* or HOV facilities, are typically lanes on freeways that require vehicles to have a minimum number of occupants in order to access them. The USECLASS value, detailed above in Table 6-1, determines the minimum number of occupants required to enter a given HOV facility.

6.2.2 Expressways

An ***expressway*** is a multi-lane surface street with widely spaced signals (one-half mile or greater) and high level of driveway access control. Driveways to or from fronting properties are limited (e.g. by connecting to a frontage road or side street, or consolidated with other properties). Expressways have continuous median barriers between traffic signals, and turning lanes at intersections are heavily channelized. Traffic signal cycle lengths are generally greater than 120 seconds or more during peak periods.

A ***high capacity river crossing*** is a special category for Watt Avenue, Sunrise Boulevard and Hazel Avenue crossings of the American River. These streets have higher than normal capacity for a "surface" or non-freeway street. Although this capacity class could be used for future proposed crossings, it is currently only used to represent streets which, through a combination of design features, operational strategies, and unique driver characteristics or behaviors, are observed to operate at super-normal flows.

6.2.3 Other Urban/Suburban Surface Streets

A ***major arterial*** is a multi-lane surface street with less widely spaced signals and moderate level of driveway access control. Traffic signals are generally spaced at about one-half mile, with turning movements heavily channelized. Medians barriers are present, but breaks between traffic signals (i.e. to a mid-block driveway or un-signalized cross street) may exist. Most driveway access to major arterial streets is for larger commercial uses (shopping centers, office buildings, etc.). Traffic signal cycles are usually about 120 seconds during peak periods.

A ***minor arterial*** is a two-to-four lane surface street with traffic signals spaced at one-quarter to one-half mile intervals. Median barriers may or may not be present. If present, breaks in the median for driveways or un-signalized side streets are more frequent. In some cases, no median barrier is present, and a continuous turn-lane or median stripe is present. Driveway access to the roadway is more frequent. Most driveway access is for commercial uses, but some residential uses may have driveway access. Traffic signal cycles, where applicable, are generally less than 120 seconds. If an intersection is un-signalized, however, generally only the side street is controlled.

A ***collector*** is most often a two-lane roadway but can be up to four lanes. In many ways, collectors are similar to minor arterial, but have even less control of driveway access and potentially more closely spaced intersections. Collectors generally do not have median barriers.

6.2.4 Ramps

A ***ramp*** is a roadway facility which connects to or from the freeway system. There are several sub-classes within the general capacity classification:

- A standard ramp connects from the surface street system to the freeway system. No distinction is made between diagonal and loop ramps of this type. However, there are several types of standard ramp:
    - Metered ramps signalize access from the ramp to the freeway system during peak hours.

- HOV bypass ramps allow vehicles with two-or-more occupants to bypass a ramp meter.
- High capacity connector ramps connect from one freeway to another.
- Low capacity ramps connect from surface street to freeway, but because of unique features such as slope, curvature, etc. they have very low capacity. An example of a low capacity ramp is the South River Road on-ramp to eastbound US-50 in West Sacramento.

6.2.5 Rural Roadways

A ***rural highway*** is a two-lane surface street in a rural area, generally controlled only on side streets, and with relatively high design speeds. Examples of rural highways are State Highway 65 north of the City of Lincoln and State Highway 70 north of Marysville

A ***rural arterial*** is similar to a rural highway, but with more stop signs and lower design speeds.

6.2.6 Special Highway Links

Centroid connectors are abstract links in the travel demand model, intended to represent local street access to the collector-and-above roadway network.

Exclusive bike or walk links are special links added to the highway networks, but only accessible for non-motorized (i.e. bike/walk) path building. In most cases, bike or walk links have a one-to-one correspondence with an actual physical facility (e.g. the Guy West Bridge from Campus Commons to Sacramento State University, or one of the several pedestrian bridge overcrossings of freeways). However, in some instances, bike or walk links are intended to represent a combination of bike/walk routes or generalized bike or walk connectivity between two areas. Exclusive bike links are coded as "Class 1" facilities.

Bike lanes on roadways are coded with a special "bike"' identifier. The coding is used for Class 2 or Class 3 lanes on roadways. Chapter 8 on the bike and walk networks provides details on how the bike route coding is used in path building and skimming for the bicycle mode. Bike and Walk

Park-and-ride connectors are abstract links which provide connections from the highway network to park-and-ride lot nodes, which are only used in the transit network. These connector links must be present for paths to the park-and-ride lot to be built in the transit skimming process. Park-and-ride connectors also work to connect drop-off, or "kiss-and-ride" locations to the highway network.

HOV connectors are abstract links which mediate access between the mixed flow and HOV lane links on a freeway segment.

Disabled links are links in the master network which are not active in the scenario being modeled.

6.2.7 Tolling Attributes

Table 6-2 provides a quick description of the link attributes used to code tolled facilities into the highway network. For a more comprehensive review of how to use SACSIM's tolling capabilities, refer to Chapter 9.

Table 6-2 SACSIM Highway Network Tolling Attributes

Property (SACSIM variable name)	Convention
TOLLID	ID for a set of links comprising one tolled facility
GPID	ID corresponding to the general-purpose links that run parallel to a tolled facility. The toll for the links with the TOLLID are based on congestion on links whose GPID is the same as the TOLLID.
AUXID	ID corresponding to auxiliary lanes that run parallel to a tolled facility. Must be same value as GPID.

Source: SACOG 2020.

Table 6-3 Capacity and Free-Flow Speed

Capacity Class		Capacity	Free Flow Speed				
#	Description	(vplph)	Median	Average	Std.Dev.	Min	Max
1	Freeway (Mixed Flow)	2000	63	61	4	40	70
8	Freeway Lane (Pk Period HOV)	2000	60	51	13	20	63
51	Freeway (Auxiliary >= 1 mile)	2000	58	58	1	55	58
56	Freeway (Auxiliary <1 mile)	1500	58	55	3	50	58
12	High Capacity River Crossing	1500	42.5	43	3	40	45
2	Expressway	1000	50	49	6	35	55
3	Major Arterial	850	40	37	7	15	55
4	Minor Arterial	800	35	33	9	5	50
5	Collector	700	25	29	7	10	50
6	Freeway Ramp	1500	20	21	4	20	55
36	Ramp (Metered AM)	1500	20	21	4	20	55
46	Ramp (Metered PM)	1500	20	20	0	20	20
26	Low Capacity Ramp	500	20	18	4	10	20
16	High Capacity Ramp/Connector	2000	45	42	10	20	63
6	Ramp (HOV Bypass)	1500	20	21	4	20	55
22	Rural Highway	1000	55	51	5	35	55
24	Rural Arterial	750	40	40	6	20	55
7	Walk/Bike	n/a	3	3	0	3	3
9	Connector (Mixed Flow-HOV)	1500	63	63	0	63	63
62	Connector (PNR-Roadway)	n/a	20	20	0	20	20
63	Centroid Connector (TAZ to roadway)	n/a	20	20	0	20	20
99	Disabled	n/a	0	0	0	0	0

Source: SACOG 2020.

7 Transit Networks

The transit network represents major fixed-route transit services. In the SACSIM model, the transit network is essentially an overlay on the road network, primarily by designation of bus transit lines on the road network. Separate transit-only links are coded for light rail transit lines, which generally operate on exclusive right-of-way. The SACSIM model can represent the impacts of increased road congestion on bus travel times as well as time savings for buses traveling in HOV or managed lanes.

7.1 Working with the Transit Network

7.1.1 Fixed-Route Regular Bus Services

1. Open the transit line file (tranline.txt) in Cube to edit fixed-route, normal bus service attributes:
   - Line geometry (which streets bus routes use)
   - Line attributes, discussed below
2. Use the Cube interface to add new lines or delete lines.

7.1.2 Rail Transit Services

1. Edit the geometry (i.e., where the rail line goes):
   a. Open the transit.txt line file in Cube
   b. Add nodes to the SACSIM highway network at each stop location and significant vertex (e.g. where the line makes a significant turn).
   c. Update the CSVs of rail links and station links in Excel.
2. Update the node list and other transit line attributes in Cube.

7.1.3 Bus Rapid Transit (BRT)

There is no established, single way to represent BRT in SACSIM, but below are some general guidelines to follow depending on the flavor of BRT you intend to represent.

- For BRT that acts more like rail, with total or near-total separation from mixed-flow vehicular traffic, it may be best to code as a rail transit service.
- For bus services that have some of the operational features of BRT that speed up service (e.g. off-board fare payment, queue-jump lanes, etc.) but operate with some mixed-flow vehicular traffic, SACOG convention has been to code it as a normal bus service, but to adjust the time factor attribute to have the bus speed be closer to that of non-transit vehicular traffic.

7.1.4 Park-and-Ride Lots

To edit or update park-and-ride facilities in SACSIM, refer to the section on Park-and-Rides.

7.1.5 Coding Future or Forecasted Transit Service

How you code in future transit service into the model network entails essentially the same procedures and file types as coding in or editing existing transit service, described above. However, *what* you code in (e.g., where you put future service, how frequent you make it, what times of day it runs, which stops have park-and-ride facilities, etc.) depends on the application or scenario you are modeling transit for. Some examples include:

- Modeling future services explicitly planned by a transit agency, such as a planned rail line extension, service reorganization, or new bus route.
- Aligning future transit service with expected population in job growth, even if it is not based on explicit transit agency plans, which rarely forecast transit service more than five years out. SACOG's 2020 MTP-SCS applied this approach in developing its future-year transit services, providing new service or increased service levels to areas in which it forecasted significant job or population grown.

7.2 Transit Lines

The major fixed route transit services in the SACOG region are explicitly represented in the transit networks as "lines", or series of stops served by a transit vehicle at a specified service frequency. Table 7-1 provides a listing of the operators included. Each line operating on a fixed (or largely fixed) route, and with a published schedule, is coded into the SACSIM transit networks.

7.2.1 Transit Service Periods

SACSIM fixed-route transit considers five different service periods:

- Period 1, spanning from 5:00am until 9:00am
- Period 2, from 9:00am until 3:00pm
- Period 3, from 3:00pm until 6:00pm
- Period 4, from 6:00pm until 8:00pm
- Period 5, from 8:00pm until 11:00pm

By breaking up transit service into these periods, SACSIM aims to accurately represent how transit service varies throughout the day, e.g.:

- Transit availability and frequency differences throughout the day
- How transit is affected by changes in highway traffic congestion throughout the day

7.2.2 Transit Line Attributes

Table 7-2 provides a listing of the key variables coded for each transit line.

- The NAME of the line.
    - For lines existing in the base year, the first 4 characters refer to the operator name:
        - AMTR – Amtrak Capitol Corridor service
        - AUBT – Auburn Transit
        - CSUS – California State University Sacramento Hornet Shuttle
        - ELDO – El Dorado Transit
        - ETRN – E-Tran, in Elk Grove
        - FOLS – Folsom Stage Line
        - PLAC – Placer County Transit
        - RSVL – Roseville Transit
        - SCTL – South County Link (serving south Sacramento County)
        - SRTD – Sacramento Regional Transit District
        - UTRN - Unitrans
        - YOLO – Yolo County Transportation District (Yolobus)
        - YUSU – Yuba-Sutter Transit
    - The next characters up until the underscore (_) refer to the line number
    - The A/B indicator after the underscore refers to the direction
        - Example: SRTD1_A = Sacramento Regional Transit route 1, direction A
        - Not all routes are split out by direction
- TIMEFACs are factors applied multiplicatively to the time on the transit supply link (for transit only links like LRT or BRT) or the congested time from the highway network for the appropriate service period (for lines operating in mixed traffic on the road network) to factor

in stops and dwell time into overall transit travel times. Table 7-3 shows the typical transit time factors used in SACSIM.

- ONEWAY is an indicator for a one-way direction route. An example of a true one-way route is one of the many commuter buses into Downtown Sacramento, which operate inbound-only in the morning, and outbound-only in the afternoon. ONEWAY is also used on many two-way routes that are broken out into two separate, one-way routes to account for routing or scheduling differences between the two directions.
- CIRCULAR is an indicator of routes operating as a loop, with the last station or stop on one trip being the first station or stop on the next trip. Riders of CIRCULAR routes do not incur any wait time penalty if their trip takes them through the route's last/first stop.
- OPERATOR is a variable which serves both as an identifier for the operating entity for each line, and as a lookup reference for fares.
- MODE is an indicator of the transit "submode" for each line. Submodes include: rail; commuter bus; and all other bus.
    - Note - links added to the lines through the Cube PT "autogenerate" functions (MODE =12, 13) are used for controlling access to and from stations or stops
- COLOR indicates more general service types, listed below. Important to note is that COLOR value does not in any way affect a line's attractiveness, travel speed, etc. It is primarily used to visually denote different service types when mapping transit lines, or for getting ridership or other tallies grouped by service type.
    - *1 = Light Rail*. Lines are generally longer, linear, run in their own dedicated right of way, and outside of downtown centers usually have stops spaced more than 0.5 miles apart.
    - *3 = Commuter Bus*. These bus services usually serve only during the AM and PM peak periods and serve major employment centers such as downtown Sacramento and UC Davis. These services generally have several stops at the "home end" where users live and at the "work end" where users work, with few if any stops in between.
    - *4 = Bus Rapid Transit (low)*. As discussed under Working with the Transit Network, bus rapid transit, or BRT, usually has routes that are similar to fixed-route local buses, but with varying levels enhancements like dedicated lanes, queue-jump lanes, off-board fare payment, etc. to improve operations and provide an experience closer to rail service.
    - *5 = Fixed Route Local Bus*. Local fixed-route buses typically travel longer, linear routes that cross large parts of the operator's service area. Stops are generally less than 0.25mi apart.
    - *6 = Regional/Commuter (Heavy) Rail* includes service such as Amtrak's Capitol Corridor service to the Bay Area. Regional rail has generally infrequent service, but has higher speeds and long distances (10+ miles) between stops.
    - *7 = Neighborhood shuttle.* Like a local fixed-route bus but serves a smaller area and is more likely to be a circular or loop-shaped route rather than a longer linear route. Most of UC Davis's Unitrans routes are considered neighborhood shuttles.
    - *8 = Streetcar.* Like light rail, but generally has more frequent stops and serves a smaller area.

As with capacity class designations for the highway network, some of the distinctions between service type COLORs are not black-or-white. Examples are: so-called "hybrid" streetcar systems that operate more like light rail; or certain types of lower end bus rapid transit (BRT) that operate more like a normal fixed-route local bus. The model user must use his/her professional judgement in such situations to decide which COLOR to assign a specific line.

- HEADWAY(#) is the average headway, or time spacing between scheduled buses or trains, in minutes. The # in parentheses indicates the service period. HEADWAY is computed as follows:
    - Total minutes in service period / Total trips made by the route in service period
        - E.g. if the service period is AM peak, the total minutes is 240. For a route with 4 trips during this period, that route's AM peak headway is 240/4 = 60 minute headway between arrivals.
    - HEADWAY values of 0 denote times during which there is no service. E.g., if the HEADWAY for midday is 0, it means that route makes no trips during the midday period.

Table 7-1 SACSIM Transit Operators

Operator/Fare Group Number	Description
1	RT light rail lines
2	RT fixed-route bus lines
3	Yolobus commuter/express lines
4	Yolobus local fixed route bus lines
5	Roseville commuter bus lines
6	Roseville local fixed route bus lines
7	Yuba-Sutter Transit commuter lines
8	Yuba-Sutter local fixed route bus lines
9	El Dorado Transit commuter bus lines
10	El Dorado Transit local fixed route bus lines
11	Placer County Transit commuter lines
12	Placer County Transit local fixed route bus lines
13	Unitrans local fixed route bus lines; CSUS Hornet shuttle lines
14	Heavy rail (currently Sacramento region stops for Capitol Corridor)
15	South County Transit (SCT Link)
16	E-Tran commuter lines
17	E-Tran local bus lines
18	Future Neighborhood Shuttle
19	Future Streetcar
20	Folsom Stage Line

Source: SACOG 2020.

Table 7-2 Transit Line File Variables

Variable	Description
NAME	Name of Line
TIMEFAC	Highway to transit running time factor
ONEWAY	1 = line only goes 1 direction; 0 = line runs both directions
CIRCULAR	1= circular, 0 = not circular
OPERATOR	Operator of line and fare group (1-20)
MODE	Transit submode (1-3)
COLOR	Service type
HEADWAY[1]	Morning service period (5:00 AM to 9:00 AM), in minutes
HEADWAY[2]	Midday service period (9:00 AM to 3:00PM), in minutes
HEADWAY[3]	Afternoon peak service period (3:00 PM to 6:00 PM)
HEADWAY[4]	Evening service period (6:00 PM to end of 8:00 PM)
HEADWAY[5]	Evening service period (8:00 PM to 11:00 PM)

Source: SACOG 2020.

7.2.3 Demand-Responsive Transit Services

Dial-a-ride, paratransit, private transit operations, and individual bus routes that operate within a travel analysis zone (TAZ) or that operate very infrequently were not included in the transit network. Such routes are excluded in standard transit modeling practice for several reasons. They cannot be modeled reliably using macro-level measures. Additionally, these services usually carry very small volumes, and are not addressed explicitly in regional planning or corridor studies.

SACSIM19 currently excludes “microtransit” services, such as Sacramento Regional Transit’s SmaRT Ride and West Sacramento’s Via shuttle, which essentially provide on-demand transit service within a defined area and to select light rail stations. Future versions of SACSIM may incorporate microtransit services if they rise as a significant transit mode.

7.3 Transit Access Coding and Network Additions

Transit access coding refers to the use of links explicitly coded in the highway network, links manually added to the highway network in order to provide access to transit stations or stops, and links which are "auto-generated" by Cube to provide access to transit stations or stops, and to provide transfers from one line to another line. These three sets of links, in combination, are included in a "transit background network" which is subsequently used in transit path-building, skimming and assignment.

7.3.1 Links Explicitly Coded in Highway Network

Transit access links include all highway links, except for freeway mainline and freeway ramp links. Walk paths from traffic analysis zones to the first-boarding transit station or stop include centroid connectors, all surface streets, and explicitly coded pedestrian/bike-only links. Additionally, walk paths can include "contra-flow" direction on one-way surface streets.

7.3.2 Transit Access Links Manually Added to Highway Network

One major subset of these links are links representing exclusive transit links. The biggest categories of these links are rail lines, such as the Sacramento Regional Transit light rail lines, or the portions of the Capital Corridor train service within the SACOG region. However, in the future these links could include bus-only roadway segments. These links are not actually "access links", but are alignments for transit lines to operate on. These links are included in the "transit_links.csv" file.

A second subset of these links are access links which connect between the highway network and the rail stations in the above-described rail transit links. These links allow for paths to be built from the highway network to stations or stops on exclusive guideway transit links, and for transfers between transit lines operating on exclusive guideways, and transit lines operating in mixed traffic. These links are included in the "station_links.csv" file.

A third subset of these links connect from park-and-ride lots to the nearest traffic analysis zone. The drive portion of park-and-ride transit trips are skimmed and assigned in the vehicle assignment process, and the transit portion of these trips are assigned from the park-and-ride lot node to the final destination, via the transit access links and transit lines. The connection between the park-and-ride lot TAZ, through the park-and-ride lot node and to the transit station, is built through links included in the "pnr.dbf" file.

7.3.3 Auto-Generated Transit Access Links

Links for two access modes are generated through Cube PT path-building software. One mode is walk access and egress links, which consolidate the more complicated paths built on the actual network components described above into single links connecting from TAZ to a range transit stations or stops (coded as MODE = 13). Another mode is transfer links which connect between one or more transit lines, and other transit lines, where the lines do not have stations or stops in common (MODE =12). Examples include: rail-to-bus station connections; and rail-to-rail station connections, if the rail lines do not share a common station.

7.4 Transit Travel Speeds and Stop Times

Travel speeds of buses operating in mixed flow are determined by means of a time factor relating bus speed (including stops) to auto speed. Time factors were determined separately for peak and off-peak local bus service by comparing the scheduled transit travel times with the model's respective highway travel times.

For buses, delays from stopping, deceleration, and acceleration are implicitly represented in the time factors (TIMEFAC) discussed in the line attributes. Portions of the highway network are not detailed enough to explicitly represent each bus stop, so the time factor gives a reasonable estimate unbiased by the relative fineness or coarseness of the highway network. Table 7-3 provides the default time factors for a variety of typical operating contexts.

Table 7-3 Highway to Bus Transit Time Factors

Service Type	Time Factor
Urban Fixed Route (most RT bus routes)	2.01
Urban Fixed Route w/in Sac. CBD	2.25
Urban BRT w/ Signal Priority	1.78
Rural Fixed Route	1.62
Commuter Bus (Freeway Segments)	1.18

Source: SACOG 2020.

For most of the LRT system, light rail vehicles operate on exclusive right-of-way, with pre-emption of traffic signals at crossings of surface streets. For this reason, travel times are less subject to road conditions, and more stable and predictable. LRT travel times are influenced by the characteristics of the track they operate on, performance of the LRV's, and the spacing of stations. Table 7-4 provides the performance characteristics of LRVs used for estimation of travel times. Although for base year (in this case, 2016) it is not necessary to have a method of estimating LRV travel times, since they can be observed directly, for future lines an estimation method is required.

Table 7-4 Light Rail Vehicle Operating Assumptions

Variable	Performance
Acceleration Rate	2.5 mph/sec
Deceleration Rate	-2.5 mph/sec
Maximum Running Speed	55 mph
Station Dwell Time	0.5 minutes

Source: SACOG 2020.

7.5 Park-and-Ride Locations

Park-and-ride (PNR) locations with transit service are included in the transit network. Where they are coded in the network, enable transit trips in which the traveler drives to the PNR, parks in it, then transfers to its corresponding transit stop to continue his/her journey. SACSIM does not include PNR locations that are not served by transit. Table 7-5 lists the attributes for the PNR DBF table.

Table 7-5 Park-and-Ride Table Fields

Field	Description
PNR_NODE	Node ID from highway network representing PNR location
STA_NODE	Node ID of the bus or rail stop served by the PNR lot
ZONE	Node ID of the TAZ centroid tagged to the PNR lot
PNRCAP	Number of parking spaces (enter zero if KNR)
PRKCOST	Daily parking cost, in cents
DESC_	Location description. Include station name and indicate if KNR or PNR
X/Y	Latitude/longitude

Source: SACOG 2020.

7.5.1 Transit Drop-Off Locations (KNR)

Transit drop-off zones, also knows as “kiss-and-ride”, or KNR locations, enable trips in which a traveler rides as a passenger in a private auto and gets dropped off at a transit stop. KNR locations are coded using the same process as PNRs and are stored in the same “pnr.dbf” table.

7.5.2 Adding PNR or KNR locations

To code in a park-and-ride or kiss-and-ride location:

1. Add a node to the SACSIM highway network at the PNR location.
2. Include it in the “pnr.dbf” table of PNR nodes and attributes.
3. Include it in the station_links CSV.
4. Ensure it is connected to the rest of the highway network with a link of CAPCLASS 62.

8 Bike and Walk Networks

8.1 Coding Bike Facilities into the Highway Network

8.1.1 Off-Street Bicycle-Pedestrian Facilities

Exclusive bike or walk links are coded into the highway network to reflect more detailed skims across features like parks, etc., where biking or walking is allowed, but where no motorized access is allowed.

Off-street bike paths are separate links in the model network, coded with a CAPCLASS value of 7 and BIKE value of 1. Normally, the free-flow SPEED value for these off-street bike-walk links is 3mph. Use these links to represent any off-street bike and pedestrian paths, bridges, etc.

8.1.2 On-Street Bicycle Facilities

On-street bicycle facilities (i.e., on a street where motor vehicles can operate) are represented by the BIKE value in the highway network. The values for each on-street bicycle facility type are listed below. A link's bicycle facility type influences the perceived cost of bicycling on that link, as described below in the section on Building Bike and Walk Skims.

BIKE values in the highway network correspond to the following facility types:

- 0 = bikes are allowed, but no signage or other special infrastructure exists for cyclists.
- 1 = off-street bike-ped path. Motorized vehicles are not allowed on these links. Only off-street bike facilities should have a BIKE value of 1.
- 2 = Class 2 on-street painted bike lane.
- 3 = Class 3 on-street bike route, usually indicated by "bike route" signs and/or shared-lane markings, known as "sharrows".
- 8 = Class 2 painted bike lane, but on the arterial overpass or underpass of a freeway interchange. These are coded separately from BIKE values of 2 to capture the higher levels of stress associated with cycling through freeway interchanges.
- 9 = The arterial overpass or underpass of a freeway interchange. These are coded separately from BIKE values of 0 to capture the higher levels of stress associated with cycling through freeway interchanges.

8.2 Building Bike and Walk Skims

8.2.1 Building Bike and Walk Paths for Skims

Separate TAZ-to-TAZ distance skims are prepared for walk modes, which include the following features:

- Bike and walk links are included in path building
- All surfaces streets are included in path building
- Reverse direction on one-way streets are allowed
- Ramps and freeways are excluded.

8.2.2 Effect of Bike Facility Type

Research has shown that bicyclists have unique route preferences and aversions, based route characteristics such as presence or absence of a bike lane and traffic volumes[10,11]. SACSIM attempts to model these preferences, based on the type of bicycle facility coded and the traffic volume (if any) on the link. The adjustment to distance is scaled to reflect the level of preference (indicated by an adjustment factor < 1.0—effectively "shortening" the perceived distance on the link) or aversion (indicated by an adjustment factor >1.0—effectively "lengthening" the perceived distance on the link). Table 8-1 Distance Adjustment Factors for Skimming Bicycle Facilities summarizes how these preferences are represented in SACSIM. In general, the assumptions for preferences are:

- Bicyclists prefer exclusive, Class 1 bicycle facilities where available and will travel extra distance to use them.
    - The distance adjustment factor sets this preference at 16 percent—i.e. a cyclist might travel 16 percent further in order to use Class 1 bicycle facility, compared to a shared roadway.
- If exclusive, Class 1 facilities are not available, bicyclists prefer roadways with lower vehicle volumes.
    - The aversive effect of higher volumes increases with increasing volumes. For example, roadways with about 12,000 daily vehicles are perceived as being 13 percent longer than a low volume roadway, but a roadway with 60,000 or more vehicle is perceived as being 150 percent longer.
    - Looked at the other way, a bicyclist might travel 150 percent extra distance in order to avoid a high volume roadway with no bike lane.
- If a Class 2 bike lane is provided, the aversive effect of higher vehicle volumes on a roadway is somewhat reduced.
    - For example, while a bicyclist might travel 150 percent extra distance to avoid a roadway with 60,000 vehicles and NO bicycle lane, they might travel 100 percent extra distance to avoid the same roadway WITH a Class 2 bike lane.
- Bicyclists avoid routes which take them on surface streets crossing freeways, with ramp intersections on the surface street, and will travel significant extra distance to avoid these facilities.
    - This factor was NOT explicitly researched in any study used by SACOG for establishing this process for path-building—it was generated by SACOG staff based on anecdotal evidence, and application of well researched factors like slope.

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[10] Broach, Joseph, et al, "Bicycle Route Choice Model Developed Using Revealed Preference GPS Data", Portland State University, November 2010.

[11] Charlton, et al, "Bicycle Route Choice Data Collection using GPS-Enabled Smartphones", San Francisco Transportation Authority, 2010.

Bicycle TAZ-to-TAZ skims are then built from the adjusted distance. In all cases, the true distance is skimmed, but the paths are built using the adjusted distance. Five different skim values are skimmed. The first value is the end-to-end distance—each of the four subsequent values area portions of the total end-to-end distance:

- The total TAZ-to-TAZ true distance;
- The distance on Class 1 bicycle lanes;
- The distance on Class 2 bicycle lanes;
- The distance on BIKE=”8” links; and
- The distance on BIKE=”9” links.

Table 8-1 Distance Adjustment Factors for Skimming Bicycle Facilities

	"BIKE" Link Coding‡					
Daily Vehicle Volume†	0	1	2	3	8	9
< 2,000	1.00	0.84	0.90	1.00	1.10	1.00
6,000	1.00	n/a	0.90	1.00	1.10	1.00
12,000	1.13	n/a	0.95	1.07	1.35	1.18
30,000	1.87	n/a	1.28	1.51	2.74	2.14
60,000+	2.50	n/a	1.50	2.00	4.00	3.00

Source: SACOG 2020.
Note: Distance adjustment factors used to scale actual link distance in SACSIM19 networks—e.g. “0.84” translates to a 16 percent reduction (shortening) of link distance; “1.50” translates to a 50 percent increase of link distance.
Daily vehicle volume is total (i.e. both directions for 2-way roads) and is drawn from the highway assignment results for each iteration of SACSIM19. Distance adjustment factors are computed from volumes—shown on this table are a few key points.
“BIKE” codes are described in detail in Chapter 3. “0”= no bike facility; “1” = Class 1 (exclusive bicycle lane); “2” = Class 2; “3” = Class 3; “8” = surface street at freeway interchange with NO bicycle lane; “9” = same as “8” but with Class 2 lane.

8.3 Estimating Bike and Walk Trip Distances

DAYSIM starts from parcel level land use inputs, and all location and destination choice models predict choices at parcel level, too. However, highway and transit networks are TAZ-based. Because of this inconsistency in spatial detail between the land use inputs and DAYSIM locations/destinations, and the highway and transit networks, an algorithm was developed to merge parcel-to-parcel distance estimates, and TAZ-to-TAZ estimates of the same. For more detail on this process, see Chapter 5 (Bike and Walk Networks). The algorithm used is:

- TRAVDIST = NWFRAC * SKIMDtaz + (1-NWFRAC)*ORTHDparcel
- Where:
    - TRAVDIST = the travel distance between parcels, adjusted
    - SKIMDtaz = TAZ-to-TAZ distance skim
    - NWFRAC = a proportion ranging from 0 to 1, computed as:
        - Min (1, SKIMDtaz / 6)
        - ORTHDparcel = the orthogonal (x+y component) distance between the parcels

Starting with parcel/points in SACSIM provides an opportunity to replace the centroid/skim representation of proximity with something more detailed and more directly based on the actual land use pattern. In theory, the best approach would be to use a street-centerline GIS file (rather than a stick-and-ball TAZ-based highway network) to find “true” proximity of one parcel to another (rather than one TAZ to another). However, this is impractical for a working travel demand model for two reasons. First, finding actual parcel-to-parcel paths using a GIS file would be prohibitive in terms of computation time. Second, in many cases specific street patterns for future land uses are not known in the present, and some treatment of street access to future developments would need to be created.

SACSIM computes two measures of proximity at parcel level. One is a parcel-to-parcel orthogonal distance (the sum of the “X” and “Y” coordinate distance separating two parcels). The second is a conventional TAZ-to-TAZ distance skim, comparable to skims for four-step, TAZ-based models. Based on orthogonal distance estimate, the two measures of proximity are formulaically combined. For parcels which are closer, the parcel-to-parcel distance is weighted heavily; for parcels which are very distant, the TAZ-to-TAZ distance skim is weighted heavily. By using this combined approach, unique measures of parcel-to-parcel distance are computed, which reflect the “true” proximity to a greater degree than do TAZ-to-TAZ skims alone.

9 Auto Operating Costs, Pricing and Transit Fares

9.1 Auto Operating Costs

SACSIM19 uses consumer full "out-of-pocket" auto operating costs as a key concept and input for driving mode choice and usage. Cost include gasoline, maintenance and tires, and federal and state taxes; computed on a per mile basis (Table 9-1). Gasoline costs are the largest share of per-mile out-of-pocket operating costs for most vehicles. Within SACSIM19 Cube® scripts, the auto operating cost is split into the portion related to direct costs (fuel, tires, and maintenance) and the portion related to fuel tax (for base year model, and future scenarios with no Pay-as-You-Go or mileage-based fees), or for representing a PAYGO fee for future scenarios assuming transition from fuel tax to PAYGO fees.

Table 9-1 Calculation of SACSIM9 Auto Operating Costs

Variable	2016
Fuel Price Per Gal. (Yr. 2017 $)†	$2.81
Avg. Auto Miles / Gal††	23.2
Gas Cost Per Mile (Yr. 2017 $)	$0.12
Tire+Maint Cost Per Mile (Yr. 2017 $)‡‡	$0.065
Total Auto Ops Cost Per Mile (Yr. 2017 $)	$0.186
Total Auto Ops Cost Per Mile (Yr. 2000 $)	$0.128
Fuel tax shares of Auto Ops Cost	
Federal + State Fuel Tax per Mile (Yr. 2017 $)	$0.023
Non-fuel-tax Auto Ops Cost per Mile (Yr. 2017 $)	$0.164

Source: SACOG 2020.

†Based on California Energy Commission spot prices

‡Inflation adjustments based on Bureau of Labor Statistics "Western States Urban" CPI.

†† From EMFAC2014 passenger car vehicle fleet miles per gallon

‡‡From CSAA "Your Cost of Driving" reports.

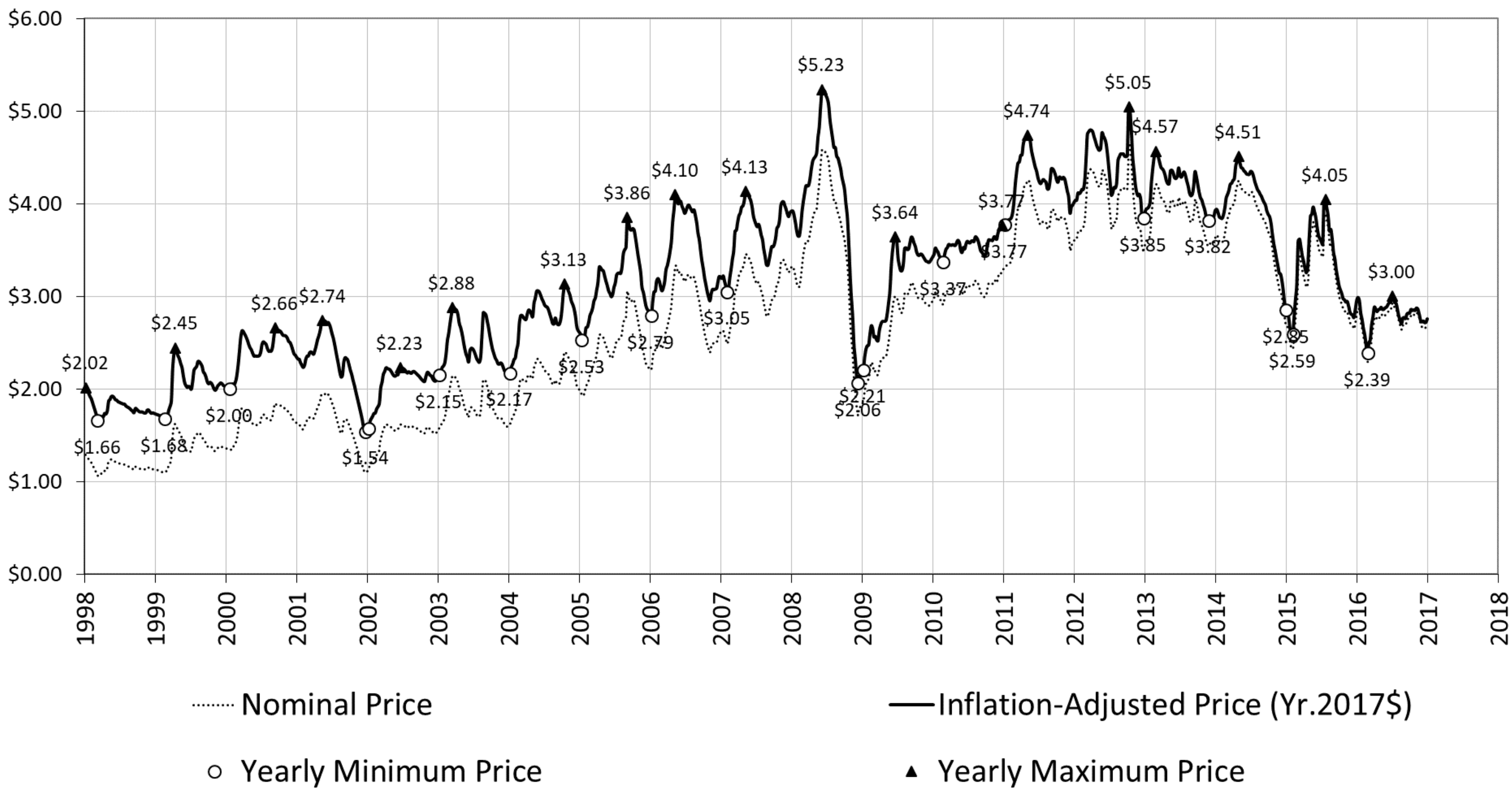
For future scenarios analyzed as part of the 2020 MTP/SCS, a similar approach used in the 2012 and 2016 MTP/SCS was used to represent future auto operating costs within SACSIM. The approach used:

- recent federal Energy Information Administration "Low" and "High" forecasts of gasoline prices;
- average passenger vehicle fleet MPG forecasts using the EMFAC emissions model;
- non-fuel costs projected based on AAA "Your Cost of Driving" data; and
- update the CA/US price differential using most recent data.

The approach to forecast auto operating costs were detailed in documents submitted to the California Air Resources Board *SACOG Technical Methodology for Greenhouse Gas Calculations for the 2020 MTP/SCS" and associated addendums*.

SACSIM and other MPO Travel Demand models have shifted to average cost per mile as standard practice (integrated as part of SACSIM since 2009). Use of average variable cost per mile have been shown to be more predictive of trip-making behavior than average "full" costs (which include vehicle ownership costs like finance charges, depreciation, insurance, etc.). The behavioral theory underpinning this is that for most households, vehicle ownership is a necessity, and choices of use of a vehicle (number of trips, length of trip, etc.) do not factor in auto ownership costs.

Figure 9-1 California Gasoline Prices, 1998 to 2017



Source: SACOG 2020.
Based on gasoline price data from the California Energy Commission, with inflation adjustments calculated using the Western States Urban consumer price index.

9.2 Facility and Mileage Based Pricing

One of the major changes from SACSIM15 to SACSIM19 was the implementation of facility and user fee-based pricing. In order to integrate pricing, major SACSIM overhauls include:

- DAYSIM calibration
- DAYSIM distribution of value-of-time (VOT)
- VOT bins during highway assignment
- Network Skimming
- Dynamic tolling adjustment algorithm during highway assignment
- Reconfiguration of Path loading by mode
- New Mileage Based User Fee spatial and temporal inputs
- New priced roadway network identification attributes and cost inputs
- Model equilibrium, population sampling, and global iterations

This section will not discuss calibration or model structure details for all topics above and instead focuses on SACSIM19's user fee or roadway pricing functionality. For model structure adjustments, see Chapter 3 on Model Structure and Chapter 12 on Calibration and Validation.

9.2.1 Facility Pricing

To incorporate effects of roadway pricing, travel choice components must be considered such as trip generation, distribution, time-of-day, congestion, mode choice, and routing. The concept is based off the *Strategic Highway Research program C04: Improving Our Understand of How Highway Congestion and Pricing Affect Travel Demand, 2012*. Consistent with the SHRP2 C04 report, SACSIM19 implements the utility-based function in Equation 9-1 to model the effects of pricing and congestion to travel.

Equation 9-1 Utility-based function to model the effects of pricing on travel[12]

$$U = \Delta + a_1 Time \times (1 + a_2 Dist + a_3 Dist^2) + b\left[Cost/\left(Inc^e \times Occ^f\right)\right] + c\, STD/Dist \quad (1)$$

Where:

Δ = Alternative-specific "bias" constant for priced facilities

a_1 = Travel time coefficient, estimated as a random parameter to capture unobserved user heterogeneity

$Time$ = Average travel time

a_2, a_3 = Coefficients reflecting the impact of travel distance on perception of travel time

$Dist$ = Average travel distance

b = Coefficient on travel cost

$Cost$ = Cost of travel including tolls, parking, and auto operating costs

Inc = Household income of traveler

e = Coefficient reflecting the impact of income on the perception of cost

Occ = Occupancy of vehicle

f = Coefficient reflecting the impact of auto occupancy on the perception of cost

c = Coefficient reflecting the impact of travel time (un-)reliability

STD = Day-to-day standard deviation

SACSIM19 does not implement all congestion pricing recommendations from the SHRP C04, but builds off the key concepts for functionality of SACSIM's existing modules and structure. SACSIM does incorporate congestion as its primary proxy for reliability, a difficult input for Demand modeling, with time factors that range from 10.05 to 1.80 based on traffic conditions. Table 9-2 compares key concepts from SHRP CO4 pricing recommendations and how they are implemented into SACSIM19.

Table 9-2 SACSIM19 Implementation of SHRP C04 Concepts

ID	Recommendations	Built into SACSIM19
1	Random coefficient on travel time to reflect unobserved user, such as a truncated lognormal distribution curve constrained as negative ensuring logical negative utility with respect to travel time.	Adjusted distributed travel time sensitivities based from a lognormal distribution with standard deviation of 0.85. Higher standard deviation shifting majority trips to lower initial VOT bin.
2	Travel time sensitivity should be a function of distance with short distances and longer distance decreasing sensitivity factors to travel time.	Not implemented due to contradictory findings from other studies.
3	Scaling travel cost coefficient by a function of household income and auto occupancy.	Already built into previous versions of SACSIM
4	Utility function include standard deviation of travel time, scaled by distance as a measure of reliability. Suggest congestion a proxy for reliability with time factors that range from 1.05 to 1.80 traffic conditions.	Cost of delays built in with time factors from 1.05 to 1.80 during highway assignment.

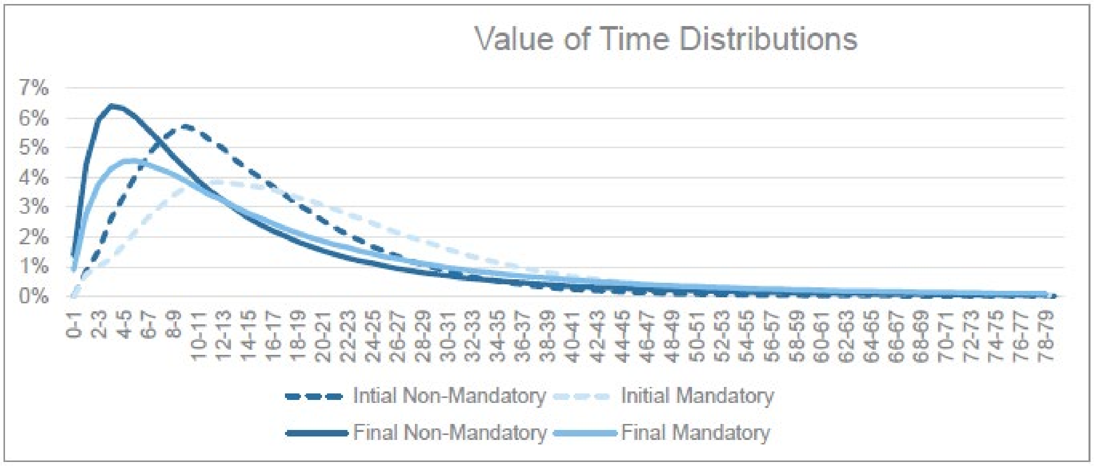
Source: SACOG 2020

9.2.1.1 Valuation of Time

Per RSG Travel demand Model Toll Enhancements[12], SACSIM uses distributed travel time sensitivities that are drawn from a lognormal distribution whose shape is controlled by the user. In the initial model, the values-of-time (VOT) for mandatory and non-mandatory SACSIM trips were drawn from log normal distributions with standard deviations equal to 0.24 and 0.15 respectively. Comparison of the resulting distributions of value-of-time with that of other regions collected by RSG indicated the need for increasing the standard deviation for SACSIM trips. Several trials were run with different values of standard deviation and compared against the other regions' distributions. A standard deviation of 0.85 was selected for both mandatory and non-mandatory trips in the current version. Figure 9-2 shows the initial and final value-of-time distributions for trips by tour type (mandatory versus non-mandatory). As shown in the plot, the new distributions use a higher standard deviation and therefore shift trips to the left (more trips with lower value-of-time than the initial distributions). These plots more closely match the results of several Stated Preference surveys conducted by RSG over the past several years1.

[12] RSG *Travel Demand Model Toll Enhancements Technical Memorandum* for SACOG, September 20, 2018

Figure 9-2 Initial Versus Final Value of Time Distributions



Source: Research Systems Group (RSG) 2018

9.2.1.2 Auto Value-of-Time Bins

Per RSG's toll modeling enhancements memo[12], the initial model setup used one value-of-time to determine path choice for all trips in the model. In the new model setup, three VOT bins were created for highway skimming and assignment. The bins were created using 33rd, 66th and 90th percentile values of the values-of-time for all trips. The corresponding dollar amount of the percentiles were $7.25, $16.85 and $38.80 respectively. These bins were used to group all trips into three VOT classes; low (1), medium (2) and high (3). The resulting cube script skims time, distance, and toll cost for three occupancy groups (drive alone, shared ride-2 and shared ride 3+) and 9 time periods for each of the three VOT classes. The total number of skim matrices thus produced is 243. A generalized cost function, shown below in Equation 9-2, was used to find the shortest path that considers both time and cost.

Equation 9-2 Generalized cost roadway utilization function with VOT and toll pricing[12]

$$cost = time + (AOC + toll) * VOT_i$$

Where:

- cost is the generalized cost on the link in minutes
- time is the congested time on the link returned by the volume-delay function
- AOC is the auto operating cost on the link, in dollars
- VOT_i is the value-of-time on the link, in minutes per dollar.
- The VOTs used for the three classes are:
  - Low VOT bin: 60/7.25 = 8.28 min/$
  - Medium VOT bin: 60/16.85 = 3.56 min/$
  - High VOT bin: 60/38.80 = 1.55 min/$

9.2.1.3 Dynamic Roadway Pricing Loop

The toll optimization algorithm was incorporated to allow dynamic roadway pricing in SACSIM19. In order to maximize travel time savings from a priced facility, the priced facility volume must continue to flow. Therefore, the price must increase or decrease based on demand to maintain the facility at an optimal level of service. The toll optimization algorithm does this at link level by comparing the travel time savings of a toll segment to the adjacent "free" or general-purpose lane. The toll price is then calculated by multiplying the time savings by the average value-of-time the highway assignment takes place. This toll value is then applied to the vehicle pathloading impedance function represented as part of the cost as describe above in Equation 9-2 to determine the demand and person who will use the priced facility. If the V/C ratio of any link in a defined toll segment exceed the optimal level of service, currently set to 0.8, or LOS D, the toll increase reducing the attractiveness, by increase the value in the impedance function. Ideally, this process continues until the facility has converged to an optimal price based on demand. In practice, this process of running the optimization loop is rather time consuming and is set to beak each toll loop when the maximum toll changes (new toll - previous toll) for any segment is less than $0.05 or 5 toll optimization loops have been run.

9.2.1.3.1 Sequential Steps of Toll Optimization Algorithm:

1. Start the toll optimization loop.
2. Read initial tolls for each segment from the tolls.csv file.
3. Calculate the travel time on the toll segments and the corresponding gp segments.
4. Calculate the time savings in the toll segment (tollseg_time – gpseg_time)
5. Multiply the time savings by the average VOT to get the current toll.
6. If the v/c ratio in any link of the toll segment is greater than 0.8, multiply the current toll by 2 (or any other factor).
7. Calculate new toll by taking an average of the previous toll and the current toll.
8. Apportion the segment toll to each link in the segment.
9. If the maximum change in tolls from the previous step is less than 50 cents, break the loop.

9.2.2 Mileage Based User Fee

A mileage-based fee, known as a pay-as-you-go, or PAYGO fee, was added into SACSIM19 path building utilization cost function. The fee is defined as:

- Combination of state and federal fuel tax per mile traveled, based on the inflation-adjusted cost of fuel taxes on a per mile basis; or
- PAYGO or mileage-based fees assumed to replace part or all of the fuel taxes in future scenarios

Within the Cube® script used to run SACSIM19, a user would set the "direct" costs of fuel, maintenance and tires on a per-mile basis for the "AOC" variable described below, and the fuel tax or PAYGO fee per mile for the "mileagefee" variable as described below.

This allows SACSIM19 new functionalities described above for travel time sensitivity distribution curves and three VOT bins for highway skimming to also be sensitive to a dynamic mileage-based fees. The fee can also vary by defined geography and time periods to represent potential fee increases based on congestion around denser land use areas or peak commute travel times. Similarly, allow fee reductions for non-congestion areas, due to off peak travel times or locations requiring longer mandatory trips to job and service areas such as rural and agricultural areas.

The generalized cost function described in Equation 9-2 for shortest path during skimming and assignment is now updated to consider not only time, costs outlined above but also, mileage-based user fees. Equation 9-3 and Equation 9-4 show the mileage-based fee integration into the cost equation.

Equation 9-3 Generalized Cost Function with Mileage Based User Fee (Equation 2 update)

cost = time + (AOC + toll + *mileagefee*) * VOT_i

Where:

- cost is the generalized cost on the link in minutes
- mileagefee is the mileage-based fee applied on the link, in dollars

Equation 9-4 Mileage Based User Fee

mileagefee = (imilagefee * spatialfactor) + congestionfee + feediscount

Where:

- imilagefee is the initial mileage-based fee applied on the link, in 2000 dollars (typically as a fraction of cents)
- spatialfactor is a multiplicative factor spatial adjustment by regional analysis zone (RAD) applied on the link level, in 2000 dollars, for “flat fee” spatial factor is set to one.
- congestionfee is a mileage-based fee increase applied on the link based on time period, in 2000 dollars, for “flat fee” congestionfee is set to zero.
- feediscount is a mileage-based fee decrease (negative value) applied on the link based on time period, in 2000 dollars, for “flat fee” feediscount is set to zero.

9.3 Auto Operating Costs and Pricing User Guide Setup

9.3.1 Auto Operating Cost User Guide Setup

9.3.1.1 Step 1: Determine AOC for scenario year

Auto Operating Cost must be determined as a SACSIM19 user input. See section Auto Operating Costs section above on how to compute AOC based on scenario year.

9.3.1.2 Step 2: Set AOC in SACSIM19 Script (.s) file

Open SACSIM19 model run script to update the auto cost input variable *auto_cost_per_mile* as shown in Figure 9-3.

Figure 9-3 SACSIM19 Auto Cost and User Fee Inputs

```
;=====================================================================

;Set per-mile auto operating cost here
auto_cost_per_mile = 0.162
userfee_per_mile =   0.014
```

9.3.2 Mileage Based User Fee User Guide Setup

9.3.2.1 Step 1: Determine Scenario Mileage Based User Fee

Determine mileage-based user fee for scenario. SeeAppendix D Fuel Tax and Mileage Fee Report for further description and examples. Must convert mileage-based fees back to 2000 dollars for SACSIM19 use.

9.3.2.2 Step 2: Set User fee in SACSIM19 (.s) file

Open SACSIM19 model run script to update the initial mileage-based user fee input variable *userfee_per_mile*. If not user fee is desired for the scenario, *userfee_per_mile* should be set to 0.00. For a flat user fee per mile, *userfee_per_mile* is the only input required. If time period or spatial adjustments are need additional inputs are required. Regardless, it is important to review other user fee inputs to confirm they are set on or off properly.

9.3.2.3 Step 3: Spatial and Time Period Fee Adjustments

Spatial and temporal components can be set using the *RAD_Userfee.csv* input file in the Scenario run folder. Table 9-3 describes the four inputs in the *RAD_Userfee.csv* required and an example with and without the mileage based fee adjustments. Figure 9-4 shows an example of the *RAD_Userfee.csv*.

Table 9-3 Spatial and Temporal Mileage-Based Fee Adjustment

Header (Not in actual file)	RAD	Multiplicative Factor	Peak Adjustment	Off Peak Adjustment
Required input description	Regional Analysis Distract Spatial Geography where factor will apply to roadways. **Default is all RAD Zones within region.**	Factor used to multiple userfee_per_mile input. **Default is 1.**	Peak congestion rate adjustment factor applied to AM (7am-10am) and (4PM – 6PM) peak hours. **Default is 0.**	Off Peak period discount rate during non-congested times applied to Evenings (7-9), Nighttime (10-5am) and Midday. **Default is 0**
Example Spatial Adjustment **Turned On**	1	2	0.007	-0.007
Example Spatial Adjustment **Turned Off**	1	1	0	0

Figure 9-4 RAD_Userfee.csv Example

26	26	1	0.007	-0.007
27	27	2	0.007	-0.007
28	28	1	0.007	-0.007

RAD_UserFee

9.3.3 Facility Pricing User Guide Setup

SACSIM19 requires two facility pricing inputs:

- Network Segment Identification
- Toll Input Cost
- Model Run Script *(only for adjusting all-lane toll facility)*

9.3.3.1 Step 1: Network Segment Identification

Open the base network, typically named **<scenario year>_base.net.** Every priced facility must have a TOLLID number associated. For parallel general purpose and auxiliary lanes. The same ID number must be assigned to GPID (general purpose lanes) and AUXID (auxiliary lanes). This is used to determine the cost of the managed facility relative to the congestion on the parallel "free" facilities. Depending on the type of managed lane, USECLASS must also be set with a value of 0, 2, or 3 to determine the allowed vehicle type on the managed facility. Zero allows all users to drive on the facility being priced. Note, USECLASS does not determine which vehicles are priced, the prices are set in the Toll Input File described below. Two refers to vehicle occupancy of 2+ and 3 allows vehicle with 3 or more passengers only to enter the facility. Figure 9-5Figure 2-8 shows an example of a managed lane facility coding on the base network. In this example all vehicle types are allowed on the managed lane facility. For more information on other network attributes that may influence the network toll segment see chapter 4 on Highway Network.

9.3.3.1.1 Define Network Toll Segment

Defining toll segment distance and extents is an important input to determine the cost and utilization of the priced facility. Each toll segment has multiple links, but only one TOLLID identifier, one GPID identifier, and one AUXID identifier (if auxiliary lane exists along segment). Travel time savings is taken as the total toll segment time minus the total general-purpose segment time, and if any V/C ratio link is greater than the level of service threshold, cost increases. Taking into consideration distance, number of lanes, interchanges, ramps, and speeds is important for a priced facility to work properly. Figure 9-6 shows an example where the number of lanes and demand of the highway facility changed for different toll segments were defined before and after the ramps.

Figure 9-5 Base Network Toll ID Coding

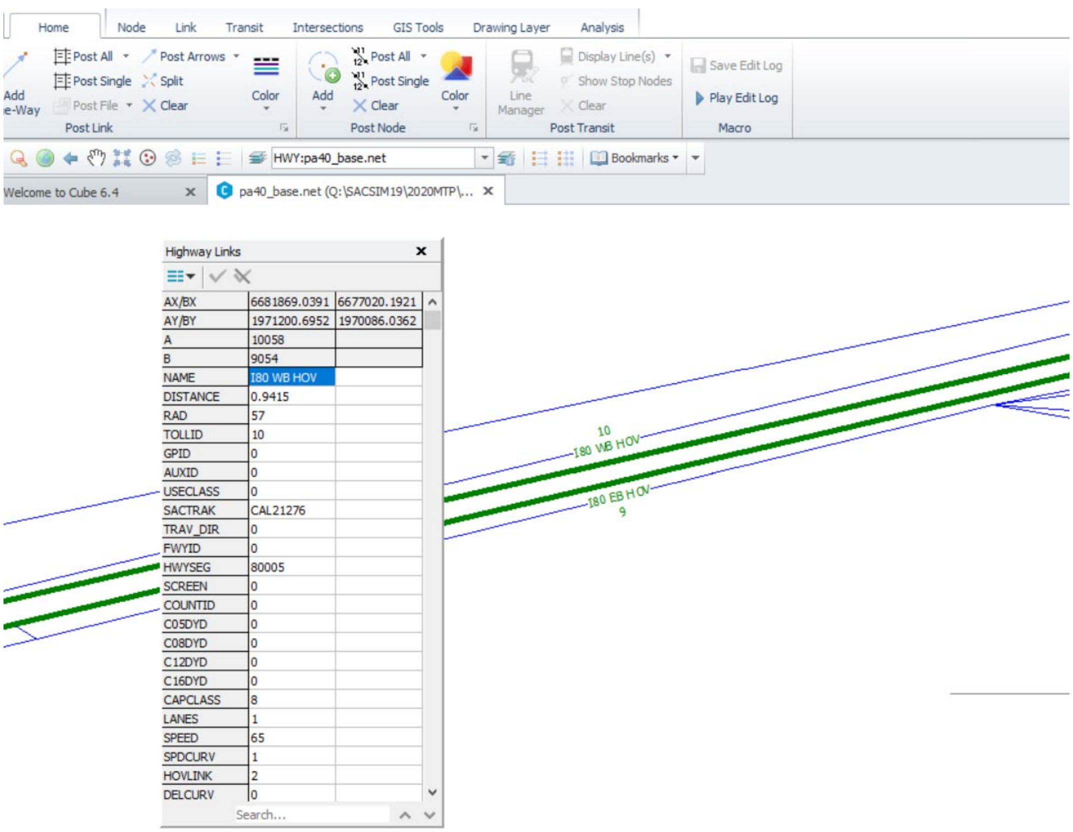
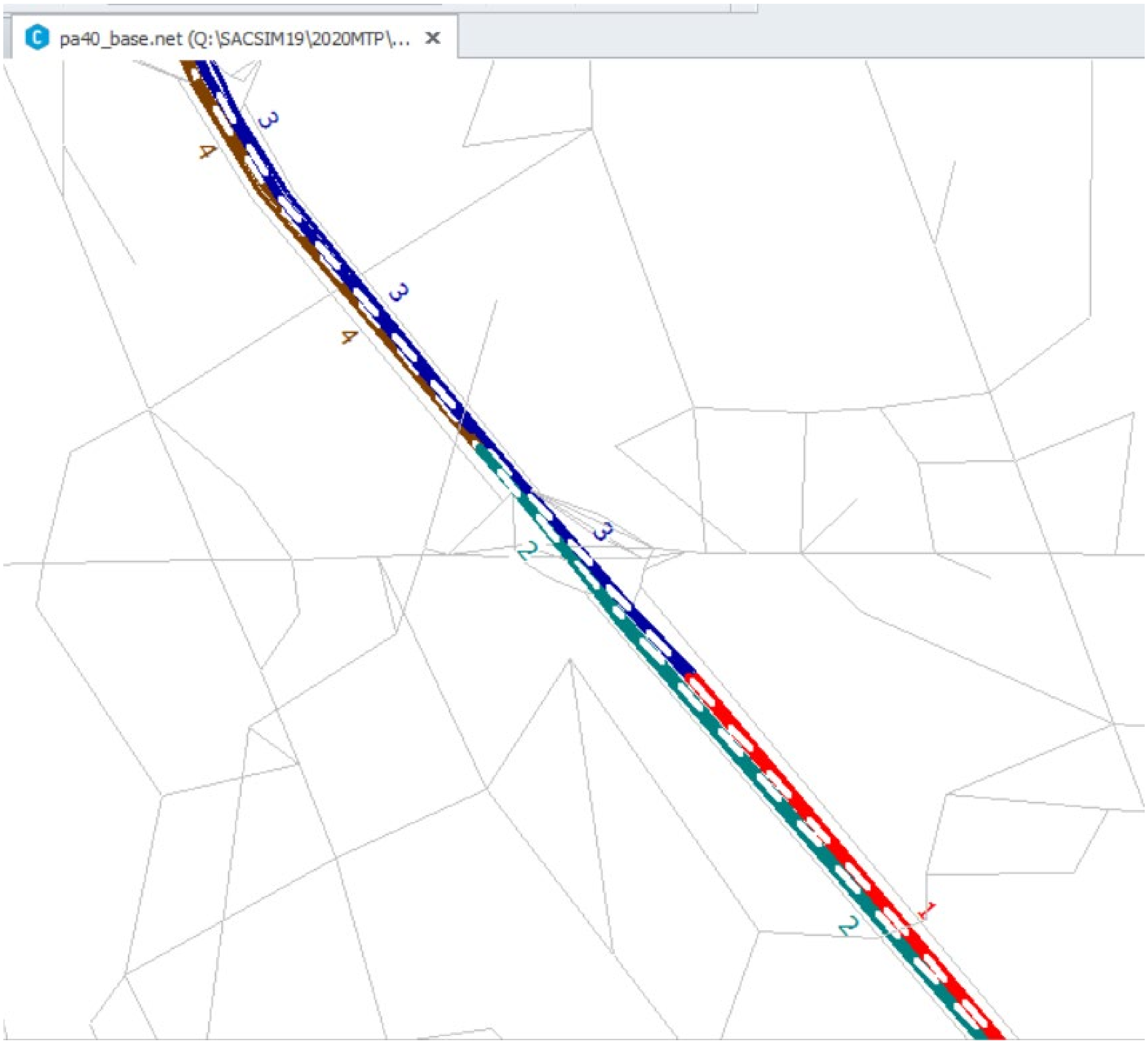


Figure 9-6 Multiple Toll Segments Identified on Network



9.3.3.1.2 Define Network General Purpose and Auxiliary Segment

Since the travel time from the general-purpose lane is needed to compare savings to the priced facility, the general purpose segment length must be the same distance as the priced facility distance. If these distances are too far off this will affect the travel time savings function. For this reason, if the total general-purpose distances less or greater than 0.25 miles different from the priced facility, SACSIM will immediately error out. These lengths can be checked in the tollseg_length.csv file created during SACSIM initial setup. Auxiliary lanes are not used in the pricing optimization algorithm and therefore do not require and maximum or minimum lengths. Auxiliary lanes need to be coded to ensure the vehicles do not skip the facility all together and allow the total volume across all lanes to be accounted for.

9.3.3.1.3 Define Network Segments for All-Lane Toll Facility

To define an all-lane toll facility. The TOLLID must be identified for all lanes, including what may have been previously coded as general-purpose lanes or auxiliary lanes. Additionally, the model run script input variable *AllLaneToll* must be set from 0 (default) to 1, as shown in Figure 9-7. Since the toll optimization loop is based off the travel time savings from the parallel free option, the dynamic pricing is not available for all toll facilities, instead users will have to specify the cost of the toll as an input in the toll cost file *toll.csv*.

Figure 9-7 SACSIM19 All-lane Toll Facility Input

```
; this block of code calculates the total length of each toll segments, which will later be used to apportion tolls to each link
   AllLaneToll = 0 ;1 True, 0 False. Turn true if all lane toll facilities exist.
   run pgm = hwynet  MSG='step 0 Calculate toll segment length'
```

9.3.3.2 Step 2: Toll Cost File

The TOLLID coded on the network identifies the toll segments. The costs by vehicle types then need to be associated and defined to the network toll segments. This is done in the Toll Input Cost File *tolls.csv***.** Each row represents a unique TOLLID segment by time period. For every tolled there will be nine additional rows added to the input file (1 tollid X 9 SACSIM time periods). Table 9-4 describes the columns required for the toll cost file. Table 9-5 Toll Cost Input Example shows an example of the Toll Input Cost File with one toll segment. The actual csv file does not have column headers and must be written in the same order as Table 9-4.

Table 9-4 Toll Cost Inputs

Input Order	Columns	Description	Value Type
1	Facility Index	unique ID for a link during a time period: toll_gp_id*100 + period	Unique Integer >100 (based on Segment Number and period)
2	Segment #	corresponds to TOLLID, GPID, and AUXID in model network	Unique Integer
3	period	SACSIM time period	1-9
4	adjustment	1/0 indicating if toll optimization algorithm is applied	Binary (0-1)
5	toll_da	starting toll value for drive-alone	2000 dollar
6	toll_s2	starting toll value for HOV2	2000 dollar
7	toll_s3	starting toll value for HOV3	2000 dollar
8	toll_cv	starting toll value for commercial vehicles	2000 dollar
9	mintoll_da	minimum toll value for drive-alone	2000 dollar
10	mintoll_s2	minimum toll value for HOV2	2000 dollar
11	mintoll_s3	minimum toll value for HOV3	2000 dollar
12	mintoll_cv	minimum toll value for commercial vehicles	2000 dollar
13	maxtoll_da	maximum toll value for drive-alone	2000 dollar
14	maxtoll_s2	maximum toll value for HOV2	2000 dollar
15	maxtoll_s3	maximum toll value for HOV3	2000 dollar
16	maxtoll_cv	maximum toll value for commercial vehicles	2000 dollar
17	Reversable Lane AM	add managed lane(s), remove opposite flow general purpose lane, during AM peak period (7-10am), general purpose removal should be on different toll segment ID.	positive integer to add managed lane(s), negative integer to remove general purpose lane(s)
18	Reversable Lane PM	add managed lane(s), remove opposite flow general purpose lane, during PM peak period (3-6pm), general purpose removal should be on different toll segment ID.	positive integer to add managed lane(s), negative integer to remove general purpose lane(s)

Input Order	Columns	Description	Value Type
19	Shoulder lane AM	add managed lane(s) during AM peak period (7-10am), assumption is shoulder space is converted to a managed or general purpose along the facility adding width for an additional managed lane.	positive integer to add managed lane(s)
20	Shoulder lane PM	add managed lane(s), during PM peak period (3-6pm)	positive integer to add managed lane(s)
21	Take a Lane AM	add managed lane(s), remove adjacent general-purpose lane, during AM peak period (7-10am)	positive integer to add managed lane(s), (will subtract value from general purpose lane(s))
22	Take a Lane PM	add managed lane(s), remove adjacent general-purpose lane, during PM peak period (3-6pm)	positive integer to add managed lane(s), (will subtract value from general purpose lane(s))

Table 9-5 Toll Cost Input Example

Fac. Index	Seg.	Per.	Fac. Type	Adjust	Toll DA	Toll S2	Toll S3	Toll CV	Min DA	Min S2	Min S3	Min CV	Max DA	Max S2	Max S3	Max CV	Reversable Lane AM	Reversable Lane PM	Shoulder lane AM	Shoulder lane PM	Take a Lane AM	Take a Lane PM
101	1	1	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
102	1	2	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
103	1	3	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
104	1	4	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
105	1	5	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
106	1	6	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
107	1	7	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
108	1	8	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0
109	1	9	2	1	1	0	0	2	0.1	0	0	0.2	30	0	0	30	0	0	0	0	0	0

Referring to the Input Order Column of Table 9-4:

Inputs 1-3 are used to tie the network toll links identified to the cost per time period. Input 1 should be calculated by input 2 * 100 + input 3. If additional time periods or toll segments are added, these rows will need to be expanded on in the same format for every new toll segment added to the network.

If a scenario requires no toll pricing, Inputs 4-22 should all be set to zero.

Input 4 adjustment if the toll optimization algorithm is turned on or off. This must be turned on to use the dynamic pricing. There are a few reasons to turn off:

- User want toll prices fixed, may have already determined the optimal cost or running post processing assignments.
- All toll lane scenario or facility is being applied
- For testing purpose, user wants to reduce model run time.

Inputs 5-8 are user specified initial toll prices by four mode vehicle classifications. These values are put into model as part of the initial cost function and then adjusted during the toll optimization loop. If a fixed or all lane toll scenario is being ran, the initial inputs will also be the final cost. Based on default settings, the toll optimization loop is set to run a maximum of five iterations. If toll price curve results seem too high or too low based on no osculation occurring or not enough convergence in price, it is recommended to start the next run with a higher or lower initial toll to help convergence to occur within the 5 iterations.

- DA = drive alone or single occupancy vehicle
- S2 = Shared Occupancy Vehicle with two persons (SOV2)
- S3+ = Shared Occupancy Vehicle with three or more persons (SOV3+)
- CV = Commercial Vehicles, currently defined as SACSIM category CV 2 axle, 3+ axle CVs are not allowed access to managed lanes. This can be adjusted in the model run script.

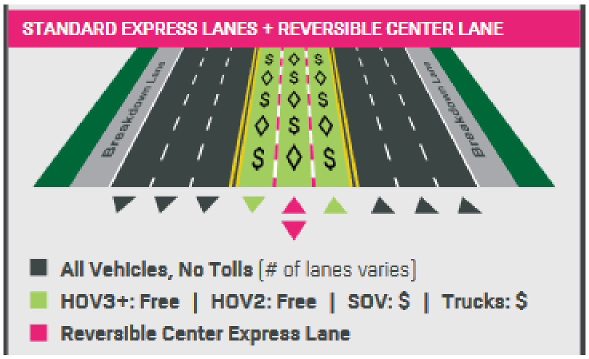
Inputs 9-16 are user specified toll prices constraints. Inputs 9-12 are the minimum by set price by mode. Input 13-16 are the maximum price by mode. For example, if a minimum toll price was set to $1.00 and a maximum to $10.00, the final price must be at or between these upper and lower bounded constraints regardless of demand, or lack thereof, along the facility. Since the toll optimization loop sets the price based on the vehicle demand, the more constraints added the less likely the algorithm can find the optimal price to set.

Inputs 17-22 are user specified lane configuration adjustments on both the general purpose or “free” lanes and the managed lanes or “priced” lanes.

Inputs 17 and 18 add reversable lanes to the priced facility to the peak period: 17: 3 AM peak hours 7-8, 8-9, 8-10 am, 18: 3 PM peak hour 3-4,4-5,5-6 pm. If positive value is entered to a toll segment, a priced lane(s) will be added. If a negative value is added a general-purpose lane(s) will be added.

Using this logic, to maintain the number of lanes defined in the scenario base network file, a negative value should always be assigned to the parallel opposite direction toll segment ID. If no negative number is specified, an additional lane is added to the network. Figure 9-8 shows an example of a reversable lane as an additional middle lane that can reverse directions based on the peak period traffic flow directional demand of travel.

Figure 9-8 Express Lane Configuration: Reversible Center Lane

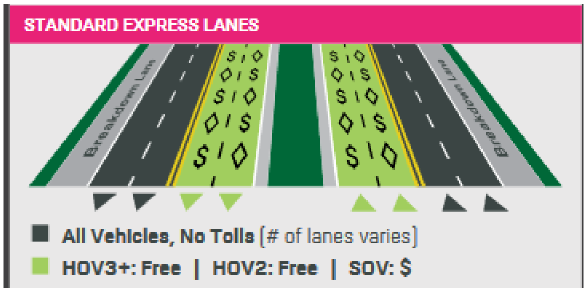


Inputs 19 and 20 add a managed lane(s) during AM peak period (7-10am) and PM peak periods (3-6pm) respectively. SACSIM19 assumption is shoulder space is converted to a managed or general purpose along the facility adding width for an additional managed lane. Since SACSIM19 assignment is a "stick and ball" network, land configuration curvature and geometry is not accounted for at the demand level software. Nor is type of pricing facility implementation infrastructure design. Microsimulation or CAD software's may be used to determine if adding a shoulder lane scenario is realistic based on a roadway geometry. SACSIM19 simple provides the capability to add or remove the lane during assignment. Figure 9-9 shows an example of a shoulder or breakdown lane converted into an additional lane during peak periods.

Figure 9-9 Express Lane Configuration: Flexible Breakdown Lane

Inputs 21 and 22 add an additional managed during AM peak period (7-10am) and PM peak periods (3-6pm) respectively by removing a general-purpose lane during the defined time period. This allows scenarios with multilane express lanes during times of high demand to manage congestion, and "free" or general-purpose lanes during lower demand. An facility example of could be a highway with high morning peak congestion into downtown in the mornings, however, during the PM the traffic may be more evenly dispersed throughout the duration of the afternoon evening and not require as many managed lanes available. Figure 9-10 shows an example of a multi-lane express lane configuration where a “Take A Lane” may be applied.

Figure 9-10: Multilane Express Lane



9.4 Transit Fares

Zone-to-zone transit fares are required as inputs to the mode choice model, reflecting boarding fares, transfer discounts, and (where applicable) zonal fares along the transit paths.

9.4.1 Transit Pass and Discount Models

By default, SACSIM assumes a potential transit user will pay the single-ride adult cash fare for each transit trip and pay the price, if applicable, for any transfers. However, significant shares of transit users either use a transit pass or receive a significantly discounted fare.

DAYSIM's transit pass model predicts whether a person would own a transit pass based on his/her age, type, access to transit from his/her home, employment status, and student status. If a person owns a transit pass, then the fare cost of taking a trip by transit is zero. Model users can adjust the coefficients for predicting transit pass ownership or turn the pass ownership model off if desired.

DAYSIM also predicts whether a person will pay a discounted fare, as well as how much that discount is, by applying a percentage discount to the adult cash fare based on the person's age (e.g. for a senior/child discount) and student status (e.g. students ride for free or pay a discounted fare).

Both fare discounts and the transit pass model are configurable in the DAYSIM configuration file, though there is a separate coefficient file for adjusting the transit pass model coefficients.

9.4.2 Limits of Transit Fare Estimation

While SACSIM captures the bulk of transit fare types, it cannot capture all of them. Examples of fare types not estimated by SACSIM include day passes and week passes that, respectively, allow unlimited boardings during a 24-hour day or 7-day week. Also, even within the discount factors applied above, SACSIM does not capture the full variation of discounts that apply across different operators, e.g., while one operator allows students to ride for free, another operator may just give them a discounted fare. Ideally, SACSIM would capture all fare policies and variations, but doing so would add considerable complexity to the model while only very marginally improving model accuracy.

9.4.3 SACOG Transit Operator Base Fares and Transfer Policies

Table 9-6 lists the undiscounted adult cash fares for operators included in SACSIM. Boardings and transfer fares are defined for each group of transit services.

Note that although fares in Table 9-6 are stated in year 2016 dollars, for the model fare input table, "ptfare.txt", all fares are converted to year 2000 dollars. This is consistent with other dollar cost model inputs such as auto operating cost.

Table 9-6 Year 2016 Transit Fares (in 2016 Dollars)

Fare Group	Transit Service	2016 Adult Cash Fare, in 2016 Dollars	Discount(s)	Monthly Passes
1,2	RT LRT & Bus	$2.75	Seniors, youth	Yes
3	Yolobus Express	$3.25	Seniors, youth	Yes
4	Yolobus Local / Intercity	$2.25	Seniors, youth	Yes
5	Roseville Commuter	$3.25	Seniors, youth	Yes
6	Roseville Local	$1.50	Seniors, youth	Yes
7	Yuba-Sutter Commuter	$4.00	Seniors, youth	Yes
8	Yuba-Sutter Local	$1.00	Seniors, youth	Yes
9	El Dorado Transit Commuter	$5.00	Seniors, youth	Yes
10	El Dorado Transit Local	$1.50	Seniors, youth	Yes
11	Placer County Transit Commuter	$4.25-$5.75	Seniors, youth	Yes
12	Placer County Transit Local	$1.25	Seniors, youth	Yes
13	Unitrans	$1.00	Seniors, UCD goClub members	Yes
14	Heavy Rail	Varies	Seniors	Yes
15	South County Link (Galt)	$3.25	Seniors, youth	Yes
16	E-Tran Commuter	$2.25	Seniors, youth	Yes
17	E-Tran Local	$2.25	Seniors, youth	Yes
20	Folsom Local	$2.50	Seniors, youth	Discount groups only

Source: SACOG 2020.

10 Model System Equilibration

10.1 Background and Concepts

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

The theory of system equilibrium was developed based on trip-based models[13]. A wide range of trip-based models have a fixed point solution for all zone-to-zone and link flows, which can be solved with proper algorithms. These have been rare in practice until the 1990s, which saw development of many convergent model systems.

Almost all convergent trip-based models, at some stage in an iteration process, use the method of convex combinations. This is to update the current best solution of flows (zone-to-zone matrices and/or link volumes) with a weighted average of the previous best solution of those flows ($\mathbf{x}_{i-1}$), and an alternative set of flows calculated by the new iteration shown in Equation 10-1. The first iteration normally uses network performance skim matrices based on free-flow link times.) When flows are combined in this manner, the result meets the same conservation-of-flow constraints as the iteration matrices.

Equation 10-1 SACSIM Iteration

($\mathbf{y}_i$): $\mathbf{x}_i = (1-\lambda)\mathbf{x}_{i-1} + \lambda\mathbf{y}_i$

Where the step size λ must satisfy $0 < \lambda \leq 1$. In the first iteration, there is no $\mathbf{x}_{i-1}$, so λ must be 1.

[13] Evans, Suzanne P. "Derivation and Analysis of Some Models for Combining Trip Distribution and Assignment", *Transportation Research*, Vol. 10, pp. 37-57 (1976).

Several trip-based model systems are defined so that the step size can be chosen at each iteration to optimize an objective function, or approach the solution to a variational inequality. But most models in practice do not satisfy those models' specific requirements, so the step size must be predetermined. The classic reliable workhorse is the Method of Successive Averages (MSA). This reliably converges for a wide range of models for which there is no determination of an iteration's optimal λ. This method chooses λ =1/*i*, so that, in effect, after any iteration *n*, the solution approximation is the average of all the iteration-result vectors computed so far:

$\mathbf{x}_i = \frac{\mathbf{y}_1 + \mathbf{y}_2 + ... + \mathbf{y}_i}{i}$. Some trip-based models converge reliably and more efficiently with a fixed step size[14], though care must be taken in the choice of that step size, which depends on the problem.

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

The equilibration procedure in SACSIM employs equilibrium assignment iteration loops (a-iterations) nested within iterations between the demand and assignment models (da-iterations).

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

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

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

(1) "Pre-assignment blending" - Blend the trip demand matrices from the system-iteration's demand model, with the previous system-iteration's blended trips, into a weighted average[15]. Then assign these new blended trips in equilibrium.
(2) "Post-assignment blending" - assign the new iteration trips alone in equilibrium, then blend those volumes with the previous system-iteration's blended link volumes[16].
(3) Assign each iteration's trips in an all-or-nothing assignment on the same paths used to derive the skims[17]. Most modeling software, and the several whole-matrix processes in SACSIM (and most trip-based models) conspire against the practicality of such an approach. Consequently, the Evans model and numerous generalizations[18] are rarely used in practice.

[15] Boyce, David, et.al., "Introducing 'Feedback' into Four-Step Travel Forecasting Procedure vs. Equilibrium Solution of Combined Model", Transportation Research Record No. 1443, Transportation Research Board, Washington, D.C, 1994, pp. 65-74.
[16] Boyce, David, et.al. (1994), ibid.
[17] Evans (1976) ibid.
[18] Miller, Harvey J., "Towards Consistent Travel Demand Estimation in Transportation Planning: A Guide to the Theory and Practice of Equilibrium Travel Demand Modeling", U.S. Department of Transportation, Bureau of Transportation Statistics, June 27, 2001.

10.2 SACSIM19 Equilibrium Solution Procedure

As mentioned in Chapter 3 and 9, SACSIM19 has two important enhancements to support the modeling needs of the 2020 MTP/SCS: VOT class and pricing. SACSIM19 has three VOT classes, where previous SACSIM versions only had one during trip tables and assignment development. This enhancement increases the skimming from one class to three classes, and thus affects a traveler's choices based on its VOT class as well as road use choice when pricing is applied. The pricing modeling is included in SACSIM19 to model how pricing affect travelers' behavior and then GHG emissions.

Both enhancements increase not only the complexity of modeling but also the model run time. To make a balance between the modeling capacities and the computer running time, SACSIM19 adopts the same system equilibrium procedure as SACSIM15 but different specifications in a-iterations and da-iterations.

SACSIM19's equilibrium procedure also includes pricing optimization for tolled facilities, described in more detail in Chapter 9.

Pricing optimization in SACSIM19 is implemented after the initial assignment converges and forms an internal feedback loop of up to 5 toll iterations around each assignement. There, including toll optimization takes a much longer time to converge. After many trial runs, five loops are specified as the maximum number of iterations. In the full gloabal model iterations, SACSIM19 run three iterations with 100% sampling rates of households and persons for each iteration.

11 Sensitivity Testing

11.1 Introduction

Testing and documentation of travel demand model sensitivity is not new, but has garnered more interest in recent years due to passage of Senate Bill 375 (SB375), subsequent discussions of travel demand modeling at the Regional Targets Advisory Committee meeting, and the workshops and public meetings leading up to the California Transportation Commission's (CTC) 2017 update of the "Regional Transportation Plan (RTP) Guidelines". In combination, these initiatives resulted in expansion of documentation and testing of regional travel demand models.

This chapter reports results of testing SACSIM's sensitivity to several key policy input variables and other, exogenous inputs. The testing falls into four categories:

- **Traditional "experimental" testing**, where one input factor is systematically varied, holding all other factors constant, and comparing the variations in the input factor to variations in key outputs. Variables tested in this manner are:
    - Auto-operating costs,
    - Off-street parking price,
    - Household income,
    - Transit fares, and
    - Highway capacity.

- **Cross-sectional testing**, where variations in multiple input variables for a single model run are statistically analyzed for correlations to variations in key outputs. Because of the disaggregate nature of SACSIM output for household-generated travel, the options for performing statistical testing of cross-sectional (i.e., single model run) results are more straightforward than for an aggregate "four-step" travel demand model. Variables tested in this manner are land use/transportation interaction variables, also known as "the Ds":
    - Regional accessibility (or "destinations"),
    - Mix of use (or "diversity"),
    - Proximity to transit (or "distance"),
    - Street pattern (or "design"), and
    - Residential density.

- **Testing of random variation** in the microsimulation of demand for household-generated travel, where the random "seed" for the simulation is varied. A seed variable is common to most simulation models like the DAYSIM submodel of SACSIM. The seed determines the order of simulation of events within the model run. In DAYSIM, it determines the order of simulation of person-level activities. Even with identical input files, the results of the simulation can vary based on the order in which person-level activities are modeled. This testing is not different than the traditional "experimental" testing described above, but the test variable (the random seed) is unique to simulation models and is not a policy variable or exogenous input. The purpose of this testing is to quantify the potential random variation in the simulation results themselves.

11.2 Experimental Testing of Key Exogenous Input Factors

For experimental sensitivity tests, each factor was varied by fixed amounts in six test runs, using the model inputs from year 2008 and the DAYSIM submodel of SACSIM19. We used 2008 data because 2016 data were not available at the time and 2012 was a low point of the Great Recession and its elasticities may not be reflective of "normal" conditions. The following input factors were tested:

- Auto operating costs (a function of gasoline price and average fleet efficiency), in cents per mile, using year 2000 dollars. The model program only allows for costs to be stated in whole cents;
- Off-street parking price;
- Household income, in year 2000 dollars;
- Transit fares (average discounted transit fares, in year 2000 dollars); and highway capacity, stated in vehicles per lane per hour, and used in the SACSIM vehicle assignment scripts.

Sensitivity to changes were tested in each of these inputs by performing three increases (+10%, +25%, +50%) and three decreases on their base input values (-10%, -25%, -50%), except for highway capacity, whose base input value was only tested for changes of -10%, -5%, +5%, and +10%.

We further explored parking price sensitivity through focused tests for trips heading specifically to the downtown core, as well as how parking price sensitivity differed for workers who must pay to park at their usual workplace.

Tests were made with full runs of SACSIM, so secondary effects of the changes on choice of destination are included in the test results. Sensitivities for the following outputs were checked, based on household-generated activity for people living within the SACOG region:

- total person trips,
- total vehicle trips,
- total vehicle miles traveled (VMT),
- congested vehicle miles traveled (CVMT),
- total transit person trips, and
- total bike and walk person trips

11.2.1 Elasticity

Reasonable sensitivity is judged by comparing the model sensitivity to the consistent range of observed sensitivity to the test factors in published literature. The most common measure of sensitivity is *elasticity*, which is defined as the ratio of percent change in a dependent factor (e.g., numbers of trips or vehicle miles traveled) to percent change in a test factor (auto costs, income, transit fares, or highway capacity). If a consistent range of elasticities for the exact factors tested is available, the changes of test variables in the predicted direction based on travel behavior theory will be the reasonableness criteria.

The elasticity formulation, known as arc elasticity, used for most SACSIM sensitivity calculations was:

Elasticity = [log (Output_1) - log (Output_0)] /[log (TestFactor_1) - log (TestFactor_0)]

Where "_0" variables are the base run, and "_1" variables are the test runs with one variable changed.

Due to the difficulty of getting exact test factor values for it, highway capacity elasticity was calculated with the following alternative elasticity formula:

Elasticity = [percent change in output] / [percent change in test factor]

11.2.2 Auto Operating Cost

Reported sensitivities to auto operating costs vary widely in research literature. The values discussed below were used as a range of reasonable sensitivity. The model sensitivities shown are "end-to-end" elasticities, or the elasticity based on comparing the highest and lowest test values. Elasticity typically varies as you change the value of the test factor (e.g., the effect of increasing the auto operating cost from 12 cents to 15 cents on VMT will be different than increasing it from 15 cents to 18 cents), and the end-to-end elasticity helps give a rough average elasticity we can use for comparing with observed data.

- **VMT**: Studies summarized in Litman (2017) show short term elasticity of VMT with respect to auto cost as low as -0.03 (i.e., a 10 percent increase in auto cost results in a 0.3 percent decrease in VMT), and as high as -0.38 in the long term[19]. A separate study by Small and Van Dender (2007), which attempted to account for the "rebound" effect (i.e., people switching to more efficient vehicles, changing driving habits, and changing other trip-making behavior) estimated the long run VMT/auto cost elasticity as between -0.11 and -0.15[20].
    - Reasonable range of elasticity = -0.03 and -0.38
    - Model results = -0.135
    - The model was somewhat less sensitive to reductions from base auto costs than to increases, likely because there are diminishing returns to additional vehicle travel, and once auto travel becomes cheap enough, it ceases to matter and further reductions generate little to no additional travel.

- **CVMT**: No research was found linking auto operating cost to congested vehicle miles traveled (CVMT), though we expect the elasticity to be negative and somewhat greater than VMT elasticity because reducing even a small proportion of vehicle trips can disproportionately reduce congestion.
    - Reasonable range of elasticity: somewhat greater magnitude and same direction as VMT
    - Model results = -0.442

- **Transit person trips**: Less research has been conducted on the relationship between auto operating costs and transit trips. A 2008 study conducted for small urban and rural areas

[19] Litman, Todd, "Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior", Victoria Transport Policy Institute, 2017, pp. 34-36, 46-47.

[20] Small, Kenneth A. and Van Dender, Kurt, "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect," *Energy Journal,* vol. 28, no. 1 (2007), pp. 25–51.

found an elasticity of transit ridership with respect to fuel price, a reasonable proxy for auto operating cost, ranging from +0.08 to +0.16[21]. An additional study of continental European cities from 1999 and summarized in Litman (2017) indicated a cross elasticity of transit trips with respect to fuel price of +0.13[19]. However, a study from Chicago from 2013 suggested that the elasticity of transit demand with respect to fuel price varies with the fuel price, and that elasticities for fuel prices below $3.00/gallon can be less than +0.05[22].

  - Reasonable range of elasticity = +0.05 to +0.16
  - Model results = +0.121
  - As with VMT, the changes transit trips in response to decreases in auto operating costs were smaller than changes in response to increases.

- **Bike and walk person trips**: The only research found on the relationship between auto operating cost and bike/walk trips is a 1999 study summarized in Litman (2017), which found a cross-elasticity of bike/walk trips with respect to fuel price to be +0.13 in continental European cities[19]. European cities generally have a more pedestrian-friendly urban form and land use context than the SACOG region, making walking a more attractive substitute to driving relative to the SACOG region, which has large areas in which walking is a relatively unattractive option compared to driving.

  We also predict that the magnitude of the relationship would be less than the VMT/auto cost elasticity, given that a significant share of the VMT change results from shortening vehicle trips (e.g., choosing destinations closer to place of residence) rather than changing modes, and the transit elasticity shows that some of the mode shift goes to transit rather than non-motorized modes.

  - Reasonable range of elasticity = less than +0.13, lower magnitude than auto cost-VMT elasticity
  - Model results = +0.119

- **Person trips**: We did not find any recent research could be found on the relationship between total person trips and auto operating costs. We predicted the elasticity of person trips with respect to auto operating cost to be slightly negative, assuming an increase in auto cost would may slightly reduce overall travel, but in many cases people would either make shorter trips or shift modes.

  However, as shown below, trip elasticity was slightly positive, indicating that increasing auto operating cost slightly increased the number of trips. One explanation for this finding is that as auto operating cost increases, people shift to other modes like transit that do not allow combining trips in the way that auto travel does. To test this explanation, we measured the elasticity of tours with respect to auto operating cost and found that there was a slight negative elasticity, indicating that a higher auto operating cost will slightly increase the number of trips people make, but those trips will be consolidated into a smaller number of tours.

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[21] Jeremy Mattson, "Effects of Rising Gas Prices on Bus Ridership for Small Urban and Rural Transit Systems", Upper Great Plains Transportation Institute (www.ugpti.org), North Dakota State University; 2008. www.ugpti.org/pubs/pdf/DP201.pdf

[22] Nowak, William and Savage, Ian, "The cross elasticity between gasoline prices and transit use: Evidence from Chicago", Northwestern University, 2013

- Reasonable range of elasticity = very small, negative
- Model results, person trips = +0.010
- Model results, person tours = -0.002

- **Vehicle trips**: Litman (2017) summarized a 2001 European study of elasticity of vehicle trips with respect to fuel price, which is a reasonable proxy for auto operating cost. Observed elasticities in this study ranged from -0.06 to -0.22 in the short term and -0.07 to -0.4 in the long term[19], depending on trip purpose. As with the walk/bike cross elasticity, we expect this relationship to be somewhat less elastic in the SACOG region given that European cities generally provide more attractive alternatives to driving (e.g., older, more walkable urban areas, more extensive transit systems, etc.), making walking a more attractive option relative to driving.
  - Reasonable range of elasticity = very small, negative in sign
  - Model results = -0.008

Table 11-1 presents results of sensitivity testing of auto operating costs. The base cost used was 17 cents per mile, in year 2000 dollars. Tests added or subtracted two, five, and nine cents from the average auto operating costs.

Table 11-1 Sensitivity to Auto Operating Cost, All Incomes

AO Cost (Cents per Mile)	8	12	15	17	19	22	26	**End-to-End**
Change From Base	-9	-5	-2	0	2	5	9	**Changes**
% Change from Base	*-52.94%*	*-29.41%*	*-11.76%*	*0*	*11.76%*	*29.41%*	*52.94%*	
Response Variable								
Person Trips	7,949,371	7,986,235	8,008,099	8,020,393	8,032,540	8,046,464	8,056,731	n/a
Change From Base	-71,022	-34,158	-12,294	0	12,147	26,071	36,338	107,360
% Change from Base	*-0.89%*	*-0.43%*	*-0.15%*	0	*0.15%*	*0.33%*	*0.45%*	1.34%
Computed Elasticity	*0.012*	*0.012*	*0.012*	0	*0.014*	*0.013*	*0.011*	*0.011*
Vehicle Trips	5,183,097	5,177,483	5,171,133	5,166,547	5,162,398	5,151,431	5,131,435	n/a
Change From Base	16,550	10,936	4,586	0	-4,149	-15,116	-35,112	51,662
% Change from Base	*0.32%*	*0.21%*	*0.09%*	0	*-0.08%*	*-0.29%*	*-0.68%*	1.00%
Computed Elasticity	*-0.004*	*-0.006*	*-0.007*	0	*-0.007*	*-0.011*	*-0.016*	*-0.008*
VMT	41,374,141	39,785,756	38,692,778	37,986,521	37,388,773	36,440,782	35,296,600	n/a
Change From Base	3,387,620	1,799,235	706,257	0	-597,748	-1,545,739	-2,689,921	6,077,541
% Change from Base	*8.92%*	*4.74%*	*1.86%*	0	*-1.57%*	*-4.07%*	*-7.08%*	16.00%
Computed Elasticity	*-0.113*	*-0.133*	*-0.147*	0	*-0.143*	*-0.161*	*-0.173*	*-0.135*
CVMT	3,185,413	2,810,910	2,564,859	2,410,182	2,302,205	2,131,799	1,892,268	n/a
Change From Base	775,231	400,728	154,677	0	-107,978	-278,383	-517,914	1,293,145
% Change from Base	*32.16%*	*16.63%*	*6.42%*	0	*-4.48%*	*-11.55%*	*-21.49%*	53.65%
Computed Elasticity	*-0.370*	*-0.442*	*-0.497*	0	*-0.412*	*-0.476*	*-0.569*	*-0.442*
Transit Person Trips	96,568	99,205	102,457	104,015	105,669	107,879	111,410	n/a
Mode Share	*1.21%*	*1.24%*	*1.28%*	*1.30%*	*1.32%*	*1.34%*	*1.38%*	0.17%
Change From Base	-7,447	-4,810	-1,558	0	1,654	3,864	7,395	14,842
% Change from Base	*-7.16%*	*-4.62%*	*-1.50%*	0	*1.59%*	*3.71%*	*7.11%*	14.27%
Computed Elasticity	*0.099*	*0.136*	*0.121*	0	*0.142*	*0.141*	*0.162*	*0.121*
Bike+Walk Person Trips	458,770	475,749	487,101	494,825	501,559	513,273	527,780	n/a
Mode Share	*5.77%*	*5.96%*	*6.08%*	*6.17%*	*6.24%*	*6.38%*	*6.55%*	0.78%
Change From Base	-36,055	-19,076	-7,724	0	6,734	18,448	32,955	69,010
% Change from Base	*-7.29%*	*-3.86%*	*-1.56%*	0	*1.36%*	*3.73%*	*6.66%*	13.95%
Computed Elasticity	*0.100*	*0.113*	*0.126*	0	*0.122*	*0.142*	*0.152*	*0.119*

Source: SACOG 2020.

11.2.3 Off-Street Parking Price

SACSIM19 incorporates parking pricing with data on the parking supply at the parcel level and data on how many people pay to park at their usual work places. Parcel-level parking data include:

- Count of daily and hourly parking spaces on the parcel.
- Daily and hourly price for spaces on the parcel.
- Count of daily and hourly spaces off the parcel but within quarter and half mile buffers around the parcel. Daily and hourly prices for spaces off the parcel but within quarter and half mile buffers around the parcel.

SACSIM19 only considers off-street parking available to the general public, and does not factor in any free parking supply or private parking (e.g., employees only, customers only, etc.).

Price Adjustment at the Parcel Level

For each sensitivity test, we modified the parking prices associated with each parcel, specifically we modified the following for each parcel:

- The price of parking on the parcel
- Prices for parking on parcels within ¼ mile of the parcel
- Prices for parking on parcels within ½ mile of the parcel

Aggregating to Calculate Elasticity

We used the regional median parking price as the regional cost of parking that we would adjust to check sensitivity to the parking price. The regional median price incorporated the parking prices of on-parcel spaces for all parcels with a parking price greater than zero.

To account for the fact that only a small portion of parcels in the region have paid parking, making the "regional average" parking price is essentially free, we experimented using a regional average parking price that included parcels without any paid parking, as well as a regional average price weighted by the number of spaces. These two experiments gave elasticities that were identical to the median-based elasticities, which makes sense considering that elasticities are based on percentage changes in prices, rather than absolute changes in prices. So even if the absolute value of the regional average price differed significantly from the regional median price, the proportional changes in parking cost were the same, therefore resulting in the same elasticity value.

11.2.3.1 Limitations of Literature Comparison

While there is an ample body of literature on parking price elasticities, it is hard to perform an "apples to apples" comparison with elasticities found in literature with those we found through SACSIM19 testing. The literature we reviewed generally measured the effect of parking prices within a limited geographic area such as a central business district (Litman 2017, Farber et al 2009, NAS 2005) or a college campus (Farber et al 2009) where a relatively high share of drivers must pay to park, meaning that a price change will affect a greater share of travelers. In contrast, SACSIM19 looks at the entire SACOG region, which is primarily rural or suburban and has mostly free parking outside of limited areas like downtown Sacramento and select college campuses. In addition, we only adjusted parking prices on parcels that had paid parking in the base scenario and did not add or remove any paid parking in our initial tests, so parking price increases only would have potentially affected travelers with destinations in the limited areas that had paid parking.

11.2.3.2 Region-Level Parking Price Elasticities

We initially calculated the elasticities of the response variables (VMT, vehicle trips, total person trips, transit trips, CVMT, and walk/bike trips) with respect to parking price for all trip types at the regional level. For the reasons discussed above, we expected these elasticities to be of lower magnitude but in the same direction as observed elasticities. Because most trips within the SACOG region are made to destinations that have free parking, increasing parking prices only applied to a relatively small portion of the regional population (about eight percent of the model's input population pays to park at their workplace).

Bearing in mind the above limitations, Table 11-2 summarizes the cross-elasticities for parking estimated through SACSIM19 runs, and below is a summary comparing observed elasticities with those found in SACSIM19 for all trips at the regional level.

- **VMT**: A 1999 study cited in Litman (2017)[19], based on observations in European cities, found an elasticity of VKT (vehicle kilometers traveled) with respect to parking price to be about -0.07. Another study summarized in Litman (2017), conducted in Seattle in 2011, found an elasticity to be about -0.04[23], based on a model developed from a 2006 regional household travel survey. We expect these elasticities to be higher than those in the SACOG model, because the 1999 study looks at European cities, which generally have less free parking and more alternatives to driving. The 2011 Seattle study should also show different elasticities, given that it looks at the effect of VMT at an individual level rather than at a region level.
  - Reasonable range of elasticity = less than -0.04, negative in sign
  - Model results (entire region) = -0.005
- **Transit person trips**: Litman (2017) reviewed an ample body of literature on parking pricing. He references a 1999 study he references, for "auto oriented urban areas," indicated an elasticity of +0.02[19]. Another study in Litman (2017), based on U.S. central business districts, found elasticities ranging from +0.023 to +0.291, the latter applying to "preferred [central business district] locations." [19] We would expect elasticities to be at the lower end of this range when referring to the SACOG region, given that our transit sensitivity considers transit trips made to all parts of the region, with mostly free parking, and not just downtown Sacramento (the region's equivalent of a central business district and limited free parking).
  - Reasonable range of elasticity = +0.02 to +0.29, closer to +0.02
  - Model results (entire region) = +0.08
- **Bike and walk person trips**: While there are scarce data on the cross elasticity between parking price and a shift to bike/walk modes, data from 1999 provided in Litman (2017) indicate an average cross elasticity of approximately +0.03[19] to +0.05, depending on trip purpose. This is an expected elasticity assuming that a higher parking price will incentivize some travelers to switch from driving to biking or walking.
  - Reasonable range of elasticity: +0.03 to +0.05
  - Model results (entire region) = +0.037

[23] Frank et al "An Assessment of Urban Form and Pedestrian and Transit Improvements as an Integrated GHG Reduction Strategy", Seattle DOT, 2011

- **Person trips**: Our literature review did not find provide any information on how parking pricing influences the total number of person trips. We assume elasticity to be zero to slightly negative given that a parking price increase will either result in a mode switch (meaning no change in total trips) or cause some travelers to forego a trip altogether (resulting in a decrease in total trips).
  - Reasonable range of elasticity = small, negative in sign
  - Model results (entire region) = -0.001
- **Vehicle trips**: There are several studies looking at how parking price affects vehicle trips. A 1999 study of European cities, summarized in Litman (2017) indicated an elasticity of -0.08 to -0.3, depending on trip purpose, with business trips being the least elastic. Several studies, including Farber and Weld (2013)[24] and Shoup and Pierce (2013)[25] found parking price elasticities ranging from -0.1 to -0.4.

  None of these studies provides an ideal “apples to apples” comparison with SACSIM19 outputs. Farber and Weld focused their study on a university campus, while Shoup and Pierce observed behavior in downtown San Francisco. Both locations have little free parking to “dilute” the effects of increasing the prices of paid parking. In addition, the dependent variable in these studies was parking occupancy, rather than vehicle trips. Bearing these weaknesses in mind, we expect SACSIM19 elasticities to be the same direction as those in the literature, though of lesser magnitude because any effects in parking price changes on the small portion of parcels that have parking pricing will be significantly reduced by the presence of free parking on most other parcels.

  - Reasonable range of elasticity = -0.08 to -0.4, SACOG region should be toward lower end if not below low end.
  - Model results (entire region) = -0.007

[24] Farber, Weld “Econometric Analysis of Public Parking Price Elasticity in Eugene, Oregon”, University of Oregon, 2013

[25] Shoup and Pierce “SFPark: Pricing Parking by Demand”, University of California, 2013

Table 11-2 Sensitivity to Parking Cost, Entire Region

Median Day Park Price *% Change from Base*	$ 4.60 *-50%*	$ 6.90 *-25%*	$ 8.28 *-10%*	$ 9.20 *0%*	$ 10.12 *10%*	$ 11.50 *25%*	$ 13.80 *50%*	**End-to-End Changes**
Response Variable								
Person Trips	8,022,335	8,020,511	8,021,376	8,020,393	8,017,518	8,016,678	8,016,669	n/a
Change From Base	1,942	118	983	n/a	-2,875	-3,715	-3,724	5,666
% Change from Base	0.02%	0.00%	0.01%	n/a	-0.04%	-0.05%	-0.05%	0.07%
Computed Elasticity	*0.000*	*0.000*	*-0.001*	n/a	*-0.004*	*-0.002*	*-0.001*	*-0.001*
Vehicle Trips	5,188,309	5,176,737	5,171,582	5,166,547	5,161,257	5,155,468	5,146,365	n/a
Change From Base	21,762	10,190	5,035	n/a	-5,290	-11,079	-20,182	41,944
% Change from Base	0.42%	0.20%	0.10%	n/a	-0.10%	-0.21%	-0.39%	0.81%
Computed Elasticity	*-0.006*	*-0.007*	*-0.009*	n/a	*-0.011*	*-0.010*	*-0.010*	*-0.007*
VMT	38,310,753	38,251,676	38,223,861	38,202,941	38,176,399	38,137,827	38,111,117	n/a
Change From Base	107,812	48,735	20,920	n/a	-26,542	-65,114	-91,823	199,635
% Change from Base	0.28%	0.13%	0.05%	n/a	-0.07%	-0.17%	-0.24%	0.52%
Computed Elasticity	*-0.004*	*-0.004*	*-0.005*	n/a	*-0.007*	*-0.008*	*-0.006*	*-0.005*
CVMT	2,420,233	2,410,674	2,399,875	2,384,933	2,392,870	2,378,733	2,346,677	n/a
Change From Base	35,301	25,742	14,943	n/a	7,937	-6,200	-38,255	73,556
% Change from Base	1.48%	1.08%	0.63%	n/a	0.33%	-0.26%	-1.60%	3.08%
Computed Elasticity	*-0.021*	*-0.037*	*-0.059*	n/a	*0.035*	*-0.012*	*-0.040*	*-0.028*
Bike+Walk Person Trips	99,645	101,937	103,112	104,015	105,412	106,782	108,853	n/a
Change From Base	-4,370	-2,078	-903	n/a	1,397	2,767	4,838	9,208
% Change from Base	-4.20%	-2.00%	-0.87%	n/a	1.34%	2.66%	4.65%	8.85%
Computed Elasticity	*0.062*	*0.070*	*0.083*	n/a	*0.140*	*0.118*	*0.112*	*0.080*
Transit Person Trips	484,578	488,864	492,197	494,825	496,317	499,377	504,541	n/a
Change From Base	-10,247	-5,961	-2,628	n/a	1,492	4,552	9,716	19,963
% Change from Base	-2.07%	-1.20%	-0.53%	n/a	0.30%	0.92%	1.96%	4.03%
Computed Elasticity	*0.030*	*0.042*	*0.051*	n/a	*0.032*	*0.041*	*0.048*	*0.037*

Source: SACOG 2020.

11.2.3.3 Downtown Parking Elasticities

To attempt a more "apples to apples" comparison between the model and the literature review environments, we compared elasticities for trips at the region level to trips made only to the downtown RAD, which contains most of the region's parcels with paid parking and the highest percentage of employees that pay for parking. While we anticipate higher parking elasticities in the downtown RAD due to fewer free parking substitutions, we expect these elasticities to still be lower than those shown in the literature since even the downtown RAD, as represented in the model, has a relatively small share of paid parking when compared to the examples in literature.

As Table 11-3 shows, parking price elasticities are significantly higher for trips made to the downtown RAD and generally in line with the observed elasticity ranges. Bike and walk trip elasticity for downtown trips, however, appears to be somewhat higher than indicated by the range found in literature. However, the literature, from 1999 is an average based on a survey of several European cities.

Table 11-3 Comparison Of Observed Elasticities, Regional Elasticities, And Downtown Elasticities For Parking Price - All Trips

Response Variable	Observed Elasticities		Region	Downtown Sacramento
	Low	High		
Person Trips	No data, expect weak negative		-0.001	-0.072
Vehicle Trips	-0.05	-0.3	-0.007	-0.134
VMT	-0.04	-0.07	-0.005	-0.097
CVMT	No data, expect weak negative		-0.028	-0.095
Transit Person Trips	0.01	0.3	0.080	0.159
Bike+Walk Person Trips	0.03	0.03	0.037	0.180

Source: SACOG, March 2020, based on 2020 MTP/SCS forecasts and modeling

11.2.3.4 Elasticity by "Pay to Park" Status for Work Tours

As described above, we predicted that region-wide parking elasticities would have a lower magnitude than those found in literature because while most observed elasticity data is from areas where a large share of motorists must pay to park, most of the parking in the SACOG region is free.

To approximate a more apples-to-apples comparison, we performed a separate sensitivity check in which we compared two trip groups: trips belonging to work tours for people who had to pay to park at work and trips belonging to work tours for all travelers[26]. For this test we only considered work tours because the "pay to park at work" status only applies to work trips.

We predicted that people who need to pay to park at work would be more sensitive to parking price changes because they were less likely to have a free parking alternative and therefore more likely to respond to the price change by switching modes. As Table 11-4 shows, all elasticity magnitudes are greater for people who pay to park at their workplaces and more closely in line with observed parking price elasticities. Some SACSIM19 elasticities, especially for bike and walk trips and vehicle trips, have a

[26] The SACSIM19 person table indicates whether a person needs to pay to park at work by assigning a value of 1 or 0 to the "PPAIDPRK" column.

higher magnitude than those found in the literature. This difference is not particularly surprising given that even though the literature focuses on areas where most parking is paid parking, it did not focus exclusively on travelers who must pay to park.

Table 11-4 Comparison of Observed Elasticities, Regional Elasticities, And Downtown Elasticities For Parking Price - Work Trips

Response Variable	Observed Elasticities		Region		Downtown Sacramento	
	Low	High	People who Paid to Park at Work	All Travelers' Work Trips	People who Paid to Park at Work	All Travelers' Work Trips
Person Trips	No data, expect weak negative		-0.014	-0.002	-0.064	-0.04
Vehicle Trips	-0.05	-0.3	-0.033	-0.007	-0.174	-0.08
VMT	-0.04	-0.07	-0.026	-0.004	-0.128	-0.062
CVMT	No data, expect weak negative		-0.05	-0.027	-0.136	-0.072
Transit Person Trips	0.01	0.3	0.25	0.097	0.297	0.137
Bike+Walk Person Trips	0.03	0.03	0.126	0.055	0.228	0.145

Source: SACOG 2020.

11.2.4 Household Income

Reported sensitivities of travel demand quantities to household income are thinly reported in research literature. The model sensitivities shown are "end-to-end" elasticities, or the elasticity based on comparing the highest and lowest test values, giving a rough average elasticity to compare with observed data.

- **VMT**: A 2011 Study of the Portland, OR region a near-term elasticity of VMT with respect to income of +0.05, and a long-run elasticity of +0.24[27], while a 1992 study for the U.S. overall found elasticities of +0.18 in the short run and as high as +1.0 for the long-run[28].
  - Reasonable range of elasticity = +0.05 to +0.18 in near term
  - Model results = +0.12
- **Transit person trips**: One study relating transit trips to household income, from 2015 and based on data from 198 U.S. transit systems, found near-term transit trip elasticity with respect to household income to be -0.36 for large urban areas (population > 1M) and -0.26 for small urban areas (population <1M). While the SACOG region as a whole is a "large" area with more than 2M residents, this population is broken up into several smaller urban areas within the region, with

[27] B. Starr McMullen, Nathan Eckstein, "The Relationship Between VMT and Economic Activity" OSU TREC, 2011

[28] Sterner, T., Dahl, C. and Franzén, M., "Gasoline Tax Policy, Carbon Emissions and the Global Environment", Journal of Transport Economics and Policy, 1992

large sections being rural. Therefore, we would consider it reasonable for modeled elasticity of transit trips with respect to household income to tend closer to the “small” UZA estimate. Also important to consider is that while the 2015 study uses transit systems as the unit of analysis, the modeled elasticity for transit trips is based on the entire region, which has large areas with little or no transit service. Changes to household income in these areas will have little to no effect on transit ridership and therefore we would expect it to somewhat lower the magnitude of elasticity.

    - Reasonable range of elasticity = -0.26 to -0.36, SACOG may be somewhat lower
    - Model results = -0.239

- **Bike and walk person trips**: No recent research was found which analyzed the relationship between non-motorized travel and household income. However, it is presumed here to be *negative* (i.e., increases in household income would tend to decrease non-motorized travel) and that the magnitude of the relationship would be relatively small.
    - Reasonable range of elasticity = small, negative in sign
    - Model results = -0.126
- **Person trips**: No recent research was found which analyzed the relationship between total person trips and household income. However, it is presumed here to be *positive* (i.e., that increases in household income would tend to increase the number of person and vehicle trips) and that the magnitude of the relationship would be relatively small.
    - Reasonable range of elasticity = small, positive in sign
    - Model results = +0.068
- **Vehicle trips**: No recent research was found which analyzed the relationship between vehicle trips and household income. However, it is presumed here to be *positive* (i.e., that increases in household income would tend to increase the number of person and vehicle trips) and that the magnitude of the relationship would be higher than that for person trips, given that with income increases comes some shift from transit and other modes to vehicle modes.
    - Reasonable range of elasticity = higher than person trip elasticity, positive in sign
    - Model results = +0.109

Table 11-5 presents results of sensitivity testing of household income. The base income was the 2005 household income distribution. Tests added or subtracted five, ten, and fifty percent of household income for each household.

Table 11-5 Sensitivity to Household Income

Median HH Income	$ 23,466	$ 42,238	$ 44,585	$ 46,932	$ 49,278	$ 51,625	$ 70,398	**End-to-End Changes**
% Change from Base	*-50%*	*-10%*	*-5%*	*0%*	*5%*	*10%*	*50%*	
Response Variable								
Person Trips	7,634,087	7,959,207	7,990,083	8,020,393	8,041,905	8,067,082	8,221,872	n/a
Change From Base	-386,306	-61,186	-30,310	n/a	21,512	46,689	201,479	587,785
% Change from Base	-4.82%	-0.76%	-0.38%	n/a	0.27%	0.58%	2.51%	7.33%
Computed Elasticity	*0.071*	*0.073*	*0.074*	n/a	*0.055*	*0.061*	*0.061*	*0.068*
Vehicle Trips	4,761,483	5,105,994	5,136,411	5,166,547	5,189,186	5,214,750	5,365,448	n/a
Change From Base	-405,064	-60,553	-30,137	n/a	22,639	48,202	198,901	603,964
% Change from Base	-7.84%	-1.17%	-0.58%	n/a	0.44%	0.93%	3.85%	11.69%
Computed Elasticity	*0.118*	*0.112*	*0.114*	n/a	*0.090*	*0.097*	*0.093*	*0.109*
VMT	34,838,042	37,737,616	37,991,946	38,202,941	38,398,670	38,583,108	39,759,080	n/a
Change From Base	-3,364,899	-465,325	-210,995	n/a	195,729	380,167	1,556,139	4,921,038
% Change from Base	-8.81%	-1.22%	-0.55%	n/a	0.51%	1.00%	4.07%	12.88%
Computed Elasticity	*0.133*	*0.116*	*0.108*	n/a	*0.105*	*0.104*	*0.098*	*0.120*
CVMT	1,642,128	2,281,920	2,324,286	2,384,933	2,445,595	2,504,470	2,789,536	n/a
Change From Base	-742,805	-103,013	-60,647	n/a	60,663	119,537	404,603	1,147,408
% Change from Base	-31.15%	-4.32%	-2.54%	n/a	2.54%	5.01%	16.96%	48.11%
Computed Elasticity	*0.538*	*0.419*	*0.502*	n/a	*0.515*	*0.513*	*0.386*	*0.482*
Bike+Walk Person Trips	545,914	500,851	497,880	494,825	491,909	489,243	475,528	n/a
Change From Base	51,089	6,026	3,055	n/a	-2,916	-5,582	-19,297	70,386
% Change from Base	10.32%	1.22%	0.62%	n/a	-0.59%	-1.13%	-3.90%	14.22%
Computed Elasticity	*-0.142*	*-0.115*	*-0.120*	n/a	*-0.121*	*-0.119*	*-0.098*	*-0.126*
Transit Person Trips	124,834	106,699	105,987	104,015	103,214	102,163	95,962	n/a
Change From Base	20,819	2,684	1,972	n/a	-801	-1,852	-8,053	28,872
% Change from Base	20.02%	2.58%	1.90%	n/a	-0.77%	-1.78%	-7.74%	27.76%
Computed Elasticity	*-0.263*	*-0.242*	*-0.366*	n/a	*-0.158*	*-0.189*	*-0.199*	*-0.239*

Source: SACOG 2020.

11.2.5 Transit Fares

Except for changes in transit ridership, we found few reported sensitivities of transit demand with respect to transit fares in research literature. As with the other tests, sensitivities shown are "end-to-end" elasticities, or the elasticity based on comparing the highest and lowest test values, giving a rough average elasticity to compare with observed data.

- **VMT**: None of the studies we reviewed explicitly quantified the relationship between transit fare levels and VMT. Two studies cited in Litman (2017) described an elasticity of "car use" with respect to transit fare to range between +0.01 to +0.19[19], though it was unclear whether "car use" referred to VMT or vehicle trips. We expect the elasticity to be small and positive, given that even a proportionally large increase in transit ridership due to lower fares would be a proportionally small decrease in VMT.
    - Reasonable range of elasticity = small, positive in sign
    - Model results = +0.001
- **Transit person trips**: A wide range of studies have analyzed the changes in transit ridership (usually measured as passenger boardings) after changes in fares. Changes in fares have included changes in cost, level or distribution of discounts, fare media, and other aspects of fare. The SACSIM model is limited to representing average transit fare, so the evaluation focused on percentage changes to average fares by operator for all operators. Studies summarized in Litman (2017) found transit ridership changes with respect to overall transit fare range from -0.2 to -0.3 in the short run and -0.4 to -1.0 in the long run[19].
    - Range of observed elasticities = -0.2 to -1.0
    - Model results = -0.098
- **Bike and walk person trips**: No recent research was found which analyzed the relationship between non-motorized travel and transit fares. However, it is presumed here to be *positive* (i.e., that increases in fares would tend to increase non-motorized travel) and that the magnitude of the relationship would be small.
    - Reasonable range of elasticity = small, positive in sign
    - Model results = +0.000
- **Person trips**: No recent research was found which analyzed the relationship between total person trips and transit fares. However, it is presumed here to be *negative* (i.e., that increases in fares would tend to decrease the number of person and vehicle trips) and that the magnitude of the relationship would be small.
    - Reasonable range of elasticity = small, negative in sign
    - Model results = -0.000
- **Vehicle trips**: Like the relationship between VMT and transit fares, none of the studies we reviewed explicitly quantified the relationship between transit fare levels and vehicle trips. Two studies cited in Litman (2017) described an elasticity of "car use" with respect to transit fare to range between +0.01 to +0.19[19],though it was unclear whether "car use" referred to VMT or vehicle trips. We expect the elasticity to be small and positive, given that even a proportionally large increase in transit ridership due to lower fares would be a proportionally small decrease in vehicle trips.
    - Reasonable range of elasticity = small, positive in sign
    - Model results = +0.001

Table 11-6 presents results of sensitivity testing of transit fares. Tests added or subtracted five, ten, and fifty percent of fares for each operator.

Table 11-6 Sensitivity to Transit Fare, All Incomes

Regional Avg Transit Fare	0.82	1.47	1.56	1.64	1.72	1.8	2.46	**End-to-End Changes**
Change From Base	-0.82	-0.17	-0.08	n/a	0.08	0.16	0.82	
% Change from Base	*-50%*	*-10%*	*-5%*	*0%*	*5%*	*10%*	*50%*	
Response Variable								
Person Trips	8,020,162	8,018,744	8,014,028	8,020,393	8,020,909	8,019,385	8,016,944	n/a
Change From Base	-231	-1,649	-6,365	0	516	-1,008	-3,449	3,218
% Change from Base	*0.00%*	*-0.02%*	*-0.08%*	0	*0.01%*	*-0.01%*	*-0.04%*	0.04%
Computed Elasticity	*0.000*	*0.002*	*0.016*	*0*	*0.001*	*-0.001*	*-0.001*	*0.000*
Vehicle Trips	5,162,864	5,164,734	5,159,516	5,166,547	5,167,673	5,167,863	5,168,531	n/a
Change From Base	-3,684	-1,813	-7,031	0	1,126	1,315	1,984	5,668
% Change from Base	*-0.07%*	*-0.04%*	*-0.14%*	0	*0.02%*	*0.03%*	*0.04%*	0.11%
Computed Elasticity	*0.001*	*0.003*	*0.027*	*0*	*0.005*	*0.003*	*0.001*	*0.001*
VMT	38,171,355	38,193,424	38,136,913	38,202,941	38,220,631	38,216,735	38,216,640	n/a
Change From Base	-31,586	-9,517	-66,028	0	17,690	13,794	13,699	45,285
% Change from Base	*-0.08%*	*-0.02%*	*-0.17%*	0	*0.05%*	*0.04%*	*0.04%*	0.12%
Computed Elasticity	*0.001*	*0.002*	*0.035*	*0*	*0.010*	*0.004*	*0.001*	*0.001*
CVMT	2,383,238	2,412,445	2,412,035	2,384,933	2,381,873	2,406,136	2,416,036	n/a
Change From Base	-1,694	27,513	27,102	0	-3,060	21,203	31,104	32,798
% Change from Base	*-0.07%*	*1.15%*	*1.14%*	0	*-0.13%*	*0.89%*	*1.30%*	1.38%
Computed Elasticity	*0.001*	*-0.105*	*-0.226*	*0*	*-0.027*	*0.095*	*0.032*	*0.012*
Transit Person Trips	110,190	105,136	104,921	104,015	103,433	103,472	98,936	n/a
Mode Share	*1.37%*	*1.31%*	*1.31%*	*1.30%*	*1.29%*	*1.29%*	*1.23%*	0.14%
Change From Base	6,175	1,121	906	0	-582	-543	-5,079	11,254
% Change from Base	*5.94%*	*1.08%*	*0.87%*	0	*-0.56%*	*-0.52%*	*-4.88%*	10.82%
Computed Elasticity	*-0.083*	*-0.098*	*-0.173*	*0*	*-0.118*	*-0.056*	*-0.123*	*-0.098*
Bike+Walk Person Trips	494,322	494,597	495,088	494,825	495,170	493,866	494,532	n/a
Mode Share	*6.16%*	*6.17%*	*6.18%*	*6.17%*	*6.17%*	*6.16%*	*6.17%*	0.01%
Change From Base	-503	-228	263	0	345	-959	-293	210
% Change from Base	*-0.10%*	*-0.05%*	*0.05%*	0	*0.07%*	*-0.19%*	*-0.06%*	0.04%
Computed Elasticity	*0.001*	*0.004*	*-0.011*	*0*	*0.015*	*-0.021*	*-0.001*	*0.000*

Source: SACOG 2020.

11.2.5.1 Effect of Household Income on Transit Fare Sensitivity

The sensitivities shown in Table 11-6 reflect trips made by people of all income levels. We also tested how a traveler's household income affects his/her sensitivity to transit fares by comparing sensitivity for households in the highest and lowest income quartiles. Among our key findings:

- Travelers in the lowest income quartile are more sensitive to transit fare increases than the general population. Specifically, as transit fares increase, lower-income travelers are more likely to shift away from transit to either using a private vehicle, walking, or biking. This finding makes sense given that lower-income populations are generally more sensitive to price increases since a given cost will represent a larger share of their total income.
- As expected, higher income travelers are significantly less sensitive to transit fare increases than the general population. Following the logic for why lower-income travelers are more sensitive to fare increases, higher-income riders are less sensitive to fare increases because the cost of a fare represents a smaller share of their total income compared to a lower-income rider.

11.2.6 Roadway Capacity

The primary research literature analyzing the effect of roadway capacity on travel demand may be grouped into a category called "induced travel". The induced travel hypothesis is that adding roadway capacity itself generates or "induces" travel demand, even after accounting for growth in population and employment. Induced travel is at best a loosely defined term, potentially including many levels of short-term and long-term transportation and land use interactions.

The simplest effects of induced demand are based purely on traditional travel demand theory: by alleviating congestion or providing additional roadway routes, travel by auto becomes faster and shorter in time, although potentially longer in distance. The short-term **traveler response** is in shifts in travel mode, routes, and time of day, and possibly more trips accounting for latent demand. The long-term **land use response** is that people, jobs and land development relocate to take advantage of the increased accessibility along an expanded roadway corridor, eroding the speed and accessibility benefits of the expanded capacity. Over time much of the improvement in accessibility from the expansion tends to be transitory—the congestion relief provided by new or widened roadways is eroded by growth in overall demand and VMT.

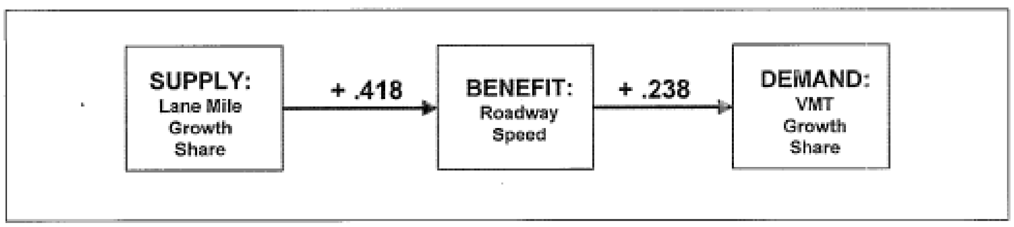
Research conclusions on induced travel have been largely agnostic as to its underlying causes, but in relative concord as to the existence of an effect which connects adding roadway capacity to increasing VMT. Most research defaulted to a definition of induced travel as a statistically significant, positive relationship between provision of additional lane mileage of roadway and VMT, after accounting in aggregate form for the most obvious other factors normally related to VMT growth (e.g., population growth, changes to income, demographic factors, changes in the cost of fuel, geographic spread of the land use pattern).

One study by Robert Cervero sorted out the near-term and long-term effects, and estimated elasticities segmented by road improvements and other variables[29]. The short term or "traveler

[29] Cervero, Robert, "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis", *APA Journal*, Spring 2003 Vol.69, No. 2.

response" induced travel effects are split into two components: the effect of added capacity on average speed of roadway travel; and the effect of speed on VMT. The Cervero study estimated elasticities for each of these short-term effects: the elasticity of speed with respect to added capacity was estimated to be +0.42 (i.e., a 10 percent increase in capacity results in a 4.2 percent increase in travel speed). The elasticity of VMT with respect to speed was estimated to be +0.24 (i.e., a 10 percent increase in speed results in a 2.4 percent increase in VMT). The "combined" effect of capacity and speed on VMT is calculated by multiplying the individual effects (0.42 x 0.24 = +0.10). The combined elasticity of +0.10 is used as a benchmark for reasonable sensitivity of the short term, "traveler response" effects of induced travel.

Figure 11-1 Short Term or Traveler Response Induced Travel Effects



Source: Cervero, Robert, "Road Expansion, Urban Growth, and Induced Travel: A Path Analysis", *APA Journal*, Spring 2003 Vol.69, No. 2.

We measured VMT sensitivity to changes in capacity by modifying highway capacity and tallying changes in VMT predicted for each change. This approach captures only the short-term traveler response to changes in auto travel speed and resulting shorter travel times as a result of increased road capacity. None of the longer-term effects of increased capacity on land use are measured in this test. The next section "Cross Sectional Testing of Sensitivity to Land Use / Transportation Factors", partly addresses these questions by analyzing the relationship between modeled travel behavior and transportation/land use factors.

Table 11-7 estimates the combined short-term effects of capacity on speed, and speed on VMT. Table 11-7 shows each effect separately, and the combined effect. The range of SACSIM sensitivity of speed with respect to capacity ranged from +0.06 to +0.08, lower than the +0.42 estimated in the Cervero study. The range of SACSIM sensitivity of VMT with respect to speed was +2.33 to +2.65, compared to +0.24 estimated from Cervero study. In combination, SACSIM elasticity of VMT with respect to capacity was +0.06 to +0.08, with an "end-to-end" average elasticity of +0.07. The range of elasticities falls slightly below the target of +0.10, and the end-to-end SACSIM elasticity is somewhat below the target. In other words, SACSIM speeds are significantly less sensitive to capacity changes than observed data show, but its predicted VMT is significantly more sensitive to speed than observed. Taking the capacity-speed and speed-VMT elasticities together, SACSIM's VMT is only somewhat less sensitive to changes in capacity than observed data show.

We expect some difference between our sensitivity test results and observed sensitivities because the nature of how we changed capacity (doing a systemwide flat percent change on all roadways) differs significantly from how Cervero et al measured capacity changes (on specific corridors).

However, we do expect the direction of sensitivity for both observed and modeled data to be the same, i.e., an increase in capacity should lead to an increase in VMT, even if the magnitude of the sensitivity is different.

Table 11-7 SACSIM19 Model Testing Results of Short Term, Traveler Response Induced Travel Effects

	Capacity Change from Base					End-to-End
Test Variables	-10%	-5%	**Base**	5%	10%	**Change**
Weekday VMT	59,648,242	59,897,121	60,120,818	60,297,761	60,474,822	826,580
System Average Speed (mph)	40.27	40.33	40.39	40.44	40.48	0.22
% Changes from Base						
VMT	-0.79%	-0.37%	n/a	0.29%	0.59%	1.37%
Speed	-0.30%	-0.14%	n/a	0.13%	0.24%	0.54%
Elasticities						
Speed w.r.t. Capacity	0.03	0.03	n/a	0.03	0.02	0.03
VMT w.r.t. Speed	2.62	2.65	n/a	2.33	2.48	2.56
Combined (VMT w.r.t. Capacity)	0.08	0.07	n/a	0.06	0.06	0.07

Source: SACOG 2020.

11.3 Cross Section Testing of Land Use/Transportation Factors

11.3.1 Background and Definition

"Land use/transportation" factors (also known as "the Ds") combine an area's land use and transportation characteristics to explain variation in travel behavior of its residents. LU/T factors are very well-studied in research literature, using household travel surveys and disaggregated land use data as the basis of analysis. For evaluating SACSIM19, our primary reference was a 2010 meta-analysis (a review and compilation of studies) by Ewing and Cervero[30]. Although several years old, a more recent (July 2017) article by Litman[31] summarizing research done on the land use-transportation relationship indicated that the 2010 Ewing-Cervero meta-analysis is the most recent of its kind, therefore we consider it reasonable to continue using its findings in our evaluation of SACSIM19. The meta-analysis examined the following land use/transportation factors, with results summarized in Table 11-8:

- **Regional accessibility**, which quantifies how connected a given area is to existing development, and is usually stated as the number of jobs within an average auto commute time. Regional accessibility is usually higher in areas within the existing urbanized area, and tends to be lower in outlying areas or areas on the urban edge. This factor has the strongest potential effect on VMT—a 10 percent increase in an area's accessibility results in a roughly two percent decrease in VMT for residents of that area.
- **Street pattern/urban design**, or how walkable a given area is based on characteristics of its street pattern and is usually measured as intersection density. A higher intersection density typically means smaller blocks and more potential walking connections there are in that area. Although other factors affect walkability and walk mode share (e.g., presence/absence of sidewalks, pedestrian amenities on the street, traffic volumes on streets, presence/absence of crosswalks, treatment of pedestrians at signalized intersections), intersection density has been used in research as a proxy for walkability, in part because it is relatively easy to assemble data. In terms of VMT reduction, street pattern is the second strongest factor with a 10 percent increase in intersection density resulting in a roughly one percent decrease in VMT.
- **Mix of use** refers to the inclusion in an area of a range of complementary land uses, which allows for more activities (i.e., working, shopping, school) to be contained within that area. Good land use mix allows for reductions in VMT through shortening of vehicle trips or shifting to other non-vehicle modes of travel such as walking. The most common measures of mix of use combine the relative proportions of residential, overall jobs, retail and other residential-supporting land uses into an "entropy" formula, which translates the balance of land use mix into a 0 to 100 scale[32].

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[30] Ewing, R. and Cervero, R., "Travel and the Built Environment: A Meta-Analysis," *Journal of the American Planning Association*, Vol. 76, No. 3, Summer 2010.
[31] Litman T., "Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior" Victoria Transport Policy Institute, July 2017
[32] Hossack, Gary, "Measuring and Visualizing the Diversity of Land Use and Its Relationship with Travel Behavior", TRB 2008 Annual Meeting, Paper #08-2742, Session 337.

- **Proximity to transit** refers to the distance from a residence to the nearest transit station or stop, with VMT declining, and both walking and transit use increasing, as distance to the nearest transit decreases.
- Residential density refers to the number of persons or dwellings within a given area. Conceptually, density is quite easy to understand—the number of persons or housing units within a given area. However, different definitions of area (e.g., net acreage, gross acreage, total area) and the fact that higher densities often co-exist with other land use/transportation factors such as high regional accessibility, walkable street patterns, and more transit service, the effects of density are often over- or under-stated. The Ewing/Cervero meta-analysis controlled for differences in definition of density across the studies they reviewed.

Table 11-8 provides a summary of the results of the Ewing/Cervero meta-analysis of LU/T factors and travel outcomes, stated as an elasticity of the travel outcomes for each land use/transportation factor. These elasticities will be used as a basis for evaluating whether SACSIM19's sensitivity to LU/T factors is reasonable.

Table 11-8 Land Use/Transportation Factors and Travel Outcomes

	Travel Outcome		
Land Use /Transportation Factor	*VMT**	Walk	Transit
Reported Elasticities[33,34,35]			
Regional Accessibility	-0.20 [*-0.13 to -0.25*]	+0.15	n/a
Street Pattern/Urban Design	-0.12 [*-0.03 to -0.19*]	+0.39	+0.23
Mix of Use	-0.09 [*-0.02 to -0.11*]	+0.15	+0.12
Proximity to Transit	-0.05 [*uncertain*]	+0.15	+0.29
Residential Density	-0.04[*-0.04 to -0.19*]	+0.07	+0.07

*Ranges were reported for VMT but not for other travel outcomes because the amount of research done on the land use/transportation effects on VMT is more robust.

11.3.2 Challenges of Testing Land Use-Transportation Sensitivities

Although it is tempting to assume that the relationships shown in Table 11-8 are discrete dials that can be adjusted to achieve pre-defined results, there are many factors that confound attempts to isolate individual effects. Self-selection bias is a major confounding factor, which is poorly accounted for in most of the research. Self-selection bias refers to fact that personal preference affects where someone chooses to live and the travel choices they make. E.g., people who like walking may

[33] Elasticities are stated as the proportional change in the travel outcome with respect to a change in the land use/transportation factor.

[34] Unbracketed elasticities from Ewing, R. and Cervero, R., "Travel and the Built Environment: A Meta-Analysis," *Journal of the American Planning Association*, Vol. 76, No. 3, Summer 2010.

[35] Bracketed elasticities are the range of elasticities reported by in research syntheses by, as well as by Boarnet, M. and Handy, S. and posted on the CARB website: http://arb.ca.gov/cc/sb375/policies/policies.htm

gravitate to walkable environments in their place of residence or place of work, and some of the land use-transportation relationships which are shown in research based on travel surveys may simply be measuring personal preferences rather than the environment's effects on behavior. Replicating in new areas the high walk share observed in existing well-mixed, walkable neighborhoods may be impossible, simply because the existing areas may have attracted a unique population of individuals who prefer walking.

Further, interactions among the land use-transportation factors themselves are difficult to control, and many factors are highly correlated. For example, many areas with denser street patterns (i.e., more intersections per unit of area) also have higher development densities, simply because their block and lot sizes are also smaller. Research has also recognized that the combined effects of many factors is not always equal to adding up the individual effects of each factor—there may be ceilings on some of the combined results. On the other side, some of the combined effects may be greater than the sum of the individual effects. For example, evidence from transit-oriented developments suggests that the combined effects of density, proximity to transit, and street pattern around rail stations with frequent service may far exceed the reductions in VMT and increases in walking and transit travel suggested by Table 11-8.[36] Although some factors are known to have greater potential influence (e.g., regional accessibility), significantly changing those factors may be difficult.

11.3.3 Land Use-Transportation Sensitivity Testing with SACSIM

The approach used to evaluate the sensitivity of SACSIM to LU/T factors focused on the household-generated travel and DAYSIM submodel outputs. SACSIM has several advantages in doing this sort of evaluation:

- Land use data in SACSIM is maintained at parcel/point level (see Chapter 1), which allows for much more nuanced and accurate representations of the land use context for a given area. Land use context is defined at parcel/point level, with surrounding land uses based on one-quarter and one-half mile "buffers" around each parcel/point. This provides more accurate land use context than the zone or fixed subarea systems typically used in travel demand modeling. SACSIM19's buffering system further increases the accuracy by basing its buffers on a "circuity factor," which instead of assuming a circle-shaped, or radial buffer, modifies the buffer's shape to consider street network characteristics that affect what is actually within a quarter or half mile. For example, two destinations may be 500 feet apart "as the crow flies", but due to some obstacle like a freeway or river would require a much longer trip to travel between using the street network.
- Demographics is a disaggregate, representative population file rather than a zone-aggregated summary or cross-classification of households. The population file includes characteristics such as an individual's age , worker or student status, and income of the household he/she lives in. The file also includes variables related to household structure (e.g., presence/absence of school age children) which are highly influential in determining travel behavior. Realistically zeroing in on the LU/T effects *requires controlling for key*

[36] Arrington, G.B., and Cervero, Robert, "Effects of TOD on Housing, Parking, and Travel", Transit Cooperative Research Program No. 128, Transportation Reseach Board, 2008.

demographic factors. Often these controls are not implemented, and LU/T factors are consequently over-attributed with effects on travel behavior.

- The activity/tour based modeling approach used for household-generated travel allows for a more complete accounting of travel by residents of the region. Tours are series of trips made from home to an activity (e.g., work), and back home. All trips on the tour are counted and "tracked" by DAYSIM as part of a given person's travel. This allows for all travel to be attributed to a given person or household, and be correlated with the LU/T characteristics of that person's place of residence or work. This contrasts with a traditional, trip-based travel demand model in which approximately one-third of all trips are "non-home-based" and the characteristics of the traveler and the traveler's place of residence or place of work are unknown and unaccounted for.

Given the disaggregate nature of the DAYSIM travel outputs, the units of analysis for LU/T sensitivity testing are individual people. For this test, all VMT and person trips by mode of travel are tallied by person and attributed to the person's place of residence. LU/T characteristics of the place of residence are tallied for each person in the population (2.2 million in this case). Key demographic characteristics (e.g., age, income, worker status, student status) as well as household structure characteristics (e.g., household size) are used as continuous (in the case of income or age) or categorical (in the case of worker or student status) variables.

The analysis performed is *cross-sectional*—that is, it examines a single set of data for one point in time, and evaluates variations in independent (in this case, a combination of demographic and LU/T factors) and dependent (household-generated VMT per person, transit trips per person, and walk trips per person) variables across the dataset, then evaluates the correlations between these variables. This is distinct from the experimental approach, which tests variables through direct manipulation of independent or input variables, and measures variations in output variables. Because LU/T factors by definition combine several different factors, this sort of experimental approach is difficult or impossible. For example, varying density means, of course, adding population or jobs to a given area—but that variation also affects mix of use and regional accessibility. The cross-sectional approach relies on statistical analysis to sort out and quantify the major LU/T effects.

Table 11-9 provides a comparison of the LU/T effects, converted from regression coefficients to elasticities, to the elasticities reported in the Ewing/Cervero meta-analysis[30] referred to above. Two values for SACSIM-estimated elasticities are provided; one is an "all variables" value, in which the elasticity was drawn from regression coefficients from a regression with all LU/T factors and all demographic factors in the model. The second is a "single variable" elasticity, in which the elasticity was drawn from regression coefficient from a regression with only a single LU/T variable and all demographic factors.

We determined how reasonable SACSIM's sensitivity to Land Use factors was by comparing its land use-transportation elasticities to those in Ewing and Cervero meta-analysis[30]. If the elasticity found in the meta-analysis fell within SACSIM's all-variable and single-variable elasticities, the LU/T factor is considered to be reasonably sensitive. This general test of reasonable sensitivity is not a "hard and fast" rule, nor do Ewing and Cervero recommend rigidly applying the values published in the meta-analysis.

In part, this flexible approach to comparing to the meta-analysis elasticities is consistent with the level of certainty around the research and limitations of "borrowing" research results from a range of geographic areas and a range of studies. The flexibility recognizes that many of the studies combined in the meta-analysis include some, but not all, of the LU/T factors, and some, but not all, of the demographic control variables.

Many of the LU/T variables themselves correlate with one another. An example is residential density and street pattern, which in the SACOG region show partial correlation of 0.52. Other LU/T factors which are highly correlated area residential density and transit accessibility to jobs (0.40), and street pattern and level of land use mix (0.36). By combining all variables within one statistical regression, some of the strength of variables may be shared, which may in turn account for the "all variables" elasticities falling somewhat below the published meta-analysis elasticities.

Finally, some of the research studies in the Ewing/Cervero meta-analysis[30] treated households as units of analysis while some treated persons as units of analysis. The effects of differences in units of analysis were not controlled in the meta-analysis[37]. Because households in areas with higher density and access to good transit service (i.e., areas which have "good" LU/T context) also tend to be smaller in size, results of person-level analysis, which was used for the SACSIM testing, may result in slightly lower LU/T elasticity effects.

As shown in Table 11-9, all but two SACSIM LU/T elasticities bound the meta-analysis elasticities (i.e., the meta-analysis elasticity fell within the range bound by the all-variable and single-variable SACSIM elasticities). The exceptions were:

- SACSIM's range of elasticity of VMT with respect to mix of use is somewhat higher than the meta-analysis elasticity, indicating that SACSIM is slightly more sensitive to mix of use than the literature suggests.
- SACSIM's range of elasticity of transit trips with respect to residential density is significantly higher than the meta-analysis elasticity, indicating that SACSIM is more sensitive to residential density than the literature suggests.

Because the elasticities computed from the regression results matched the published Ewing/Cervero elasticities as to sign, and closely matched the elasticities as to magnitude of effect, SACSIM is reasonably sensitive to land use/transportation factors.

[37] Personal communication from Reid Ewing, December 2011.

Table 11-9 Land Use/Transportation Elasticity Comparison

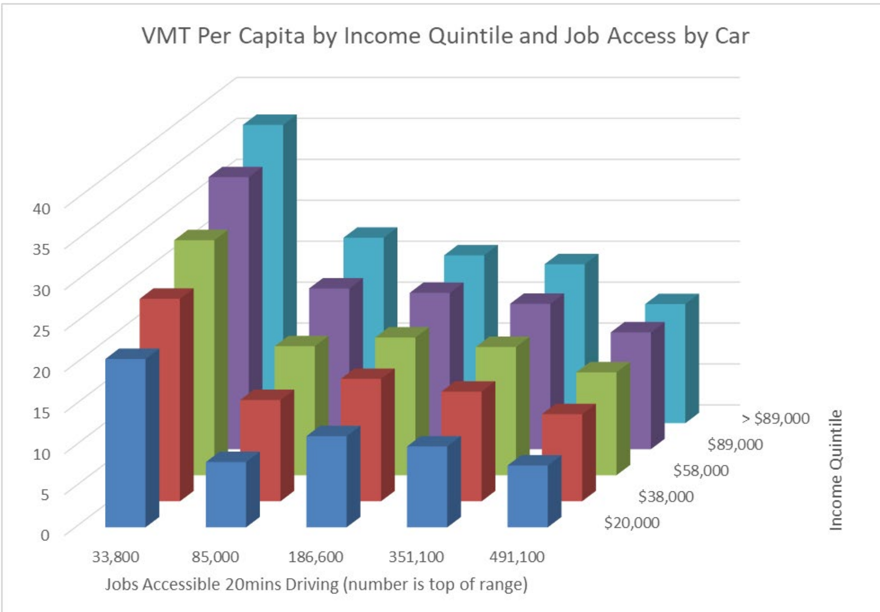
Land Use/Transportation Factor	Variable	Elasticities		
		From Literature[38]	Estimated From SACSIM19 (all variables)	Estimated From SACSIM19 (single variable)
VMT Per Person				
Regl Auto Accessibility	Jobs w/in 30-Min Drive[†]	-0.2	-0.217	-0.38
Regl Transit Accessibility	Jobs w/in 30-Min Transit Trip[*]	-0.05	-0.006	-0.04
Mix of Use	SACOG Mix Index (0-1 scale)[†]	-0.09	-0.167	-0.31
Street Pattern	3- and 4-way Intersections within 0.25mi of residence	-0.12	-0.093	-0.31
Proximity to Transit	Distance to Nearest Transit Stop (miles)[**]	-0.05	-0.001	-0.32
Residential Density	Households within 0.25 miles of residence[†]	-0.04	-0.100	-0.27
Transit Trips Per Person				
Regl Transit Accessibility	Jobs w/in 30-Min Transit Trip	na	0.128	0.22
Mix of Use	SACOG Mix Index (0-1 scale)[†]	0.12	0.235	0.57
Street Pattern	3- and 4-way Intersections within 0.25mi of residence	0.23	-0.164[††]	0.66
Proximity to Transit	Distance to Nearest Transit Stop (miles)[**]	0.29	0.000	0.39
Residential Density	Households within 0.25 miles of residence[†]	0.39	0.520	0.87
Walk Trips Per Person				
Destination Accessibility	Jobs within 0.25mi of parcel[*]	0.15	0.030	0.09
Mix of Use	SACOG Mix Index (0-1 scale)[†]	0.15	0.253	0.41
Street Pattern	3- and 4-way Intersections within 0.25mi of residence	0.39	0.172	0.54
Proximity to Transit	Distance to Nearest Transit Stop (miles)[**]	0.15	0.001	0.23
Residential Density	Households within 0.25 miles of residence[†]	0.07	0.307	0.53

[*] Range of SACSIM elasticity magnitudes below meta-analysis elasticity magnitude.
[†] Range of SACSIM elasticity magnitudes greater than meta-analysis elasticity magnitude.
[**] Persons living more than 30 miles from a transit stop in the model were tagged as having a distance of 999 miles to transit. We included these cases for the all-variables regressions, but excluded them from the single-variable regressions for distance to nearest transit stop due to the skewing effect of having most cases being between 0-30 miles from transit, then have all other cases be "999" miles from transit.
[††] Street pattern has high collinearity with housing density (0.52), job driving access (0.39), job transit access (0.39), and mix index (0.39), which likely explains the unexpected negative relationship between street pattern density and transit trips per person when all other land use factors are considered. As a single-variable regression, however, street pattern density shows an expected strong positive relationship with transit trips.

[38] Ewing, R. and Cervero, R., "Travel and the Built Environment: A Meta-Analysis", Journal of the American Planning Association, Vol. 76, No. 3, Summer 2010.

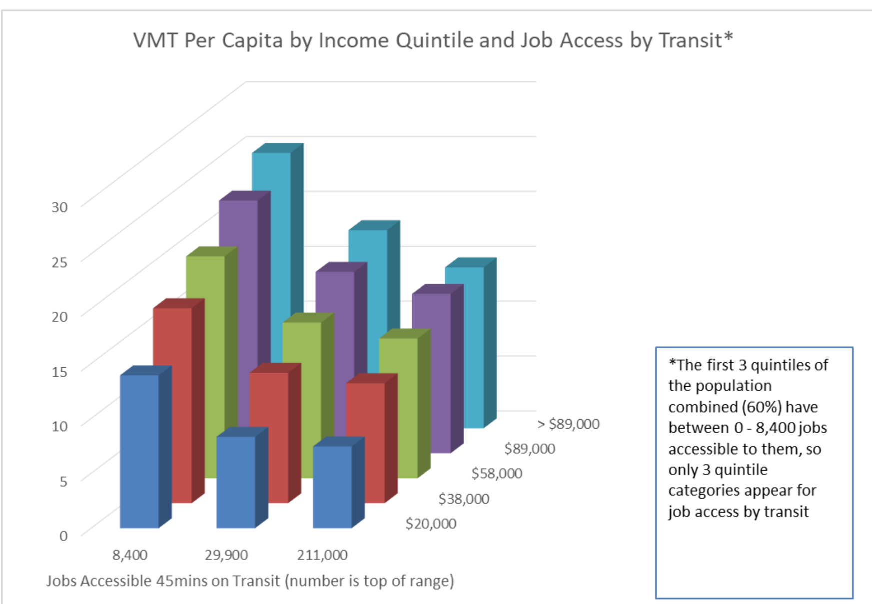
The charts in Figure 11-2 through Figure 11-5Figure 11-2 help illustrate the relationships between demographic factors, LU/T factors, and VMT per capita:

Figure 11-2 Modeled VMT Per Capita by Income and Job Accessibility by Car



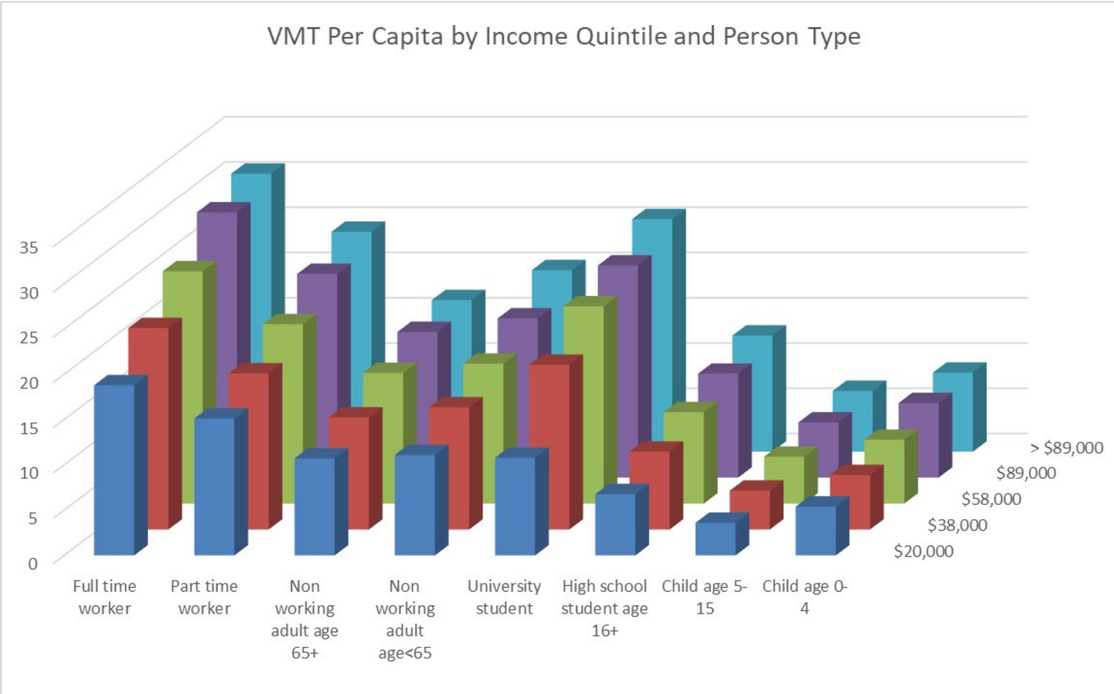
Source: SACOG 2020.

Figure 11-3 Modeled VMT Per Capita by Income and Job Accessibility by Transit



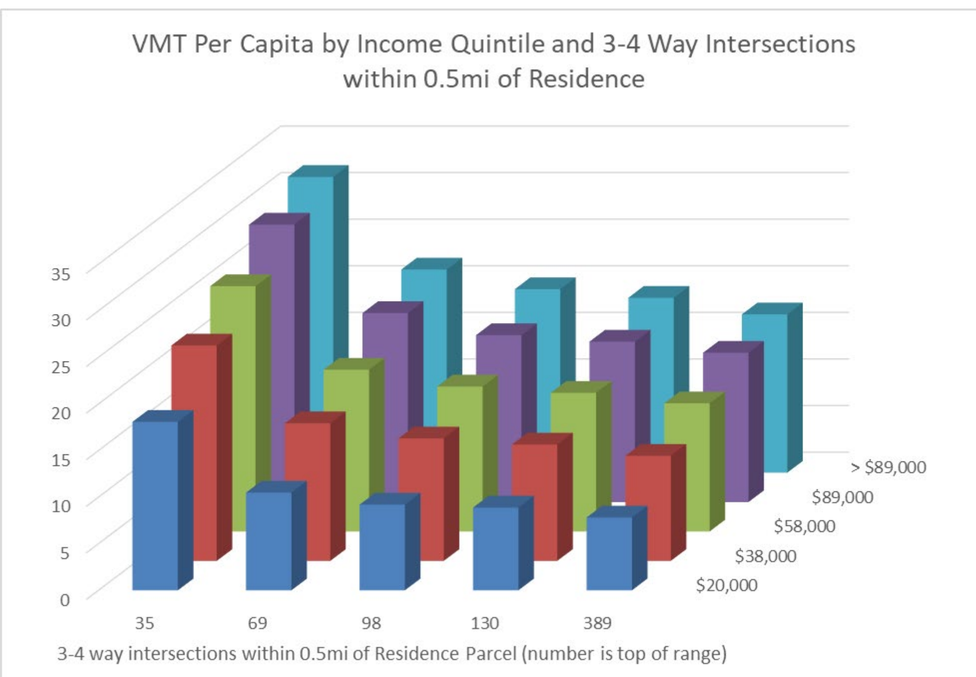
Source: SACOG 2020.

Figure 11-4 Modeled VMT Per Capita by Income and Person Type



Source: SACOG 2020.

Figure 11-5 Modeled VMT Per Capita by Income and Street Intersection Density Near Residence



Source: SACOG 2020.

11.4 **Testing of Random Variation in Model**

Testing of random variation is performed to assess the potential “noise” in the DAYSIM simulation of household-generated travel. Because DAYSIM is a person-level simulation of demand, travel patterns of each person in the representative population file is computed in a randomized order. The order of this simulation is varied using a numeric seed value. Changing this seed value generates a different order of stepping through the simulation, and of applying choice probabilities to each person-day activities and travel. This randomization means that the results of one model run may vary somewhat from the results of another run, assuming the “seed” value is varied from one run to the next.

We ran a series of 10 model runs using different seed values using SACSIM19 to estimate random variation of key travel outputs. To measure variation, we compared individual model run output values for vehicles, work tours, other tours, person trips, vehicle trips, transit trips, and VMT against the 10-run average values of these outputs. Specifically, we compared the model runs whose outputs were most different from the 10-run average. We performed this comparison at the region level, for the largest-population RAD, median-population RAD, and smallest-population RAD to observer how the amount of variation changed at different granularity levels. Results are summarized in Table 11-10.

As Table 11-10 shows, random variation increases as the scale of the output decreases. E.g., a “large scale” output like VMT at the region level had a maximum difference from the 10-run average of only -0.06 percent. In contrast, transit trips in the smallest-population RAD had a maximum difference from the 10-run average of about -60 percent while transit trips in the median-population RAD had a maximum difference of about -75 percent.

These large percentage differences, however, are due to the very small absolute number of transit trips taken in these RADs, with an average of 12 transit trips taken in the smallest RAD and 45 transit trips taken in the largest RAD. Therefore, even a small numeric variation in model outputs equates to a large percentage variation. Furthermore, our findings are generally in line with Bradley et al.’s 2003 findings from a random-seed test they performed on San Francisco’s microsimulation model, which utilized 100 model runs[39]. Similar to our SACSIM19 results, they found overall very low random variation at the city level, with greater levels of variation at the TAZ level and when looking at more specific outputs (e.g., estimated tours between two specific neighborhoods as opposed to total tours in the entire city).

[39] Mark Bradley, Joe Castiglione, Joel Freedman, “Systematic Investigation of Variability due to Random Simulation Error in an Activity-Based Microsimulation Forecasting Model”, Transportation Research Record 1831, 2003

Table 11-10 Random Variation of DAYSIM Submodel

Variable	10-Run Average Value	Max % Difference from Average	
		High	Low
Regional Totals			
Vehicles	1,538,828	0.04%	-0.04%
Work Tours	766,727	0.11%	-0.07%
Other Tours	2,260,177	0.08%	-0.04%
Person Trips	8,023,709	0.06%	-0.05%
Vehicle Trips	5,169,100	0.07%	-0.07%
Transit Trips	103,943	0.68%	-0.89%
VMT	38,201,565	0.05%	-0.06%
Largest-Population RAD			
Vehicles	96,277	0.18%	-0.27%
Work Tours	46,909	0.45%	-0.48%
Other Tours	173,890	0.48%	-0.27%
Person Trips	577,242	0.19%	-0.17%
Vehicle Trips	348,582	0.18%	-0.30%
Transit Trips	8,892	3.37%	-2.97%
VMT	2,037,169	0.30%	-0.34%
Median-Population RAD			
Vehicles	13,247	0.54%	-0.51%
Work Tours	5,404	0.74%	-0.87%
Other Tours	16,402	1.00%	-0.77%
Person Trips	58,709	0.75%	-0.79%
Vehicle Trips	40,778	1.03%	-0.76%
Transit Trips	45	30.65%	-76.73%
VMT	368,112	0.98%	-1.03%
Smallest-Population RAD			
Vehicles	4,206	0.97%	-0.93%
Work Tours	1,036	4.17%	-4.32%
Other Tours	4,357	2.18%	-2.32%
Person Trips	14,965	1.52%	-1.20%
Vehicle Trips	9,697	1.89%	-1.36%
Transit Trips	14	56.20%	-60.58%
VMT	174,439	1.88%	-2.01%

Source: SACOG 2020.

Borrowing methodology from Bradley et al's test of San Francisco's microsimulation model, we also charted running averages for each output to see how quickly those outputs converged toward the 10-run average. This test enables model users to better estimate how many times the model needs to be run in order to give a reasonably stable "average" output value.

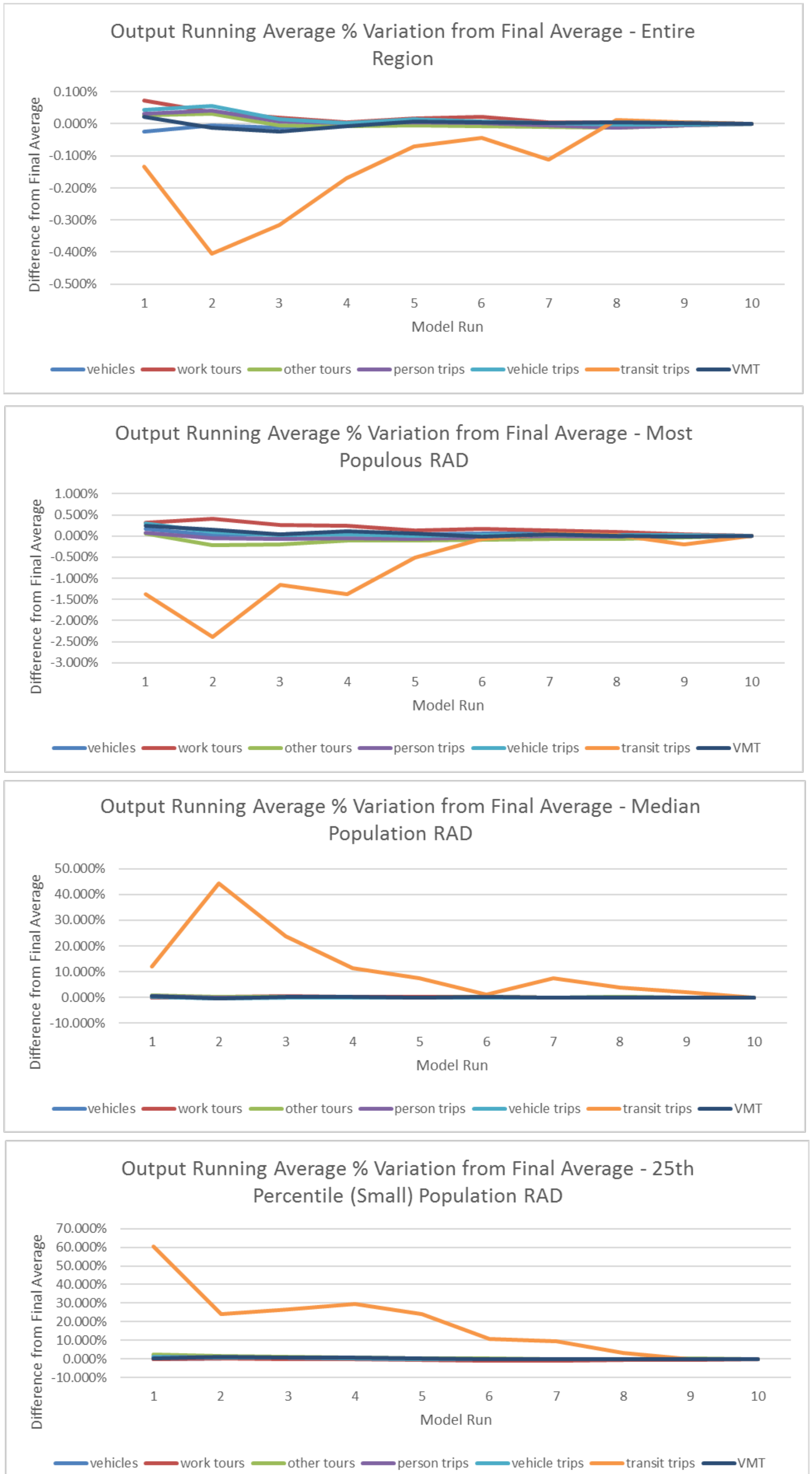
As the charts in Figure 11-6 show, variation is lower and convergence is faster at larger scales. At the region level, the maximum variation from the 10-run average for most outputs is less than +/- 0.1 percent even on the first run, and by the third run is effectively identical to the 10-run average. At the RAD levels, and particularly the smallest RAD level, variation is somewhat higher and convergence somewhat lower because the absolute values of the outputs are smaller and a smaller numeric change equates to a larger percentage change.

Transit variation is higher and takes longer to converge at all levels (region, large-population RAD, medium-population RAD, and small-population RAD), largely due to transit having very small absolute numbers of riders, leading even small output changes to appear as larger percentage changes.

As a general takeaway, the effect of random seed variation on SACSIM19's is generally very small, especially at larger scales. In practice, for region-level estimates a single model run will be sufficient, though seeking estimates at smaller scales (e.g., for modes with fewer trips like transit, looking at trips between a specific pair of RADs or TAZs, etc.) may require taking the average output values from multiple model runs to account for variation. Based on findings from SACSIM19, most values stabilize within five model runs, that is, after five model runs, the running average output values are negligibly different from the 10-run average output values.

When reviewing each figure, it is important to note the vertical scale bar, which is different for each geographic level.

Figure 11-6 Results of Testing Sensitivity to Random Variation



Source: SACOG 2020.

11.5 Facility-Based and Pay-as-You-Go Pricing Testing

Pricing corridors and a VMT user fee are strategies implemented to meet 2020 MTP/SCS key performance targets. Express lanes along major corridors are included to improve traffic management and reliability throughout the region. A mileage-based or Pay-As-You-Go (PAYGo) fee charge is implemented as a sustainable replacement to the gas tax and manage transportation network efficiently and equitably.

Both corridor pricing and user fee are a new feature to SACSIM19. Around the country, implementation of travel modeling software to capture express lanes is recognized as a very complex challenge, so testing of these features is critical. Testing of these new features included sensitivity testing and reasonableness checking, based on guidelines provided by state and federal agencies[26]. In addition to SACOG's testing, the beta-test group and early release of the draft SACSIM19 software and data files, described above in the "Public Access to the Model and Data" section, provided significant additional critical review of these new features. Testing focused on the high-occupancy/toll (HOT) and express lanes facility pricing, because those facilities are the major priced facilities included in the proposed MTP/SCS. HOT lanes, for purposes of this document, are conventional, one-lane HOV lanes, which allow priced access to drive alone vehicles or trucks. Express lanes, for purposes of this document, are generally multi-lane facilities that may allow HOV2 or HOV3+ vehicles access at reduced (or no) price, but allows priced access to drive alone vehicles and trucks. SACSIM19 has the capability to model "all-tolled" roadway facilities, however—given that no all-tolled facilities are included in the propose MTP/SCS, testing mainly focused around HOT and express lanes.

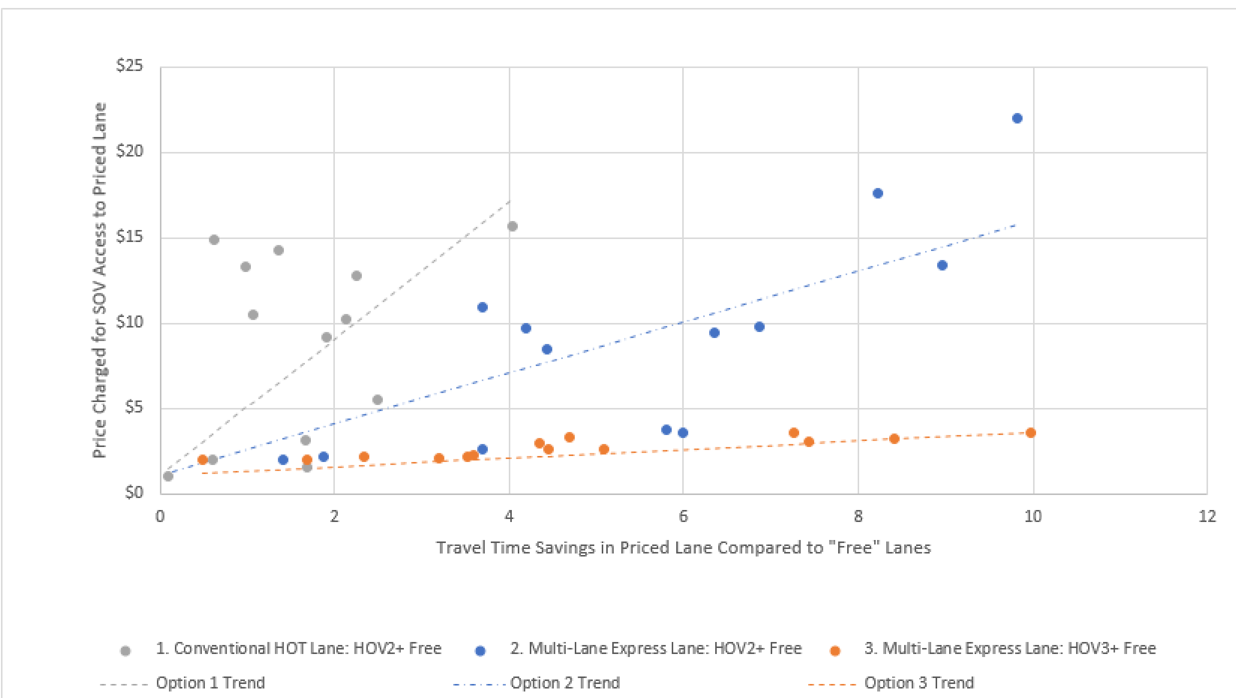
For HOT or express lanes facilities, SACSIM19 pricing software was developed to represent different rules on free versus paid access to HOT or express lanes. The general framework of the software is to iteratively identify a balance point between price of access, based on the rules for access for a given project, that ensures some level of travel time savings for the HOT or express lane, relative to the "free" parallel lanes. Testing focused on two dimensions: sensitivity of price-setting to time savings; and variations on the relationship between price and time savings, based on the rules governing access to the priced facility. Testing results summarized for three options:

- A conventional single-lane HOT lane, with HOV2 and HOV3+ vehicles allowed access for free, and drive alone vehicles and trucks accessing for a price. Available capacity for priced access to the HOT lane is the smallest for this option, because in the highest demand corridors, HOV2 and HOV3+ vehicle nearly fill up the lane. In order to limit the number of drive alone vehicles and trucks that can access the facility, the prices may have a drastic increase surge.
- A conventional 2-lane express facility, with HOV2 and HOV3+ vehicles accessing the facility free, and drive alone vehicles and trucks accessing the facility for a price. Because the facility has two lanes per direction, rather than one, there is generally more capacity to offer for priced access, and prices tend to be somewhat lower than the HOT lane option.
- An express lane option that allows free access to HOV3+ vehicles only, and priced access to HOV2 and drive alone vehicles, and trucks. This option prices off many HOV2s, so the

amount of capacity available for priced access is the highest of the three options, and the prices tend to be the lowest of the three.

Figure 11-7 graphically illustrates the results of the of the three test options, across 14 test corridors. Shown in the figure is the comparison of corridor time savings (defined as the number minutes saved in the priced lane, compared to the parallel free lane) and average price charged to access the priced lane (or lanes). For all three options, the expected relationship showing price increasing with time savings offered by the priced facility is evident. The three options differed very widely, and in expected ways, on the magnitude of price and its volatility across the corridors within each option. Option 1, the conventional HOT lane, showed the highest prices (average just under $10) relative to time saved, largely because in the highest priced corridors, very little-to-no capacity was available to priced access, and virtually all potential users had to be priced off. Table 11-11 Managed Lane / Pricing Tests provides option-level tallies, and shows that of users of the HOT lane, only 2 percent paid their way into the lane—98 percent had access for free. At the other end of the spectrum is option 3, the express lane, which allowed free access only to HOV3+ vehicles. This option offered priced access to the largest number of users, and the prices charged were the lowest at under $3 average, and 50 percent of the users paying. Option 2 (express lane with free access to HOV2 and HOV3+ vehicles) splits the difference between Options 1 and 3.

Figure 11-7 Price Versus Time Savings for Three Managed Lane Options



Source: SACOG 2020.

Table 11-11 Managed Lane / Pricing Tests

	Facility Pricing Scenario	Drivers Accessing Time Savings for Free	Drivers Accessing Time Savings with Toll	Travel Time Savings in Priced Lane (minutes)	Average Toll Rate per Mile	Average SOV Toll Facility Price	VMT Accessing Travel Time Savings (thousands)	Percent VMT Accessing Travel Time Savings	Percent VMT Accessing Travel Time Savings and Paying Toll
1	Conventional HOT Lane	HOV2+	SOV, Truck	-1.5	$0.89	$9.71	974	21%	2%
2	Multi-Lane Express Lane	HOV2+	SOV, Truck	-5.1	$0.58	$9.68	1,170	27%	11%
3	Multi-Lane Express Lane	**HOV3+**	**HOV2, SOV, Truck**	-4.7	$0.36	$2.89	877	21%	50%

Source: SACOG 2020.

Suggested by one of the beta-testers of the new SACSIM19 pricing features was testing around extreme pricing values. The specific suggestion was to test a range of pricing for access to a facility up to $100, which is recognized as an unreasonably high price for an actual project. Testing around extreme values is informative for software testing, and not as a potential actual project proposal. A test of this nature was conducted based on change in travel decisions comparing a range in pricing, time of day, and demand of a particular route. Table 11-12 shows testing along Interstate 80 over the Causeway between Davis and Sacramento. Three scenarios of an all-lane tolled facility are compared at different pricing rates: $5, $25, and $100 dollars. It is important to note that ALL of these pricing rates were set purely for testing purposes, and that actual rates for a proposed express lane project will be the subject of extensive project development work, public input, and policy debate. It is also important to note that the test scenario was based on all-lanes tolling, as opposed to express lanes, where a "free" option always exists. The $5 rate shows a shift of 31 percent of vehicles use alternative routes. At $25, almost 90 percent of traffic avoided the facility. At $100 dollars, the price is so extreme the facility is effectively closed down, and all traffic avoids it. This test shows SACSIM19 highway assignment is sensitive to the level of pricing added to a facility as different persons have a range of valuation of time with respect to their preferred routing choices.

Table 11-12 All Lane Pricing Sensitivity to Extreme Value Test

SACSIM19	**DAILY**					
	Causeway EB			**Causeway WB**		
2035	**Quantity**	**Change**	**% Change**	**Quantity**	**Change**	**% Change**
2035 Base	95,242	0	0.00%	95,974	0	0.00%
$5 Toll, All Time Periods, Mainline & HOV	64,162	-31,080	-32.60%	65,496	-30,478	-31.80%
$25 Toll, All Time Periods, Mainline & HOV	10,334	-84,908	-89.10%	11,825	-84,149	-87.70%
$100 Toll, All Time Periods, Mainline & HOV	19	-95,223	-100.00%	16	-95,958	-100.00%

Source: SACOG 2020.

In addition to corridor pricing, a mileage-based user fee was also tested. Table 11-13 shows sensitivity testing on different mileage based user fee rates based on time of day and location. A discounted fee was applied for rural areas and off peak hours with less congestion. When the user fee increase, the household VMT and Congested VMT decrease. The orders of magnitude of decrease changes based on the rate showing the model is sensitive to different user fee rates.

Table 11-13 User Fee Sensitivity Testing

Scenario	HH VMT % Change from Base	HH Congested VMT % Change from Base
No user fee – Baseline	0.0%	0.0%
1/2 cent peak/off peak rural/urban user fee	-0.3%	-1.9%
2/4 cent peak/off peak rural/urban user fee	-1.5%	-8.2%

Source: SACOG 2020.

NOTE – These scenarios were run for sensitivity testing only and do not reflect the 2020 MTP/SCS preferred scenario.

12 Model Calibration and Validation

12.1 Observed Travel Data

Observed travel data is used for model development (estimation and calibration of statistical submodels) and for reasonableness checking and validation (comparisons of model estimates to observed data in the validation years). This section provides a description of the key observed travel datasets used for SACSIM19.

12.1.1 American Community Survey

Five-year ACS data from the Census Bureau is used as the source of demographic controls for the development of the 2016 representative population file for SACSIM19. In addition to the demographic profiles, the ACS reports commute statistics such as mode of commute. One-year samples average 1.5 percent of all households in the SACOG region. Three-year samples roll up three years of the ACS samples, and control or weight the totals to the end year of the three year sample cycle. SACSIM19 used 2016 five-year ACS data, using sampling from 2012, 2013, 2014, 2015, and 2016.

12.1.2 Household Travel Surveys

Household travel surveys (HTS) record the actual demographics, activity locations, and travel for all members of households for a known, structured sample of households within a region. HTSs are valuable for estimation of statistical models that form the basis of travel demand models like SACSIM19. HTSs are also valuable as sources of data for calibration of key submodels, to ensure that when applied, the submodels are reasonable representations of observed travel behavior. Two HTS's were used for SACSIM19: the 2000 SACOG Household Travel Survey, and the 2018 SACOG Household Travel Survey. Both HTSs were based on a structured sample of households in Sacramento, Sutter, Yolo, and Yuba Counties, and the western portions of El Dorado and Placer Counties.

- 2000 SACOG HTS. SACOG documented the survey and sample design, as well as initial results of the survey in Appendix C, "2000 Sacramento Area Travel Survey Final Report". A more detailed analysis of the 2000 HTS and extensive tabulations, are provided in Appendix H, "Pre-Census Travel Behavior Report: Analysis of the 2000 SACOG Household Travel Survey". The 2000 HTS was used to do the estimation of DAYSIM_1.7, which was later developed into DAYSIM_2.1, the version of DAYSIM used for SACSIM19.
- 2018 SACOG HTS. This was the first HTS implemented in the SACOG region using the smartphone as the primary data capture device for the survey. It was also the first HTS in the SACOG region that collected travel activities for multiple days, including weekend days. Detailed documentation of the survey and sample design, as well as initial results of the survey can be found in https://www.sacog.org/post/2018-sacog-regional-household-travel-survey. The 2018 HTS was finalized too late for use in re-estimation of SACSIM19, and its use was focused on calibration targets for selected DAYSIM_2.1 submodels, and reasonableness checking of SACSIM19 household-generated travel results.

12.1.3 Sacramento Regional Transit Airport Passenger Survey

In January and February 2002, a contractor for Sacramento Regional Transit surveyed air passengers at the Sacramento International Airport[40]. The goal of the survey was to elicit sufficient information from passengers to estimate a ground access mode choice model, and to sample enough passengers to enable using the sample database itself to apply the model using a sample enumeration approach. The survey sample included 777 departing passengers, which were pre-screened to include passengers traveling to the airport from somewhere in the Sacramento Regional Transit service area. This constitutes an approximately 1-in-10 sample of all departing passengers from the RT service area. The reasonableness of the survey as a basis for direct use using a sample enumeration approach was verified by comparison of the sample to aggregated totals from other random surveys of passengers taken in 1998 and 1999 with ground access trip origins within Sacramento, El Dorado, and Placer counties, which compares to the origin areas of the 2002 passenger surveys. By several key variables, such as ground access trip origin, whether the point of origin was a private residence, hotel, or business, and trip purpose, the 2002 sample matched very closely the near-universe sample taken in the 1999 passenger intercept survey.

The survey included both revealed and stated preference elements. The first questions related to the mode of travel actually taken to the airport on that day. Because very little transit service was present at the time of the survey, a set of stated-preference questions were asked related to transit service. A third set of questions elicited demographic information on the passenger.

12.1.4 On-Board Transit Surveys

To help validate SACSIM's transit ridership predictions, we referred to SACOG's 2013 Connect Card Survey, which surveyed nearly 17,000 transit riders in April 2013 as part of developing the Connect Card multi-agency fare card currently in use in the SACOG region. The survey gathered a rich set of demographic and travel behavior data from riders using Sacramento Regional Transit, Roseville Transit, Yuba-Sutter Transit, Yolobus, Folsom Stage Line, El Dorado Transit, and E-Tran (City of Elk Grove). Below we summarize some of the key metrics from the survey that we compared against modeled transit data outputs.

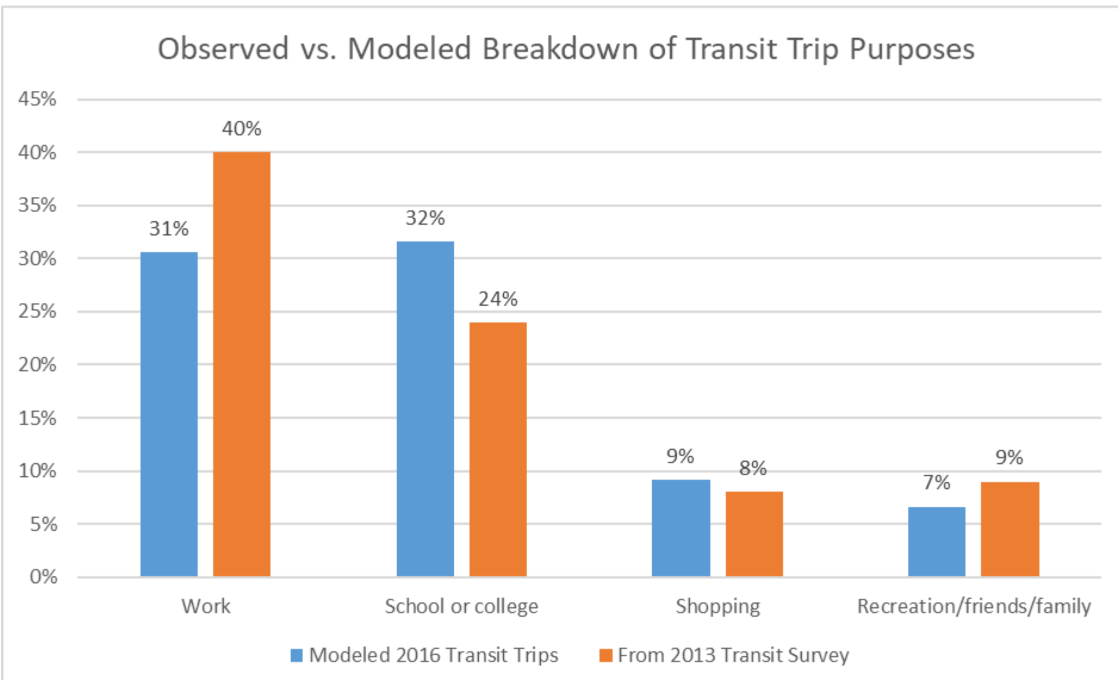
12.1.4.1 Trips by Purpose

Figure 12-1 breaks down transit trips by trip purpose, comparing the trip purpose shares of the model against those found in the 2013 Connect Card Survey. While other trip purposes are captured in the survey and by SACSIM, they are not included in the comparison because they do not have a shared, apples-to-apples definition between the two data sets. E.g., SACSIM has a "meal" trip purpose, but the survey does not. Conversely, the 2013 survey has a "medical appointment" trip purpose, but SACSIM does not.

[40] Parsons Brinckerhof Quade & Douglas, DKS Associates, and JD Franz Associates, "Methodology for Conducting the Passenger Survey at Sacramento International Airport in Support of the Downtown/Natomas/Airport Corridor Alternatives Analysis/Draft EIS Project", July 2002.

For purposes that were comparable, shown in Figure 12-1, SACSIM's modeled share of transit trips dedicated to each purpose is reasonably close to the observed share of trips dedicated to the same purpose. There is some discrepancy, e.g. 40% of observed transit trips were work trips, while only 31% of modeled transit trips were work trips, while for school trips SACSIM predicted that 32% of trips are school trips while observed data only indicated that 24% of trips are school trips. Both discrepancies are likely explained by the absence of Unitrans data in the 2013 Connect Card survey. Unitrans is the second most-used system in the SACOG region, so its riders' behaviors have a significant effect on regional aggregate numbers on rider behavior, and its riders are overwhelmingly UC Davis students. These two factors likely explain why the model data show both a lower share of work trips and higher share of student trips than the observed data.

Figure 12-1 Year 2013 Transit Trips by Purpose



12.1.4.2 Trips, Boardings, and Transfer Rates

Two distinct terms when measuring transit usage are "boardings" and "linked trips". A "linked trip" is the journey that a traveler makes from the trip origin to the trip destination, while a "boarding" occurs each time the traveler gets on a transit vehicle. E.g., if during a linked trip a traveler makes one transfer, that traveler made one linked trip but two boardings.

Table 12-1 below breaks down transfer habits for each transit agency, including how many transfers passengers made and the average boardings per trip. Considering all systems studied in the 2013 survey, the average passenger completed 1.78 boardings for every linked trip. This transfer rate is significantly higher than observed in prior on-board surveys, which ranged from 1.4 to 1.5. Important to note, and discussed in more detail in Section 12.3.4, is the absence of Unitrans data from the 2013 survey. Unitrans is the second busiest transit system in the SACOG region, and its users are less likely to transfer because the system is oriented toward giving students a "one-seat" ride to the UC Davis campus. Therefore, the transfer rate from the 2013 survey is likely somewhat higher than the regional average after accounting for Unitrans riders.

Table 12-1 Year 2013 Transfer Rates by Service Type

Operator	Transit vehicles used to make trip					Boardings/Trip
	1	2	3	4	5	
RT	31%	61%	7%	2%	0%	1.80
Elk Grove	56%	30%	12%	2%	0%	1.60
El Dorado	89%	9%	2%	0%	0%	1.13
Folsom Stage Line	28%	48%	22%	2%	0%	1.98
Roseville	51%	37%	9%	2%	1%	1.65
Yolobus	42%	46%	10%	2%	0%	1.72
Yuba-Sutter	38%	51%	8%	3%	1%	1.79
All Systems	*33%*	*58%*	*7%*	*2%*	*0%*	*1.78*

12.1.5 Transit Boarding Counts

Year 2016 weekday passenger boardings by line were assembled for use in validation of the transit assignment,

12.1.6 Traffic Counts

Traffic counts are used for validation and reasonableness checking of the SACSIM19 highway vehicle assignments for the MTP/SCS base scenario year 2016. Historical count data for 2005, 2008, and 2012 from past model generations are also used for reasonableness checking and backcast validating. Year 2016 is the base year for SACSIM19 and for analysis of the 2020 Metropolitan Transportation Plan. SACSIM uses multiple sources for the traffic counts:

- Caltrans Performance Measurement System (PeMS): Average Spring or Fall, Tuesday – Thursday Daily average counts are used where sensors have been deemed healthy by PeMS sensor health monitor, observed percentage, and staff review.
- Caltrans Traffic Census Program including Traffic Columns: Annual Daily Traffic (AADT) and Truck Traffic: Annual Average Daily Truck Traffic. Reports provide average annual daily volumes and not typical weekday volumes, where provided "Peak Month" volumes were used.

- Processed counts provided by local agency staff in various forms, but generally as paper counts.
- Processed counts provided by a local traffic sensors, provided by local city traffic monitoring systems and readily available traffic count databases.
- Processed counts provided by a local traffic count vendor, with the permission of the clients that paid for the counts.
- Historic count data from permanent electronic count stations on the State Highway system, which were provided to SACOG in raw form by the Teal Data Center.
- Counts taken by count contractor for SACOG in Fall 2008.

In general, counts were used which met the following criteria:

- Counts were daily volumes broken down by direction of travel, or daily volumes broken down by direction of travel and hour.
- Counts were taken in Spring months (March, April, or May) or early Autumn months (September or October) of calendar year.
- Counts were taken during the mid-week weekdays (Tuesday, Wednesday or Thursday).

In some cases, counts were utilized by SACOG which did not meet these two criteria. The most common exceptions were non-directional daily counts, which were split 50/50 to get to direction of travel, or counts taken outside the desired seasonal windows and year, if there was some level of confidence that the count was a reasonably good representation of weekday volumes.

No peak hour counts were processed or utilized for SACSIM. The reasons for this have to do with the limitations of static or aggregate assignment of vehicle trips onto a regional network the size and extent of SACSIM. Table 12-2 provides a tabulation of the traffic counts assembled by county of the count location by year.

Table 12-2 Traffic Counts Collected by Year

	Year			
	2005	2008	2012	2016
Functional Class				
Freeway/HOV	189	241	191	371
Arterial/Expressway/Rural Highway	556	702	481	1,065
Other Surface Streets & Ramps	520	820	368	760
Total	1,265	1,763	1,040	2,196

Source: SACOG 2020.

12.1.7 Vehicle Miles Traveled

Estimates of VMT were extracted from the annual Highway Performance Monitory System data from the California Public Road Data[41] report, and adjusted for comparison to the SACSIM19 estimates VMT. Adjustments of the CPRD VMT estimates are needed for two reasons.

First, reported VMT is based on average annual daily traffic volumes (AADT) in the CPRD, while the SACSIM19 VMT estimates are typical weekday. The technical definition for "annual average" is the sum of daily volumes on a roadway for every day of the year, divided by the number of days in the year (365 or 366 for leap years). In practice, AADT volumes are rarely computed in this way, though—they are estimated from a limited number of counts, and adjusted for presumed seasonal variation, and for weekday/weekend variations. Spot comparisons of typical weekday volumes to AADT volumes show that on average, typical weekday volumes are about 5 percent higher than AADT volumes. In comparison, SACSIM "typical weekday" (discussed in greater detail in the "Introduction" of this report) is defined as mid-weekday (Tuesday through Thursday) in spring or fall months. In general, typical weekday is more focused on "workday" travel conditions. Since annual average includes weekends, holidays, and all seasons, the volumes tend to be lower on average than typical weekday. A global adjustment factor of 1.05 (i.e. a five percent increase) is used to convert from annual average to typical weekday and regional level.

Second, the CPRD reports provide printed tables which do not allow for tabulation of geography consistent with the SACSIM model area, which is all of Sacramento, Sutter, Yolo and Yuba Counties, and the non-Tahoe-Basin portions of El Dorado and Placer Counties. SACOG assumed the non-Tahoe-Basin portions of CPRD-reported VMT are 90 percent and 95 percent for El Dorado and Placer Counties, respectively.

[41] California Department of Transportation, *California Public Road Data*, published annually, http://www.dot.ca.gov/hq/tsip/hpms/datalibrary.php

12.1.8 Other Data Sources

For reasonableness checking and manual adjustments of free-flow speeds, available estimates of vehicle speed were utilized. For 2012 speeds, SACOG used INRIX average speed estimates by time of day and direction, average for the months of September and October. For 2016 speeds, SACOG used speed data provided through the Federal Highway Administration (FHWA) "National Performance Management Research Dataset" (NPMRDS). NPMRDS data are provided at 15-minute increments for all time periods and days; however, if raw data do not meet the reporting standards of the contractor to FHWA, data are not provided. In general, NPMRDS data coverage is very good for higher volume roadways, and very poor for lower volume roadways. SACOG processes the raw data for use in regional monitoring functions and the Congestion Management Program. The processed speeds are used for reasonableness checking of individual roadway segments and manual adjustments to free-flow speeds in the SACSIM19 highway network.

12.2 Model Calibration

12.2.1 DAYSIM Model Calibration

As described in Chapter 3, DAYSIM is the core of SACSIM and is consisted of two modules: long term and short term choices. Both modules are consisted of a series of nested choice models. In operation, given the households' residence, DAYSIM runs long term module first and simulates people's long term choices such as usual work and school locations, and auto ownership, and then run short term choice module such as day pattern, main destination, tour mode, trip mode etc. With this hierarchical or nested choice structure, the lower level choices were affected or constrained by upper choices. For example:

• Choices of usual locations for work and school affect the choices of work and tour destinations, since the usual locations are the most likely destinations.

• Auto ownership affects both day pattern and tour (and trip) mode choice, by generating auto ownership market segments used in the model.

In SACSIM19, all DAYSIM choice models were re-estimated using the 2008 parcel level landuse data, skim data and the expanded 2000 survey in 2008 travel conditions. All initial re-estimated coefficients and standard error are listed in Appendix A-DAYSIM User Reference Guide. Table 12-3 lists the choice models and variables calibrated based on 2016 landuse/demographics and travel conditions with ACS 2012-2016 5 year data and 2018 Household Travel Survey:

Table 12-3 DAYSIM Choice Model Coefficients

1. WorkLocation - WorkLocationCoefficients_SACOG-v1.5

Item#	Name	Description	Ratio variable Description
6	Beta00006	workAwayFromHomeFlag * IsFulltimeWorkerFlag * [One-way drive dist--0-3.5 mi (10s of mi)]	% of full time workers with to usual-work-place distance < 3.5 mile
7	Beta00007	workAwayFromHomeFlag * IsFulltimeWorkerFlag * [One-way drive dist--3.5-10 mi (10s of mi)]	% of full time workers with to usual-work-place distance >=3.5 and <= 10 mile
8	Beta00008	workAwayFromHomeFlag * IsFulltimeWorkerFlag * [One-way drive dist--10+ mi (10s of mi)]	% of full time workers with to usual-work-place distance >= 10 mile
41	Beta00041	workAtHomeFlag	% of workers working at home

2. SchoolLocation - SchoolLocationCoefficients_SACOG-v1.8

Item#	Name	Description	Ratio variable Description
7	Beta00007	schoolAwayFromHomeFlag * IsChildUnder5Flag * [One-way drive dist--0-1 mi (10s of mi)]	% of under 5 year old kids with to usual-school-place distance < 1 mile
8	Beta00008	schoolAwayFromHomeFlag * IsChildUnder5Flag * [One-way drive dist--1-5 mi (10s of mi)]	% of under 5 year old kids with to usual-school-place distance >= 1 and < 5 mile
9	Beta00009	schoolAwayFromHomeFlag * IsChildUnder5Flag * [One-way drive dist--5+ mi (10s of mi)]	% of under 5 year old kids with to usual-school-place distance >= 5 mile
10	Beta00010	schoolAwayFromHomeFlag * IsChildAge5Through15Flag * [One-way drive dist--0-1 mi (10s of mi)]	% of 5-15 year old kids with to usual-school-place distance < 1 mile
11	Beta00011	schoolAwayFromHomeFlag * IsChildAge5Through15Flag * [One-way drive dist--1-5 mi (10s of mi)]	% of 5-15 year old kids with to usual-school-place distance >= 1 and < 5 mile
12	Beta00012	schoolAwayFromHomeFlag * IsChildAge5Through15Flag * [One-way drive dist--5+ mi (10s of mi)]	% of 5-15 year old kids with to usual-school-place distance >= 5 mile

3.AutoOwnerShip - AutoOwnershipCoefficients_SACOG-v1.5

Item#	Name	Description	Ratio variable Description
1	1 Beta00001	0 autos--household.Has1Driver.ToFlag());	% of households has 1 driver with 0 auto
2	2 Beta00002	2 autos--household.Has1Driver.ToFlag());	% of households has 1 driver with 2 auto
3	3 Beta00003	3 autos--household.Has1Driver.ToFlag());	% of households has 1 driver with 3 auto
4	4 Beta00004	4+ autos--household.Has1Driver.ToFlag());	% of households has 1 driver with 4+ auto
5	5 Beta00005	0 autos--household.Has2Drivers.ToFlag());	% of households has 2 driver with 0 auto
6	6 Beta00006	1 auto--household.Has2Drivers.ToFlag());	% of households has 2 driver with 1 auto
7	7 Beta00007	3 autos--household.Has2Drivers.ToFlag());	% of households has 2 driver with 3 auto
8	8 Beta00008	4+ autos--household.Has2Drivers.ToFlag());	% of households has 2 driver with 4+ auto
9	9 Beta00009	0 autos--household.Has3Drivers.ToFlag());	% of households has 3 driver with 0 auto
10	10 Beta00010	1 auto--household.Has3Drivers.ToFlag());	% of households has 3 driver with 1 auto
11	11 Beta00011	2 autos--household.Has3Drivers.ToFlag());	% of households has 3 driver with 2 auto
12	12 Beta00012	4+ autos--household.Has3Drivers.ToFlag());	% of households has 3 driver with 4+ auto
13	13 Beta00013	0 autos--household.Has4OrMoreDrivers.ToFlag());	% of households has 4+ driver with 0 auto
14	14 Beta00014	1 auto--household.Has4OrMoreDrivers.ToFlag());	% of households has 4+ driver with 1 auto
15	15 Beta00015	2 autos--household.Has4OrMoreDrivers.ToFlag());	% of households has 4+ driver with 2 auto
16	16 Beta00016	3 autos--household.Has4OrMoreDrivers.ToFlag());	% of households has 4+ driver with 3+ auto
18	18 Beta00018	0-4+--household has at least as many cars as workers	% of households has at least as many cars as workers

4. IndividualPersonDayPattern - IndividualPersonDayPatternCoefficients_SACOG-v1.8

Item#	Name	Description	Ratio variable Description
work			
100	W-TASC	tour constant(FTW)	% of full time workers taking 1+ work tours
101	W-SASC	stop constant	% of work tours with 1+ stops
102	W-PTW	PartTimeWorker	% of part time workers taking 1+ tours
school			
200	S-TASC	tour constant	% of people taking 1+ school tours
201	S-SASC	stop constant	% of school tours with 1+ stops
205	S-UNI	UniversityStudent	% of university students taking 1+ school tours
206	S-DAS	DriveAgeKid	% of driving school kids taking 1+ school tours

207	S-PAS	5-15 kids	% of 5 to 15 year old kids taking 1+ school tours
208	S-CU5	under 5	% of 5 to 5 year old kids taking 1+ school tours
Escort			
300	E-TASC	tour constant	% of people taking 1+ escort tours
301	E-SASC	stop constant	% of escort tours with 1+ stops
Personal Bus			
400	P-TASC	tour constant	% of people taking 1+ personal bus tours
401	P-SASC	stop constant	% of personal bus tours with 1+ stops
shop			
500	H-TASC	tour constant	% of people taking 1+ shopping tours
501	H-SASC	stop constant	% of shopping tours with 1+ stops
meal			
600	M-TASC	tour constant	% of people taking 1+ meal tours
601	M-SASC	stop constant	% of meal tours with 1+ stops
Social			
700	D-TASC	tour constant	% of people taking 1+ social tours
701	D-SASC	stop constant	% of social tours with 1+ stops
TourStopCombo			
1311	NT/NS-1/1	1 tour/1 stop	% of people taking 1 tour with 1 stop
1312	NT/NS-1/2	1 tour/2 stop	% of people taking 1 tour with 2 stop
1313	NT/NS-1/3	1 tour/3+ stop	% of people taking 1 tour with 3+ stop
1321	NT/NS-2/1	2 tour/1 stop	% of people taking 2 tour with 1 stop
1322	NT/NS-2/2	2 tour/2 stop	% of people taking 2 tour with 2 stop
1323	NT/NS-2/3	2 tour/3+ stop	% of people taking 2 tour with 3+ stop
1331	NT/NS-3/1	3 tour/1 stop	% of people taking 3 tour with 1 stop
1332	NT/NS-3/2	3 tour/2 stop	% of people taking 3 tour with 2 stop

5. PersonExactNumberofTours - PersonExactNumberOfToursCoefficients_SACOG-v1.5

Item#	Name	Description	Ratio variable Description
work tours			
	0&1 Tours		
152	WC-2Tours		% of people take 2 work tours
153	WC-3Tours		% of people take 3 work tours
school tours			
	0&1 Tours		
252	SC-2Tours		% of people take 2 school tours
253	SC-3Tours		% of people take 3 school tours
escort			

	0&1 Tours		
352	EC-2Tours		% of people take 2 escort tours
353	EC-3Tours		% of people take 3 escort tours
person business			
	0&1 Tours		
452	PC-2Tours		% of people take 2 Personal Business tours
453	PC-3Tours		% of people take 3 personal business tours
shopping			
	0&1 Tours		
552	HC-2Tours		% of people take 2 shopping tours
553	HC-3Tours		% of people take 3 shopping tours
meal			
	0&1 Tours		
652	MC-2Tours		% of people take 2 meal tours
653	MC-3Tours		% of people take 3 meal tours
social/Rec			
	0&1 Tours		
752	RC-2Tours		% of people take 2 social/Rec tours
753	RC-3Tours		% of people take 3 social/Rec tours

6. WorkBasedSubTourGeneration - WorkbasedSubtourGenerationCoefficients_SACOG-v1.5

Item#	Name	Description	Ratio variable Description
1	Beta00001	work stop	% of work based tours with work purpose stop
3	Beta00003	school stop	% of work based tours with school purpose stop
4	Beta00004	escort stop	% of work based tours with escort purpose stop
6	Beta00006	personal business stop	% of work based tours with personal business purpose stop
8	Beta00008	shopping stop	% of work based tours with shopping purpose stop
10	Beta00010	meal stop	% of work based tours with meal purpose stop
13	Beta00013	social/rec stop	% of work based tours with social/rec purpose stop

7. WorkTourMode - WorkTourModeCoefficients_SACOG-v1.5 - Copy.F12

Item#	Name	Description	Ratio variable Description
10	dt-const	Drive to Transit Constant	Drive to Transit Tours
20	wt-const	Walk to Transit	Walk to Transit Tours
30	s3-const	Shared Drive 3 Constant	Shared Drive 3+ Tours

40	s2-const	Shared Drive 2 Constant	Shared Drive 2 tours
50	da-const	Drive Alone Constant	Drive Alone Tours

8. Other home based tour mode - OtherHomeBasedTourModeCoefficients_SACOG-v1.5.F12

Item#	Name	Description	Ratio variable Description
20	wt-const	Walk to Transit Constant	Walk to Transit Tours
30	s3-const	Shared Drive 3 Constant	Shared Drive 3+ Tours
40	s2-const	Shared Drive 2 Constant	Shared Drive 2 tours
50	da-const	Drive Alone Constant	Drive Alone Tours
60	bi-const	Bike Constant	Bike tours

9. TripMode - TripModeCoefficients_SACOG-v1.5.F12

Item#	Name	Description	Ratio variable Description
20	wt-const	Walk to Transit Constant	Walk to Transit Trips
30	s3-const	Shared Drive 3 Constant	Shared Drive 3+ Trips
40	s2-const	Shared Drive 2 Constant	Shared Drive 2 Trips
50	da-const	Drive Alone Constant	Drive Alone Trips
60	bi-const	Bike Constant	Bike Trips

12.3 **Model Validation and Reasonableness Check**

12.3.1 DAYSIM Reasonableness Check and Validation

As mentioned in model calibration section, DAYSIM submodels were estimated using expanded 2000 household travel survey data based on 2008 land use and travel conditions. Selected DAYSIM submodels and variables were calibrated based on 2016 land use and demographic data and ACS 2012-2016 5-year data. Only mode choice models were recalibrated based on 2018 household travel survey due to time and resource constraints during SACOG's 2020 MTP/SCS development.

As reasonableness check, the sections below compare model results to 2018 household travel survey data on the following metrics:

- Usual Work Location
- Auto Ownership
- Mode Share
- Trip Length

12.3.1.1 Usual Work Location

As described in Chapter 3, usual work location is the top-level model in the DAYSIM hierarchy. Each worker is designated a usual work place based on the worker's demographic characteristics and job availability in the region. Table 12-4 compares the average one-way commute distance estimated by DAYSIM to the average observed distance from 2018 Household Travel Survey, broken out by worker type (e.g. full time vs part time).

Figure 12-2 shows the number of commute trips by travel distances. Compared to the 2018 survey, DAYSIM's average commute distance is slightly lower overall, with much of this difference due to DAYSIM predicting a higher share of short commute distances (less than ~5 miles).

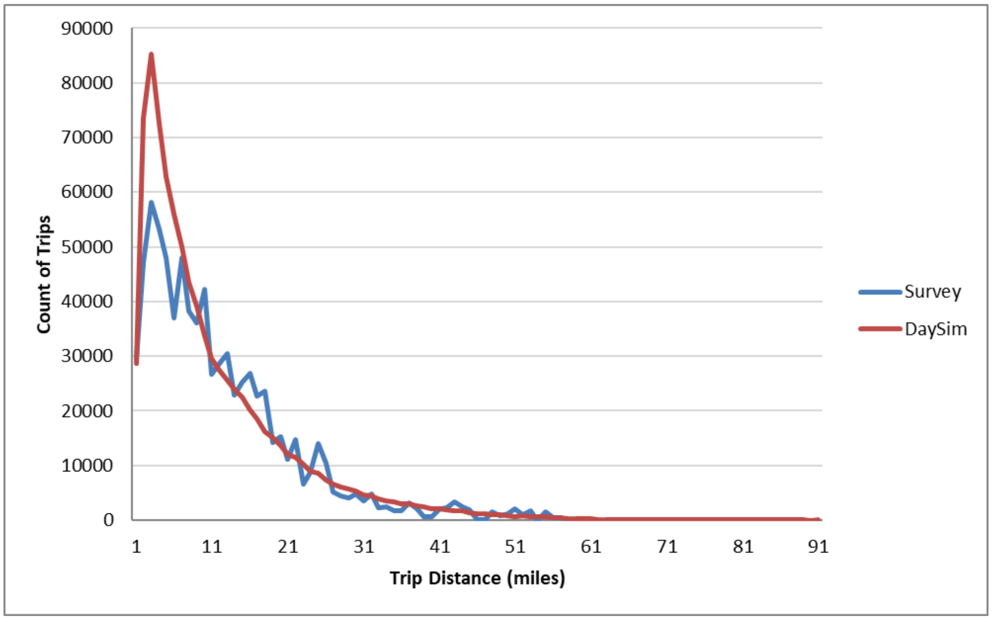
The total work location choices are constrained to TAZ-level total jobs by a shadow price process. Figure 12-3 demonstrates a good fit between the number of jobs in each TAZ and how many workers' usual work locations are in that TAZ.

Table 12-4 Average Commute Distance by Auto (2016 DAYSIM vs 2018 HTS)

Worker Type	Survey	DaySim	Ratio (DAYSIM/Survey)
Full Time	12.12	11.41	0.94
Part Time	8.76	7.66	0.87
Others	7.57	6.93	0.90
All	11.26	10.33	0.92

Source: SACOG 2020.

Figure 12-2 Commute Distance Frequency – All Workers



Source: SACOG 2020.

Figure 12-3 Jobs vs Workers at the Usual Work Locations by TAZs

Source: SACOG 2020.

12.3.1.2 Auto Ownership

The Auto Ownership submodel includes constants to predict how many vehicles a household owns (0, 1, 2, 3, or 4+) as well as the number of potential drivers (0, 1, 2, 3, or 4+). Table 12-5 presents a comparison of modeled auto ownership distribution to the distribution from 2018 Household Travel Survey by the number of vehicles vs the potential drivers in the household. At the region level, the ownership distributions by the number of vehicles or the number drivers estimated by DAYSIM match the distributions presented in 2018 Household Travel Survey well.

Table 12-5 Auto Ownership Validation

2018 HTS		Number of Vehicles					
	HH # of Potential Drivers	*0*	*1*	*2*	*3*	*4+*	*Total*
	1	5%	20%	4%	1%	0%	30%
	2	1%	9%	27%	7%	3%	47%
	3	0%	2%	5%	5%	2%	13%
	4+	1%	1%	2%	2%	5%	10%
	Total	7%	32%	39%	15%	8%	100%
DAYSIM							
	HH # of Potential Drivers	*0*	*1*	*2*	*3*	*4+*	*Total*
	1	6%	19%	3%	1%	0%	30%
	2	1%	8%	30%	6%	2%	47%
	3	0%	2%	4%	6%	2%	13%
	4+	0%	3%	2%	1%	4%	10%
	Total	8%	32%	39%	14%	8%	100%
Validation Ratio (DAYSIM Vs 2018 HTS)							
	HH # of Potential Drivers	*0*	*1*	*2*	*3*	*4+*	*Total*
	1	1.3	1.0	0.8	1.6	0.8	**1.0**
	2	1.5	0.9	1.1	0.8	0.6	**1.0**
	3	0.5	1.0	0.9	1.2	1.1	**1.0**
	4+	0.1	3.2	1.0	0.5	1.0	**1.0**
	Total	**1.2**	**1.0**	**1.0**	**0.9**	**1.0**	**1.0**

Source: SACOG 2020.

12.3.1.3 Mode share

As Table 12-6 shows, modeled all-purpose trip mode share distribution matches the distribution in 2018 household travel survey. Below, Table 12-7 also shows a close fit between modeled versus observed mode split for tours when considering all tour purposes. As shown in Table 12-9, modeled mode split for work tours (commutes) generally also is quite close to observed 2018 travel survey commute mode split. As Table 12-8 and Table 12-9 show, the model predicted a higher share of commute tours and trips made by walking and transit than was observed in the 2018 survey. This larger difference is still reasonable and not surprising given the small number cases in the household travel survey who walked or took transit as their primary commute mode.

Table 12-6 Mode Split Validation, 2016 Model Results vs. 2018 Household Travel Survey – All Trips

	2018 Household Travel Survey	2016 Travel Model	Validation Ratio
Walk	7.6%	7.8%	1.0
Bike	2.3%	2.5%	1.1
Drive Alone	42.4%	42.1%	1.0
Shared Drive 2	22.4%	22.4%	1.0
Shared Drive 3+	22.9%	22.7%	1.0
Transit	1.2%	1.2%	1.0
Other	1.3%	1.2%	0.9

Source: SACOG 2020.

Table 12-7 Mode Split Validation, 2016 Model Results vs. 2018 Household Travel Survey – All Tours

	2018 Household Travel Survey	2016 Travel Model	Validation Ratio
Walk	5.4%	6.1%	1.1
Bike	2.4%	2.6%	1.1
Drive Alone	37.1%	35.5%	1.0
Shared Drive 2	22.9%	23.3%	1.0
Shared Drive 3+	28.5%	28.8%	1.0
Transit	2.5%	2.0%	0.8
Other	1.3%	1.6%	1.3

Source: SACOG 2020.

Table 12-8 Mode Split Validation, 2016 Model Results vs. 2018 Household Travel Survey – Commute Trips

	2018 Household Travel Survey	2016 Travel Model	Validation Ratio
Walk	5.9%	4.7%	0.8
Bike	2.1%	2.4%	1.1
Drive Alone	70.5%	74.6%	1.1
Shared Drive 2	12.4%	9.4%	0.8
Shared Drive 3+	7.5%	7.4%	1.0
Transit	1.6%	1.5%	0.9

Source: SACOG 2020.

Table 12-9 Mode Split Validation, 2016 Model Results vs. 2018 Household Travel Survey – Commute Tours

	2018 Household Travel Survey	2016 Travel Model	Validation Ratio
Walk	1.7%	2.9%	1.7
Bike	2.6%	2.8%	1.1
Drive Alone	65.9%	67.7%	1.0
Shared Drive 2	14.2%	14.0%	1.0
Shared Drive 3+	11.6%	10.2%	0.9
Transit	3.9%	2.5%	0.6

Source: SACOG 2020.

12.3.1.4 Trip length

Table 12-10 compares the average trip distance by mode, for all trip types, from the 2016 travel model and 2018 household travel survey. Table 12-11 provides the same comparison specifically for commute trips.

In both tables, the modeled average trip distance for auto modes (drive-alone and HOV) is generally very close to the average trip distance observed in the travel survey. In contrast, there is a significant difference between the model results and survey findings for transit and non-motorized trip distances. These significant differences stem from several challenges inherent to regional travel models. Specifically:

- Survey-based trip distances are based on users traveling the real street network, inclusive of minor streets not in the model, while the model can only roughly approximate such trips by having travelers use centroid connectors. This difference in network granularity disproportionately affects non-motorized trips, which are more likely to use minor streets in the model and be shorter trips.

- Survey-based trip distances are “parcel to parcel”, whereas modeled distances are TAZ-to-TAZ, assuming all trips start and end at TAZ centroids. The proportional difference between TAZ-TAZ distance and parcel-parcel distance is smaller for longer trips, but can be quite large for short trips, which comprise a larger share of trips that use non-motorized modes.

Modeled transit trip distances were shorter than transit trips recorded in the survey. This is likely because the modeled transit trip distances are based on the TAZ to TAZ driving distance following the most direct driving route, rather than the route followed by transit routes, which is usually longer than the most direct driving route. Accurate, route-based transit travel distances are not available from the model because it bases transit trip cost and assignment on travel times associated with transit, and not travel distance.

Given the above weaknesses of the model to accurately represent transit, walk, and bike travel distances, we are not concerned by the looser validation of these modes. And when we consider the auto modes, whose travel distances the model can provide with more accuracy, we see that the surveyed travel distances align closely with modeled travel distances.

Table 12-10 Average Trip Distance by Mode (All Trips) – SACSIM vs. 2018 Household Travel Survey

	2018 Household Travel Survey	2016 Travel Model	Validation Ratio
Walk	0.7	1.5	2.1
Bike	2.3	4.7	2.0
Drive Alone	7.9	7.9	1.0
Shared Drive 2	6.6	6.9	1.0
Shared Drive 3+	5.9	6.9	1.2
Transit	8.7	5.8	0.7
Other	10.0	4.6	0.5
All Modes	*6.5*	*6.8*	*1.0*

Source: SACOG 2020.

Table 12-11 Average Trip Distance by Mode (Commute Trips) – SACSIM vs. 2018 Travel Survey

	2018 Household Travel Survey	2016 Travel Model	Validation Ratio
Walk	0.9	1.8	2.1
Bike	3.6	4.1	1.2
Drive Alone	10.6	9.5	0.9
Shared Drive 2	9.0	8.7	1.0
Shared Drive 3+	9.3	8.8	0.9
Transit	12.7	7.0	0.6
All Modes	*9.6*	*8.9*	*0.9*

Source: SACOG 2020.

12.3.2 Land use and Demographic Reasonableness Check

Table 12-12 provides comparison of region wide totals of dwelling units, households, population and jobs from SACSIM against other independent data sources. SACSIM model data is within three percent of region wide totals. California Department of Finance (DOF) projects dwelling units, households, and population totals by county and jurisdiction.

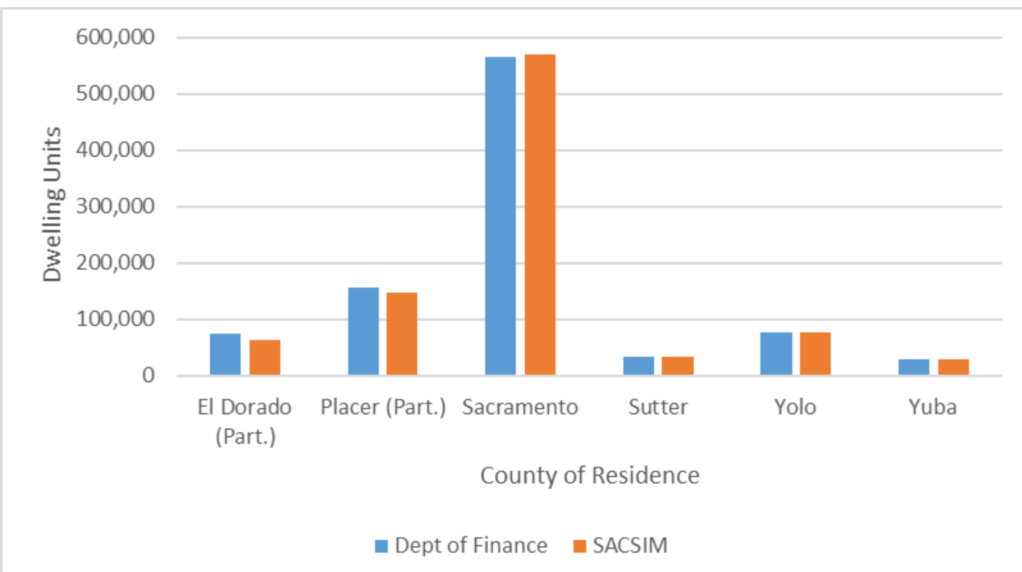
Table 12-12 Year 2016 SACOG Region Parcel Data Comparison

Variable	Observed Data	SACSIM19 Estimate	Validation Ratio
Dwelling Units[1]	932,289	921,123	0.99
Households[1]	849,779	872,699	1.03
Population[1]	2,401,837	2,412,755	1.00
Jobs[2]	1,071,199	1,060,751	0.99

Source: SACOG 2020.
[1] California Department of Finance Projections, adjusted to exclude Tahoe basin.
[2] Levy, Stephen, California Center for Continuing Study of the California Economy.

Since SACOG regional consists of six counties but excludes the Tahoe basin portion of El Dorado and Placer Counties, an adjustment must be made to compare. The DOF estimates for the City of South Lake Tahoe are excluded and the remainder is divided equally to El Dorado and Placer County unincorporated areas. Figure 12-4 provides comparisons of dwelling units by county for 2016 SACSIM MTP/SCS and 2016 DOF estimates. Table 12-13 shows a comparison of the population and average household size by county for 2016 SACSIM MTP/SCS and 2016 department of finance estimates. SACSIM model data matches county totals closely to DOF.

Figure 12-4 Year 2016 Dwelling Units by County



Source: SACOG 2020.
California Department of Finance Projections, adjusted to exclude Tahoe basin.

Table 12-13 Comparison of SACSIM Population and Household Size to Department of Finance Estimates

County	Population			Average Household Size	
	2016		%	2016	
	SACSIM19	DOF	Diff.	SACSIM19	DOF
El Dorado*	147,202	150,843	-2.41%	2.6	2.6
Placer*	363,896	361,288	0.72%	2.7	2.7
Sacramento	1,476,573	1,474,115	0.17%	2.7	2.8
Sutter	96,392	95,852	0.56%	2.9	3.0
Yolo**	214,784	203,693	5.44%	2.6	2.8
Yuba	77,464	73,047	6.05%	2.9	2.8
Total	2,376,311	2,358,837	0.74%	2.7	2.8

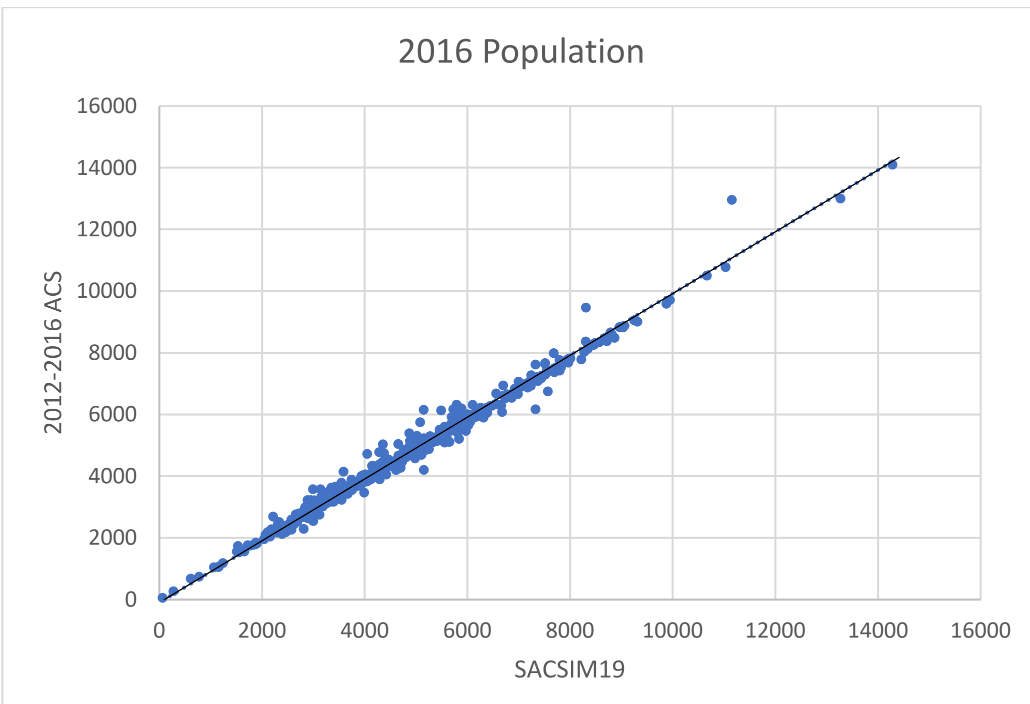
Source: SACOG 2020.

*Partial county—Tahoe Basin excluded.

**DOF has adjusted multi-family housing units in Unincorporated Yolo County in a formula to change Census identified housing units into group quarters, therefore population and households will exactly not match Census estimates.

As described in Chapter 5, the ACS 2016 5-year sample data are used to establish demographic controls at Census tract level and are then used to generating representative population file. In past SACSIM validation, SACSIM representative population was compared to the 2010 Decennial Census by Tract, since this MTP/SCS base scenario was 2016, it was deemed too out of date to use for validation purposes. In consequence, ACS 2016 5-year sample was further examined to final SACSIM population and characteristics. Figure 12-5 shows a comparison plot of ACS 2016 5-year sample household population compared to SACSIM19 2016 household population by tract. Since the ACS data is used to control the generation of the representative population file distributions, it is expected the SACSIM population match well with the ACS data. The two datasets are consistent at this much-lower level geography, too. The overall correlation between the two datasets at tract level is very high—the R-squared of a regression of ACS 2016 5-year sample data tract population using the 2016 SACSIM19 population as an independent variable was 0.98.

Figure 12-5 Comparison of 2016 Population



Source: SACOG 2020.

Table 12-14 through Table 12-17 provide comparisons between ACS 2016 5-year sample data and SACSIM19 2016 Population control household variables. These tables also show a high degree of consistency for all variables at county level.

Table 12-14 Year 2016 Household Size Distribution by County

SACSIM19 Representative Sample Data

County	1 person	2 persons	3 persons	4+ persons
El Dorado*	21%	40%	17%	22%
Placer*	24%	36%	15%	24%
Sacramento	27%	31%	16%	27%
Sutter	22%	30%	17%	31%
Yolo	24%	32%	18%	27%
Yuba	20%	32%	17%	31%
Total	25%	33%	16%	26%

ACS 2016

County	1 person	2 persons	3 persons	4+ persons
El Dorado*	23%	40%	16%	21%
Placer*	24%	36%	15%	24%
Sacramento	27%	31%	16%	26%
Sutter	22%	30%	17%	31%
Yolo	24%	32%	18%	27%
Yuba	20%	32%	17%	31%
Total	25%	33%	16%	26%

Validation Ratio SACSIM19 to ACS

County	1 person	2 persons	3 persons	4+ persons
El Dorado*	0.92	1.01	1.03	1.04
Placer*	0.99	0.99	1.00	1.02
Sacramento	0.99	1.00	1.00	1.00
Sutter	1.00	1.00	1.00	1.00
Yolo	1.00	1.00	1.00	1.00
Yuba	1.00	1.00	1.00	1.00
Total	0.99	1.00	1.00	1.01

Source: SACOG 2020.

Based on American Community Survey 2016 5-year Sample data. *Partial county—Tahoe Basin excluded.

Table 12-15 Comparison of Distribution of Workers in Household by County

SACSIM19 Representative Sample Data

County	0 worker	1 workers	2 workers	3+ persons
El Dorado*	32%	37%	28%	4%
Placer*	30%	35%	29%	6%
Sacramento	27%	40%	27%	6%
Sutter	29%	38%	26%	7%
Yolo	26%	36%	31%	7%
Yuba	32%	40%	24%	5%
Total	28%	38%	28%	6%

ACS 2016

County	0 worker	1 workers	2 workers	3+ persons
El Dorado*	31%	37%	27%	5%
Placer*	30%	35%	29%	6%
Sacramento	27%	40%	27%	6%
Sutter	29%	38%	26%	7%
Yolo	26%	36%	31%	7%
Yuba	32%	39%	24%	5%
Total	28%	38%	28%	6%

Validation Ratio SACSIM19 to ACS

County	0 worker	1 workers	2 workers	3+ persons
El Dorado*	1.02	0.98	1.00	0.98
Placer*	1.00	1.00	1.01	0.98
Sacramento	1.00	1.00	1.00	1.01
Sutter	1.00	1.00	1.00	1.01
Yolo	1.00	1.00	1.00	1.00
Yuba	0.99	1.01	1.00	0.98
Total	1.00	1.00	1.00	1.00

Source: SACOG 2020.

Based on American Community Survey 2016 5-year Sample data. *Partial county—Tahoe Basin excluded.

Table 12-16 Comparison of Household Income Distribution by County

SACSIM19 Representative Sample Data

County	< $20K	$20K - $40K	$40K - $60K	$60K - $100K	$100K+
El Dorado*	11%	16%	13%	22%	39%
Placer*	11%	14%	13%	23%	39%
Sacramento	17%	19%	16%	23%	26%
Sutter	18%	20%	16%	23%	22%
Yolo	19%	17%	15%	20%	28%
Yuba	18%	24%	18%	23%	16%
Total	16%	18%	15%	23%	28%

ACS 2016

County	< $20K	$20K - $40K	$40K - $60K	$60K - $100K	$100K+
El Dorado*	12%	17%	13%	22%	36%
Placer*	11%	14%	13%	23%	38%
Sacramento	17%	19%	16%	23%	26%
Sutter	18%	20%	16%	23%	22%
Yolo	19%	17%	15%	20%	28%
Yuba	18%	24%	18%	23%	17%
Total	16%	18%	16%	23%	28%

Validation Ratio SACSIM19 to ACS

County	< $20K	$20K - $40K	$40K - $60K	$60K - $100K	$100K+
El Dorado*	0.93	0.90	0.96	1.00	1.09
Placer*	0.98	0.99	0.98	1.01	1.01
Sacramento	1.00	1.00	1.00	1.00	1.00
Sutter	1.00	1.00	1.00	0.99	1.00
Yolo	1.01	1.00	1.00	0.99	1.00
Yuba	1.00	1.01	1.00	1.00	0.99
Total	1.00	0.99	1.00	1.00	1.01

Source: SACOG 2020.
Based on American Community Survey 2016 5-year Sample data. *Partial county—Tahoe Basin excluded.

Table 12-17 Comparison of Householder's Age Distribution

SACSIM19 Representative Sample Data

County	< 35 Years	35 - 64 years	>= 65 Years
El Dorado*	9%	60%	31%
Placer*	14%	57%	29%
Sacramento	21%	57%	21%
Sutter	20%	56%	24%
Yolo	28%	52%	20%
Yuba	27%	53%	20%
Total	20%	57%	23%

ACS 2016

County	< 35 Years	35 - 64 years	>= 65 Years
El Dorado*	11%	60%	29%
Placer*	14%	58%	29%
Sacramento	22%	57%	21%
Sutter	20%	56%	24%
Yolo	27%	52%	20%
Yuba	26%	54%	20%
Total	20%	57%	23%

Validation Ratio SACSIM19 to ACS

County	< 35 Years	35 - 64 years	>= 65 Years
El Dorado*	0.88	0.99	1.06
Placer*	1.00	1.00	1.00
Sacramento	1.00	1.00	1.00
Sutter	1.00	1.00	1.00
Yolo	1.02	1.00	0.99
Yuba	1.03	0.99	0.99
Total	1.00	1.00	1.00

Source: SACOG 2020.

Based on American Community Survey 2016 5-year Sample data. *Partial county—Tahoe Basin excluded.

12.3.3 Highway Assignment Validation

12.3.3.1 Highway Network Variables

The only global check of the reasonableness of the SACSIM highway network was a comparison of the model estimates of route and lane mileage to data reported in HPMS for 2016. "Route mileage" is the centerline mileage of roadways (i.e. one mile of road = one route mile, irrespective of the number of lanes). "Lane mileage" is the centerline length of a roadway multiplied by the number of lanes of roadway provided (i.e. one mile of 2-lane road = two lane miles, and one mile of 4-lane road = four lane miles, etc.).

Making a detailed comparison of the SACSIM route and lane mileage to HPMS estimates is not possible for various reasons. HPMS functional class coding is not currently coded to the SACSIM highway network, so lining up specific classes is difficult. HPMS data are also aggregated to jurisdiction (city and county), with no GIS or other network data provided. Finally, and most importantly, the SACSIM highway network is simplified, with actual roadways represented only to about collector level and above. Local streets, whose route and lane mileage are estimated in HPMS, are not included explicitly in the SACSIM highway networks. The access provided by local streets to the collector-and-above roadway network within SACSIM is coded using "centroid connectors".

Table 12-18 provides a comparison of SACSIM and HPMS route and lane mileage of roadways, with classifications simplified to (1) freeway/interstate and (2) surface street. To the extent possible given the basic inconsistency in coding and reporting mentioned above, SACSIM and HPMS are relatively consistent for these simplified freeway/interstate and surface street categories. In total, SACSIM route mileage matches HPMS route mileage almost exactly. For freeways, SACSIM has slightly more route miles but, interestingly, slightly fewer lane-miles than HPMS. For surface streets, which only include collectors, arterials, and non-freeway expressways, SACSIM has almost the same number of route-miles as HPMS and slightly more lane-miles. Given the level of detail in HPMS provided (i.e. area totals only, with no access to a GIS or network underlying data), there is no way to resolve these minor inconsistencies between the two networks. It is possible that differences in coding of functional class, even within the collapsed categories presented, may account for this inconsistency.

Additionally, SACSIM freeway system coding was checked against "Freeway Lane Configuration Diagrams and Traffic Monitoring Stations: Sacramento Metropolitan Area", published annually by Caltrans District 3. Other major surface streets were spot checked against aerial photos.

Table 12-18 Model Network Route- and Lane-Mile Validation

Roadway Class	Model	HPMS	Ratio
Route Mileage †			
Freeway/Interstate*	319	326	1.02
Surface Street**	3,678	3,668	1.00
Subtotal	3,997	3,994	1.00
Lane Mileage ‡			
Freeway/Interstate*	2,017	1,955	0.97
Surface Street**	8,860	9,059	1.02
Subtotal	10,877	11,015	1.01

Source: SACOG 2020, Caltrans 2016

Based on HPMS data reported in Caltrans' 2016 California Public Road Data (PRD) report.

† "Route mileage" = the centerline distance of a roadway; one mile of roadway = 1 route mile.

‡ "Lane mileage" = route miles * number of lanes; one mile of 2-lane roadway = 2 lane miles, one mile of 4-lane roadway = 4 lane miles, etc.

*"Freeway/Interstate":

- SACSIM model estimates include all classes of freeway lanes (general purpose, HOV, and auxiliary) in lane mileage estimates, but general-purpose only for calculation of route miles. Only general-purpose lanes are included for route mileage estimates to avoid double-counting.
- HPMS estimates include three classes reported in the Caltrans PRD series: "Rural Interstate", "Urban Interstate" and "Urban Other Freeway or Expressway".

**"Surface Street":

- SACSIM model estimates include all functional classes of surface street reported in Chapter 3, above: expressway, major arterial, minor arterial, collector, rural highway, rural arterial.
- HPMS estimates include Rural and Urban "Other Principal Arterial", "Minor Arterial", "Major Collector", "Minor Collector", and "Collector" classes.

NOTE - Local roadways are not possible to compare between SACSIM and HPMS. The SACSIM highway network is limited to explicitly representing roadways down to approximately "collector" class. Most local streets are represented by centroid collectors, which may represent the effective access to the collector-and-above roadway network provided by local streets. However, due to the coarseness of the centroid connectors versus the actual local roadway network, a reasonable "apples-to-apples" comparison is not possible.

12.3.3.2 Validation of Highway Vehicle Miles Traveled

Although reported in this section on traffic assignment, the amount of VMT forecasted is subject to all aspects of the model system. Although traffic assignment procedures do affect the amount of VMT, the quality of the networks, modeling of all aspects of travel demand (e.g. travel frequency, spatial distribution and mode), treatment of external travel, etc. all affect the amount of VMT forecasted. Each of the prior chapters provides validation and reasonableness checks for these other aspects of the SACSIM19.

Validation of estimates of VMT by travel demand models to estimates of observed VMT gathered through the Highway Performance Monitoring System is technically required by federal statute for agencies like SACOG which implement air quality conformity analysis[42].

This requirement has been more generally applied for validation of travel demand models used for other purposes. For example, validation to HPMS is identified as a key recommended validation task in the FHWA guidance on validation of travel demand models[43].

Table 12-19 reports the comparison of SACSIM19 estimates of VMT to HPMS-sourced estimates. At region level, SACSIM19 estimates line up very closely with HPMS-sourced estimates, with less than two percent difference for each of the three validation years (2005, 2008, and 2012). Additionally, at region level, the changes to total and per capita VMT forecasted by SACSIM19 correspond to the changes observed in HPMS data. Between 2005 and 2008, HPMS data shows a 3.3 percent decline, and SACSIM19 predicted a 2.2 percent change. Between 2005 and 2012, HPMS data shows a 4.5 percent decline in VMT per capita, compared to a SACSIM19 6.3 percent decline. Between 2005 and 2016, HPMS data shows a 6.7 percent decline, and SACSIM19 predicted 8.2% percent change. These changes are in the correct direction and the correct order of magnitude. By comparing multiple scenarios, these results provide strong evidence that the model system captures the biggest factors, roadway characteristics, demographics, population, workers, influencing vehicle travel reasonably well.

[42] *Code of Federal Regulations,* Title 40, Sec.93.122

[43] Federal Highway Administration, *Model Validation and Reasonableness Checking Manual*, 2010 edition. http://tmip.fhwa.dot.gov/resources/clearinghouse/1397

Table 12-19 Comparison of Daily Vehicle Miles Traveled Estimates: HPMS and SACSIM19

	2005		2008		2012		2016	
County	HPMS	SACSIM	HPMS	SACSIM	HPMS	SACSIM	HPMS	SACSIM
El Dorado*	4,381	4,158	4,226	3,871	4,278	3,735	4,095	3,842
Placer*	9,010	9,681	8,927	9,790	9,035	9,894	9,161	10,101
Sacramento	33,752	34,219	34,157	34,666	34,584	33,760	35,652	34,560
Sutter	2,493	2,086	2,566	2,146	2,397	2,027	2,672	2,228
Yolo	5,967	5,368	5,763	5,807	6,074	5,862	6,071	5,842
Yuba	1,941	1,799	1,876	1,772	1,875	1,732	1,928	1,866
Region	57,544	57,311	57,516	58,051	58,244	57,010	59,579	58,439
Population	2,140		2,215		2,268		2,376	
VMT per Capita	26.9	26.8	26	26.2	25.7	25.1	25.1	24.6
Change from 2005	na	na	-3.30%	-2.20%	-4.50%	-6.30%	-6.70%	-8.20%

Source: SACOG 2020, Caltrans 2016.

Based on HPMS estimates of VMT from the Caltrans *California Public Road Data* reports.

†Adjustment by SACOG to convert average annual daily to typical weekday

* Adjusted from whole county data from El Dorado and Placer Counties to the non-Tahoe-Basin portions.

Table 12-20 Comparison of Daily Vehicle Miles Traveled Ratios: HPMS and SACSIM19

HPMS to SACSIM Validation Ratio

County	2005	2008	2012	2016
El Dorado*	0.95	0.92	0.87	0.94
Placer*	1.07	1.1	1.1	1.10
Sacramento	1.01	1.01	0.98	0.97
Sutter	0.84	0.84	0.85	0.83
Yolo	0.9	1.01	0.96	0.96
Yuba	0.93	0.94	0.92	0.97
Region	1	1.01	0.98	0.98
Population	2,140	2,215	2,268	2376
VMT per Capita	1	1.01	0.98	0.98

Source: SACOG 2020, Caltrans 2016.

Based on HPMS estimates of VMT from the Caltrans *California Public Road Data* reports.

†Adjustment by SACOG to convert average annual daily to typical weekday

* Adjusted from whole county data from El Dorado and Placer Counties to the non-Tahoe-Basin portions.

12.3.3.3 Validation of Highway Link Assignment

Year 2016 is the primary year of highway assignment validation for SACSIM19. Validation guidelines are based on the follow recommendations from the California Transpiration Commissions report, *Regional Transportation Plan Guidelines for Regional Transportation Planning Agencies, 2017*:

- At least 75% of roadway links with traffic counts should be within the Caltrans deviation threshold, which differs based on magnitude of the count.
- Estimate of correlation between the model estimates and observed counts should be at least 0.88.
- Percent Root Mean Square Error (RMSE) for the roadway links with counts in the project study area should not exceed 40%.

Table 12-21 shows how SACSIM19 2016 forecasted traffic volumes compare to traffic counts based on a region static validation using the CTC recommended measures and thresholds. A more detailed discussion of the source of the counts and limitations of using counts is provided in Observed Travel Data section above. The table includes comparisons of average weekday volumes. Also included in the table is a SACSIM19 backcast comparison to Year 2005. The table shows SACSIM19 forecasts are within the validation measure threshold ranges for all three measures in both 2005 and 2016.

Table 12-21 SACSIM19 and CTC Guidelines on Highway Assignment Validation

Validation Measures	Threshold	2005	2016
% of Locations w/ Model < Max Deviation	>75%	86%	77%
Correlation Coefficient	>0.88	0.95	0.97
RMSE for Daily Traffic Assignment	<0.40	0.36	0.38

Source: SACOG 2020.
Thresholds from California Transportation Commission, 2017 Regional Guidelines for MPOs, p.49.

While the regional guidelines serve an important role for model validation, they are only a partial indication of model performance. Highway facility classification determine how much traffic volume can travel on a given roadway at a point of time. The facility classification determines road capacity levels measured as how many vehicles per hour per lane (vphpl) a facility can sustain operations; this is a major contributor to model performance. Table 12-22 provides a comparison of forecasted 2016 model volumes to traffic counts by facility type. The table includes comparisons of average weekday volumes. Table 12-23 includes SACSIM19 back-cast traffic volume to counts from 2005. This back-cast comparison serves as both the temporal validation of SACSIM19 and the base year for air quality and conformity analysis. Count locations and quantities vary between 2005 and 2016 due to different collection efforts and available data at that time. Multiple validation tables by functional class also serve as supplementary source of count data for locations of facility types that may have a smaller count samples one year and provide additional model confidence.

SACSIM19 shows both 2016 and 2005 preforming well for freeways and major arterials roadway classifications. 2016 does not preform worst in Ramps and expressways, however, this may do to a small sample collect of these facilities types. There was more traffic count data collected on ramp and expressway facilities for 2005 which does preform slightly better. Further ramp counts and validation have been for collected and analyzed for SACSIM19 on projects since this initial traffic volume data collection. Appendix E Caltrans 2019 Validation Memos Prepared by DKS Using SACSIM19 show ramp and peak period validations along I-5 and SR-51 within Sacramento County.

Table 12-22 SACSIM19 Highway Volume Validation By Roadway Functional Class for 2016

Functional Class	No. of Counts	Sum of Counts	Sum of Model (if Counted)	Validation Ratio	Avg. Link Error	RMSE
Daily Volumes						
Freeway	371	21,477,673	21,004,075	0.98	0.13	0.18
Expressway	7	88,286	115,917	1.31	0.55	0.65
Major Arterial	571	8,310,889	9,076,389	1.09	0.29	0.38
Minor Arterial	463	4,477,209	4,445,783	0.99	0.30	0.44
Collector	425	1,434,337	1,287,477	0.90	0.53	0.79
Ramp	10	54,413	75,808	1.39	1.05	1.22
Rural Highway	24	148,190	157,637	1.06	0.18	0.19
Rural Art./Coll.	325	1,150,651	1,126,654	0.98	0.37	0.51
Total	2,196	37,141,648	37,289,740	1.00	0.24	0.38

Source: SACOG 2020.

Table 12-23 SACSIM19 Validation: Highway Volume By Roadway Functional Class for 2005

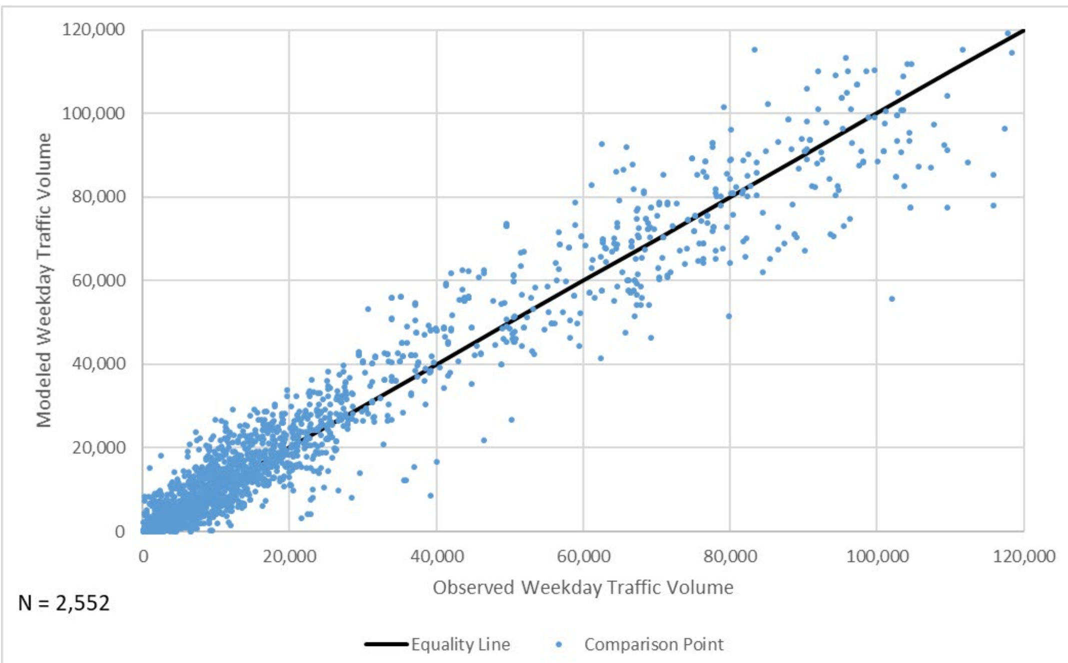
Functional Class	No. of Road Sections	Sum of Counts	Sum of Model (if Counted)	Validation Ratio	Avg. Link Error	RMSE
Daily Volumes						
Freeway	189	10,772,487	11,092,769	1.03	0.15	0.22
Expressway	12	353,236	305,954	0.87	0.16	0.34
Major Arterial	296	4,903,641	5,014,035	1.02	0.21	0.28
Minor Arterial	172	1,789,679	1,558,188	0.87	0.29	0.38
Collector	118	630,976	505,006	0.80	0.40	0.56
Ramp	264	1,199,460	1,114,769	0.93	0.53	0.85
Rural Highway	76	325,402	363,834	1.12	0.28	0.40
Rural Art./Coll.	138	511,391	543,470	1.06	0.36	0.49
Total	1,265	20,486,272	20,498,025	1.00	0.22	0.36

Source: SACOG 2020.

Figure 12-6 presents a scatterplot comparing modeled daily traffic volumes against observed daily traffic volumes for over 2,500 locations where observed counts were available. Generally, there was a good fit between modeled and observed volumes, as shown by the observation points largely following the equality line.

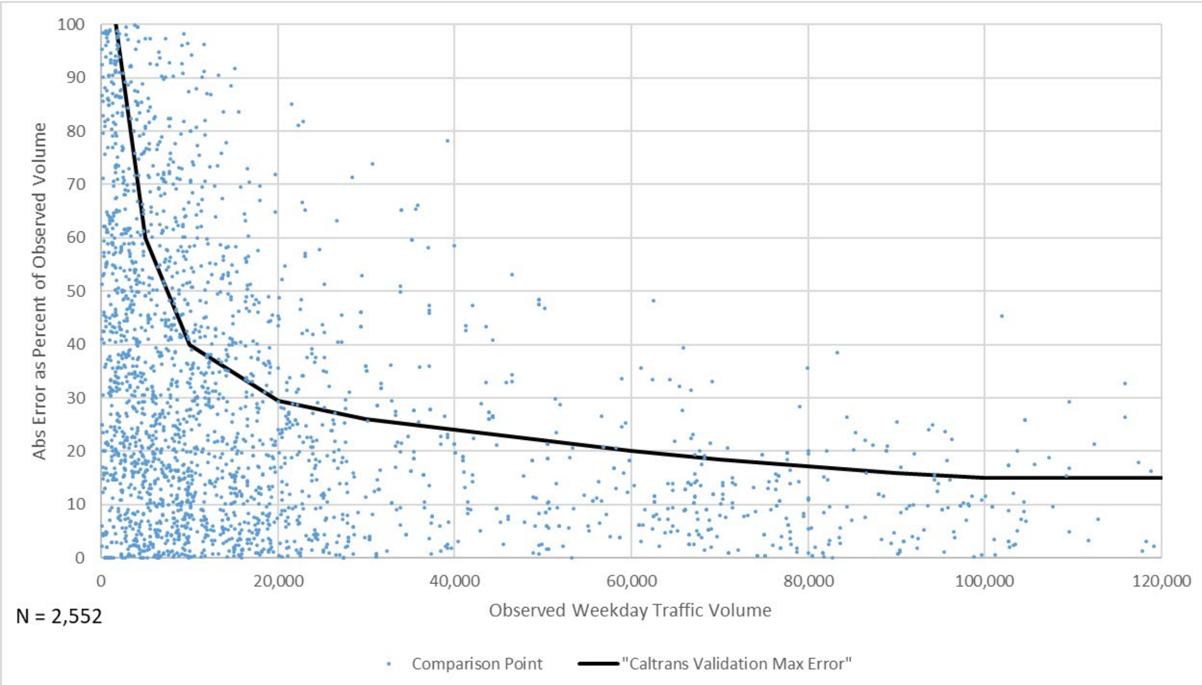
Further down, .
Figure 12-7 scatterplot points show, for each model link with observed count data, the absolute percent difference between the modeled and observed traffic on that link. The black line represents the maximum percentage difference recommended by Caltrans model validation guidelines (e.g. for weekday volumes of 100,000 or more, the absolute percent difference between modeled and observed volumes should be no more than 15%). Points below the line meet the Caltrans guidelines; points above the line do not.

Figure 12-6 2016 Weekday Modeled to Observed Volume



Source: SACOG 2020.

Figure 12-7 Year 2016 Weekday Volumes and Maximum Desirable Error



Source: SACOG 2020.
Note: "Caltrans Validation Max Error" line from California Department of Transportation, *Travel Forecasting Guidelines*, 1992.

12.3.3.4 Additional Validation for 2005 Highway Assignment

For each MTP/SCS update, SACOG also updates SACSIM-- its regional travel demand model. The travel demand model SACOG used in SCS3 was SACSIM19. The major improvements in SACSIM19 comparing to SACSIM15 used in SCS2 are listed in Chapter I - Introduction.

Due to the transition of travel model from SACSIM15 to SACSIM19, SACOG re-ran 2005 baseline and re-validated the outputs as done in SCS2. Table 12-22 and Table 12-23 show the validation results of traffic counts for SACSIM19 and SACSIM15. The overall validation measures such as the ratio of modeled volume to observed counts, average link error and RMSE from SACSIM19 and SACSIM15 are comparable. However, the ratio of modeled volumes to counts are much better on freeway, minor arterial and some other links.

Given the level of uncertainty about how much GHG was truly generated in any given year (including 2005) based on estimates of vehicle activity, the range of variation in 2005 GHG per capita between SACSIM15 and SACSIM19 is not unreasonable to expect. Additionally, given that the same model (SACSIM19) was used for both the re-estimation of the base year AND the forecast years for compliance, and difference among travel models in the base year would be accounted for consistently in the forecast years as well. Table 12-24 shows regional traffic volume compared to observed volumes backcast validation ratios for comparison for 2005, 2008, 2012, and 2016.

Table 12-24 Backcast Traffic Volume Validation Ratio Comparison

	Year							
	2005		2008		2012		2016	
Functional Class	No. of Road Sections	Validation Ratio	No. of Road Sections	Validation Ratio	No. of Road Sections	Validation Ratio	No. of Road Sections	Validation Ratio
Freeway/HOV	189	1.03	241	0.95	191	1.09	371	0.98
Arterial/Expressway/Rural Highway	556	0.98	702	1.09	481	0.91	1,065	1.06
Other Surface Streets & Ramps	520	0.92	820	1.08	368	0.49	760	0.94
Total	1,265	1.00	1,763	1.01	1,040	0.94	2,196	1.00

Source: SACOG 2020.

Validation of Measures of Roadway Congestion

Roadway congestion is an indicator with a much less specific and determined definition than roadway volumes or VMT. In general, congestion occurs on roadways when the number of drivers who wish to use a particular route exceeds the capacity of that route. This condition leads to a reduction in travel speed below the free-flow or posted speed on the roadway. For freeways, typical signs of congestion are stop-and-go driving conditions or long queues at freeway on-ramp meters waiting to enter the freeway. On the local arterial and collector system, congestion is most commonly experienced as waiting at traffic signals and accompanied by driver and passenger frustration.

"Delay" in general refers to time wasted traveling on congested facilities. However, to quantify that delay requires some presumption of what time it should take to travel on a particular route, or a standard travel time which drivers and passengers should expect. Setting a standard by which delay can be quantified is a subjective exercise. For example, some might define a standard travel time as "free-flow" or totally uncongested conditions. The standard for freeways by this definition might be 60 mph or higher, and the "standard" travel time would be 1 minute for a one-mile stretch of freeway. If the actual travel speed, with congestion, was 40 mph, the travel time would be 1.5 minutes, and the delay for each driver and passenger in that condition would be 30 seconds. Others may define the standard as modest or "tolerable" level of congestion. For the same one-mile stretch of freeway, 35 mph could be used as the standard for measurement of delay. With the same 40 travel speed in the previous example, no delay would be experienced, because the actual speed is higher than the standard.

For this and other reasons, SACOG has always focused more on the presence of congestion on roadways rather than amount of delay. Specifically, SACOG estimates and tracks how much of the total VMT occurs on roadways that are above an assigned capacity threshold. SACOG defines a congested VMT (CVMT) as VMT that occurs on roadways with volume-to-capacity (VC) ratios of 1.0 or greater. Capacity in this calculation is based on values used in the regional travel demand model (SACSIM) for trip assignment purposes and that vary by roadway functional classification (i.e., freeway lane capacities are higher than arterial lanes). The SACSIM average capacity values are not based on field measured traffic throughput at each location, but on reasonable values for roadways are approaching their operating capacity. An example of C-VMT is a vehicle and its drivers and passenger going westbound on I-80 in the morning commute period between Madison Avenue and the I-80/Capital City Freeway "Split," or on Hazel Avenue between Madison and Winding Way during commute hours and in the peak direction.

Table 12-28 provides observed data on congestion and delay in the Sacramento region for years 2005, 2008 and 2012. One measure of delay is provided: one published annually by Caltrans in the Mobility Performance Report (MPR). This comparison is provided for reasonableness checking of SACSIM19, and not for rigorous validation[44]. Key similarities in both estimates of congestion: Both

[44] SACOG is working on adapting travel speed data from the National Performance Monitoring Research Dataset (NPMRDS) for comparison to 2016 model estimates of speed on congested roadways for a future validation of estimates of congestion.

show 2005 as being the highest of the three years; both show significant decreases in overall congestion level from 2005 to 2012, which makes sense given the impact of the Great Recession on the amount of travel in the region in 2012. One key difference between the two estimates of congestion: MPR data shows a much bigger decline in congestion between 2005 and 2008 than between 2008 and 2012, while the SACSIM19 backcasts show a very slight decline in congestion between 2005 and 2008, and a much larger decline from 2008 to 2012. Without independent estimates of congestion for these same years, its impossible to determine which of these results are more reasonable. Anecdotally, the decline in congestion in the Sacramento region seemed more tied to the impact of the Great Recession after 2008, and not between 2005 and 2008.

Some of the reasons that this comparison cannot be considered a rigorous validation are that SACSIM19 utilizes equilibrium assignment, which is a "static" and "link-based" process, while the MPR congestion is purely based on link speed, relative to a minimum speed threshold.

- The assignment is "static", because time is not explicitly represented in the assignment algorithm—for each of the four assignment time periods, the entire demand period is assigned at once, with various parameters and factors to "translate" the entire demand period (three hours in the case of the AM and PM peak periods, five hours for the midday period, and thirteen hours for the late evening/early morning period) into hourly equivalents.
- The assignment is "link-based" because the volume/delay functions are implemented based on link (i.e. roadway segment) definitions of capacity and demand. So, for surface street intersections, the capacity and operations of at-grade intersections is not explicitly represented—instead, a general assumption about the throughput for at-grade intersections is built into the vehicles-per-lane-per-hour capacities assigned to links (see Chapter 3 for more details on vplph capacities of different roadway types). For example, its normally assumed that the effective capacity of a freeway lane is about 2,000 vplph, but the vplph for an major arterial in SACSIM19, for example, is 850 vplph. Part of the difference relates to design standards, presence of "friction" from parking lanes and driveways, etc., but the biggest factor accounting for the difference is the fact that major arterial roadways intersect at grade with other streets, and vehicles traveling on one street "compete" for capacity with vehicles on other streets—with the "competition" for capacity mediated by traffic signals, lane markings, traffic laws, etc. The generalized link capacities for surface streets are factored to represent a reasonable throughput of vehicles at intersections.

The limitations of this vehicle assignment process for estimating delay relate to these three characteristics of equilibrium assignment, compared to actual factors accounting for delay. On surface streets, most delay occurs at intersections, where conflicting flows of vehicles compete for capacity to get through the intersections. Delay accumulates in part due to the necessity to stop when conflicting flows are being served, and in part due to queuing of vehicles in cases when flows overwhelm the capacity of the intersection. On freeways, some delay occurs at bottleneck locations, where demand overwhelms capacity, but a larger portion of delay accumulates from the upstream effects of queues of vehicle backing up and blocking access to or from ramps and connecting lanes. Since the equilibrium assignment process does not explicitly account for surface street intersections or the effects of queuing of vehicles through time are not captured in this process, only a portion of the causes of delay are accounted for in SACSIM19.

Table 12-25 Comparison of Congested Vehicle Miles Traveled and Delay

Congestion/Delay Measure	**2005**	**2008**	**2011/12**
Freeway Vehicle Hours Delay (daily)†	5,399	3,448	2,989
Congested Vehicle Miles Traveled (weekday, in 000's)*	4,415	4,387	3,342
Annual Average Growth Rates	**'05 to '08**	**'08 to '12**	**'05 to '11/12**
Freeway Vehicle Hours Delay†	-14%	-4%	-8%
Congested Vehicle Miles Traveled*	-0%	-7%	-4%

Source: SACOG 2020.

† Caltrans District 3 "Mobility Performance Reports". Caltrans defines delay as the difference between travel time at 35mph and actual travel time, for state highways where actual travel times are below 35mph. All segments included in the monitoring reports for the SACOG region are freeways.
*SACSIM15 estimates of congested vehicle miles traveled.

12.3.3.5 Gateways Assignment Validation and Reasonableness Check

As described in Chapter 3, SACSIM19 uses an external sub module outside of DAYSIM to predict trips in and out of the SACOG region. Highway network links used during the assignment are used to represent roadway connections outside the SACOG region. These roadway links are called "gateways." Since these trips are determined separately from the DAYSIM simulation, an additional validation check on the gateways was performed for reasonableness. Table 12-26 shows the gateway SACSIM traffic volumes compared to counts using the CTC guidelines. The gateways meet all validation acceptance criterions including 100 percent of the locations within the acceptable range of deviation between traffic volume to observed count.

Table 12-26 SACSIM19 Gateways Assignment Validation

Validation Measures	Threshold	2016
% of Locations w/ Model < Max Deviation	>75%	100%
Correlation Coefficient	> 0.88	0.997
RMSE for Daily Traffic Assignment	<0.40	0.24

Source: SACOG 2020.
Thresholds from California Transportation Commission, 2017 Regional Guidelines for MPOs, p.49.

12.3.3.6 Dynamic Validation

For dynamic validation results, please refer to Appendix E Caltrans 2019 Validation Memos Prepared by DKS Using SACSIM19.

12.3.4 Transit Network and Assignment Validation

12.3.4.1 Transit Network Validation

As with highway networks, direct, independent checks of modeled transit networks against actual transit networks are difficult to perform. But as a generic check we compared vehicle service hours estimated in the model against observed vehicle service hours provided by transit operators.

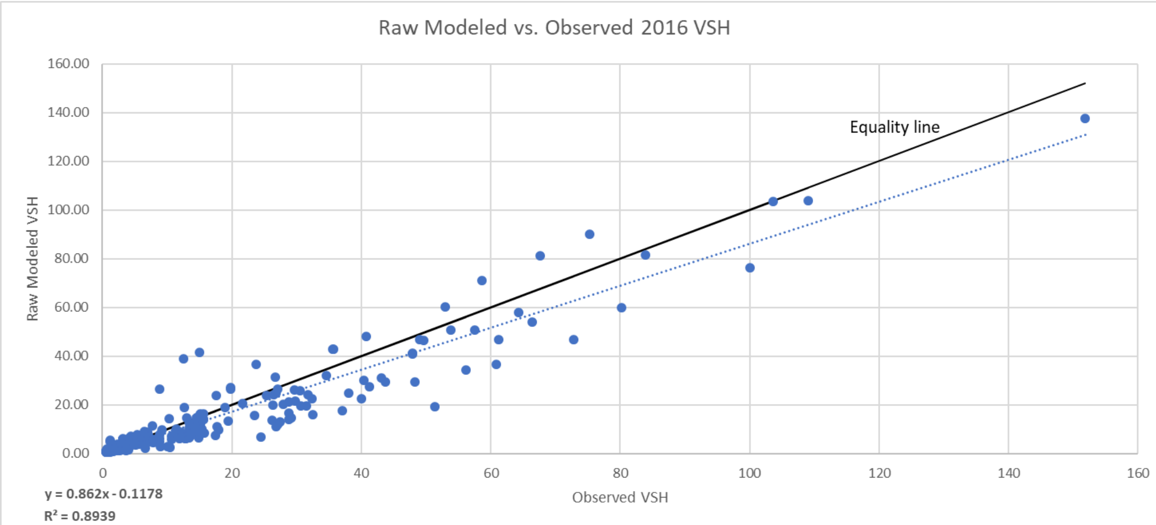
Vehicle service hours (VSH) are a common way of estimating the amount of transit service provided for passengers. One VSH is defined as one transit vehicle operating in revenue service (i.e. available for passengers to use, and not operations of vehicles for maintenance purposes) for one hour. VSH includes the time spent on a route picking up or dropping off passengers, plus turnaround or layover times (i.e. times built into schedules for vehicles to wait or layover at the end of a route, or time needed to turn around at the end of a route). VSH does not include the time that a transit vehicle spends traveling between the bus yard and its first/last stop of the day.

Figure 12-8 provides a comparison of observed data and model estimates of weekday VSH for each route operating in the SACOG region in 2016. Overall "fit" between model estimates and observed data is good, with an r-squared correlation between observed and modeled VSH of about 0.89. However, SACSIM's VSH predictions are somewhat lower than observed VSH, with a beta between modeled and observed VSH of 0.86.

Table 12-28 summarizes 2016 weekday VSH for three different transit service types: light rail, express or commuter buses, and regular fixed route buses. Overall, modeled VSH is somewhat lower than VSH reported by transit operators, with a beta of 0.86. VSH estimates for local buses are low compared to operator-reported VSH (beta of 0.8), though light rail estimated VSH is very close to operator-report VSH (beta of 1.02). VSH estimates for express buses are, on average, high, with a beta of 1.28.

One reason for this discrepancy is that SACSIM's ability to estimate transit vehicle travel times, and therefore service hours, is somewhat coarse. It relies on average headways within five different time periods and, rather than true end-to-end travel time, estimates travel times based on applying a time factor multiple to the congested link travel time. The overestimation of commuter bus VSH is largely due to difficulty representing commuter service headways. E.g., some lines were modeled as having a higher headway than in reality to capture the fact that, although infrequent, commuter bus departure times are tailored to commuters' schedules and therefore are perceived as having a higher level of service. For example, a commuter bus that only runs twice each morning has a higher utility than a local bus because it leaves at times that conveniently align with riders' work schedules, therefore to capture the line's utility it is modeled with a somewhat shorter headway. This shorter headway in turn leads to higher modeled VSH.

Figure 12-8 Year 2016 Transit Line Vehicle Service Hours: Model Estimates and Observed Data



Source: SACOG 2020. Observed VSH provided by transit operators or Google Transit Feed Specification (GTFS).

Table 12-27 Line-Level Transit Network Comparison: Model Estimates and Observed Data

	Regression Statistics (β * Model VSH= Actual VSH)	
Variable	R-Squared	Beta
2016 Vehicle Service Hours ‡	0.89	0.86

Source: SACOG 2020.
‡Model estimated line-level VSH regressed against operator-reported VSH for sample of 229 routes.

Table 12-28 Year 2016 Transit Vehicle Service Hours by Type of Service: Model Estimates and Observed Data

	Weekday Vehicle Service Hours		
Service Type	Observed	Modeled	Validation Ratio
Light Rail	301	307	1.02
Fixed Route Bus	3,318	2,651	0.80
Express Bus	320	411	1.28
All Service Types	3,939	3,368	0.86

Source: SACOG 2020.

12.3.4.2 Transit Assignment Validation

SACSIM's transit modeling, at a high level, involves the following steps:

1. Generate and distribute transit trips using DAYSIM. DAYSIM was calibrated such that the number of transit trips it predicts results in a transit mode share (I.e., the percent of total trips that were made on transit) that matches SACOG's 2018 household travel survey. Per the 2018 household travel survey, transit mode share was about 1.2%.
2. Using Cube's PT module, SACSIM assigns these transit trips to the modeled transit network.
3. Based on how trips were assigned to the transit network, SACSIM calculates the total boardings for each line. A single trip can entail multiple boardings, e.g., one transit trip that requires one transfer results in two boardings.

Below, Table 12-29 summarizes transit assignment validation results by transit mode, while Figure 12-9 plots observed versus modeled boardings at the line level. SACSIM's estimate of boardings exceeded observed boardings by about 22% for local bus routes and 24% for LRT routes, or slightly outside the California Transportation Commission's validation threshold of +/- 20% for transit boardings[45].

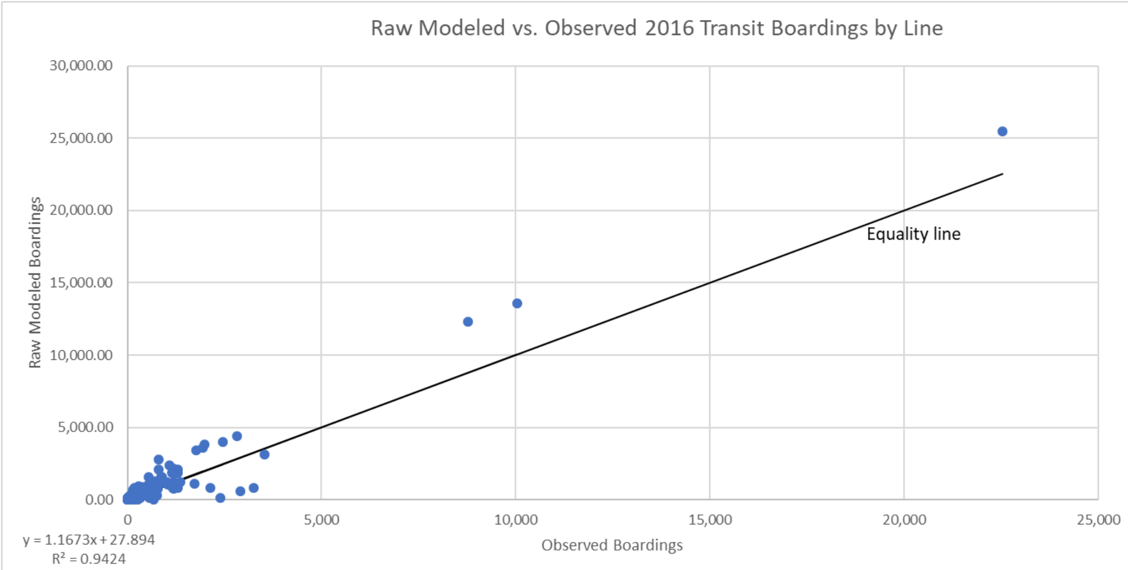
Table 12-29 Weekday Transit Passenger Boardings by Service Type: Comparison of Model to Counts

	Weekday Boardings			**Boardings per Trip**	
Service Type	Observed	Modeled	Validation Ratio	Modeled Transit Trips	Boardings per Trip
Light Rail	41,732	51,804	1.24	46,384	1.12
Express Bus	5,566	5,658	1.02	5,459	1.04
Local Bus	73,309	89,433	1.22	49,505	1.81
All Service Types	120,608	146,896	1.22	101,348	1.45

Source: SACOG 2020.
Model estimates included only for lines for which observed boardings data were available from operators.

[45] California Transportation Commision, 2017. *2017 Regional Transportation Plan Guidelines for Metropolitan Planning Organizations.* p.49

Figure 12-9 Line-Level Transit Boarding Validation



Source: SACOG 2020.

Although slightly outside of CTC's transit assignment validation threshold, SACSIM's boarding estimate is not of significant concern because, as described above, it is calibrated to match transit trip share rather than match boardings at the line level. And an alternative way to determine how reasonably SACSIM assigns transit trips, given that we are confident in its prediction of transit trip share, is to compare SACSIM's rate of boardings per trip to an observed rate of boardings per trip.

As described in the above summary of SACOG's 2013 Connect Card survey, among transit operators included in the survey, there were an average of 1.78 boardings per trip. In comparison, based on dividing SACSIM's modeled boardings by its predicted transit trips, SACSIM estimated approximately 1.46 boardings per transit trip. This difference between SACSIM's and observed rates of boardings per trip may seem significant, but critical to consider is that the survey did not collect responses from Unitrans riders. This matters because (1) Unitrans is the second most-used system in the SACOG region, so its riders' transfer rate (boardings per trip) significantly affects the regional average predicted by SACSIM and; (2) because Unitrans's service is tailored to bringing its users to the UC Davis campus, it likely has a very low transfer rate compared to other systems included in the survey. Combining these two considerations, we believe SACSIM's transfer rate, because it includes Unitrans users, should be lower than that found in the 2013 survey and that its rate of 1.46 boardings per trip is reasonable.